

EFFECTS OF GOWIN'S VEE TEACHING STRATEGY ON SECONDARY SCHOOL STUDENTS' CONCEPTUAL UNDERSTANDING AND MOTIVATION IN THE TOPIC OF HOOKE'S LAW IN PHYSICS IN KOIBATEK SUB-COUNTY, KENYA

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for the Master of Education Degree in Science Education of Egerton University**

EGERTON UNIVERSITY

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DECLARATION AND RECOMMENDATION

Declaration

This is my original work and has not been presented for award of degree or diploma in this or any other university.

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Recommendation

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DEDICATION

I dedicate this thesis to my wife Ann Kemboi, children; Collins Kiptoo, Newton Kipyegon, Lynn Jelagat, Olive Jerop and Shantel Kangogo, brothers, sisters and parents.

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ABSTRACT

Studying Physics expands frontiers of knowledge about nature, equips learners with technological skills and enhances understanding of other disciplines. Despite the importance of Physics, students' performance in the subject in secondary school has been unsatisfactory over the years. The unsatisfactory performance suggests that students' understanding of concepts and motivation to learn Physics was low. Teaching strategies have been cited among factors which affect students understanding and motivation to learn. This study investigated the effects of Gowin's Vee teaching strategy on secondary school students' conceptual understanding and motivation to learn Hooke's law topic in Physics in Koibatek sub-county, Kenya. The study adopted the quasi-experimental Solomon four research design. The target population was all Physics students in public secondary schools in Koibatek Sub-County. The accessible population was 2041 form two Physics students in 24 co-educational secondary schools in the Sub-County. Purposive sampling was used to select 138 students from four co-educational secondary schools which were randomly assigned to experimental and control groups. Two instruments; Physics Conceptual Understanding Achievement Test (PCUAT) to test and Motivation to learn Physics questionnaire (PSMQ) were used to collect data. Experts from the Department of Curriculum, Instruction and Educational Management, Egerton University and experienced secondary school Physics teachers in the four selected secondary schools examined the content and face validity of the two instruments. Reliability of the test was estimated using the Kuder Richardson (KR 21) formula while that of the questionnaire was established using the Cronbach Alpha method. The reliability coefficients of PCUAT and PSMQ were 0.94 and 0.88 respectively. Data was analyzed with the aid of the Statistical Package for Social Science (SPSS). Qualitative data was described and summarized using frequencies and percentages while hypotheses were tested at the 0.05 level of confidence using t-test and one-way ANOVA. The results showed that the differences between experimental and control group students on conceptual understanding and motivation to learn the Hooke's law topic were statistically significant. This means that Gowin's Vee teaching strategy improved students' conceptual understanding and motivation. It is expected that these findings could be used by teachers to enhance students understanding and motivation to learn Physics, and performance in the subject.

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA:	Analysis of Variance
CEMASTEA:	Centre for Mathematics, Science and Technology Education in Africa
COMEDAF:	Conference of Ministers of Education in Africa
ICT:	Information and Communication Technology
KCPE :	Kenya Certificate of Primary Education
KCSE:	Kenya Certificate of Secondary Education
KNEC:	Kenya National Examination Council
KSEF:	Kenya Science and Engineering Fair
MLT:	Meaningful Learning Theory
NACOSTI:	National Commission for Science, Technology and Innovation
PBL:	Project-Based Learning
PCUAT:	Physics Conceptual Understanding Achievement Test
PSMQ:	Physics Students' Motivation Questionnaire
SDGs:	Sustainable Development Goals
UNESCO:	United Nations Educational, Scientific and Cultural Organization

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Physics is the study of matter and energy and their interactions. Physics is important because it improves the quality of life of human beings and it develops solutions to both energy and environmental problems (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2015). Any breakthrough in science and technology is deeply rooted in the strength of science education (Kehinde & Emmanuel, 2011). It is in recognition of this importance of science that during the Fifth Ordinary Session of the Conference of Ministers of Education in Africa (COMEDAF V) held in April 2012 in Abuja, Nigeria, Centre for Mathematics, Science and Technology Education in Africa (CEMASTE) was showcased as model 'Centre of Excellence' in the promotion of quality of mathematics and science education at the basic level in Africa (Mutula, 2012). Performance in Physics has been low and many students shun the subject (Njoroge et al., 2014). Table 1 shows performance in Physics in the national exams and the percentage performance are very low. The focus on the study is to avoid the negative effects of the students' preconceptions by involving them in the twelve epistemological steps as laid down in the Gowin's Vee teaching strategy (Novak & Gowin, 1984).

In Kenya, the poor performance in Physics among students at varying levels of learning is reflected in the candidates' performance in the Kenya Certificate of Secondary Education (KCSE) Physics examination between the years 2012 and 2017. The mean score remained low over the period between 2012 and 2017. The best performance was in 2017 with a percentage score of 38.99, while 2013 recorded the worst performance with a mean score of 31.31 (Kenya National Examination Council [KNEC], 2013). Kigo (2017) attributed low achievement to poor teaching methods, which lead to lack of mastery of the subject by students. Table 1 shows candidates overall KCSE national performance in Physics in the years 2012 to 2017.

Table 1*Candidates Overall KCSE National Performance in Physics in the Years 2012 to 2017*

Year	Physics Candidates	All Candidates	Percentage Students Enrolled	Percentage (%) Score	Grades Max =12
2012	95, 754	307,012	31.19	36.71	4.41
2013	106,663	347,865	30.66	31.31	3.71
2014	110,802	358,413	30.91	35.11	4.21
2015	121,071	410, 321	29.51	36.64	4.40
2016	118,211	435, 589	27.14	37.72	4.53
2017	119,965	446,800	26.85	38.99	4.68

Source: Kenya National Examinations Council (2017)

There has been an increase in Physics student population from 95,754 in 2012 to 119,965 in 2017 may be due free primary education. The number of Physics students also in 2016 and 2017 remained stagnant but the total candidature is increasing meaning that the percentage of students doing Physics is decreasing. Although the mean score from 2012 to 2017 has been increasing, the percentage performance in Physics is still below average and the number of Physics students is reducing. The low enrolment in Physics has been attributed to poor performance partly blamed on teaching methods among other factors (Uside et al., 2013). Many students perceive the subject as difficult as established by (Musasia et al., 2012).

Motivation is the initiation, direction, intensity and persistence of behaviour. It means having the encouragement to do something, (Reeve, 2012). Teachers tend to believe that when students are motivated to perform competently on academic tasks, they will learn in accordance with their academic abilities. For this reason alone, working to enhance students' academic motivation is worthwhile (Dale, 2007). But in addition to maximizing student learning, another beneficial by-product of having highly motivated students in class is that they make the teacher's job of managing the instructional program simpler (Sulaiman, 2011). When students are academically motivated, their teachers often become professionally motivated, working hard to provide students with worthwhile educational experiences and finding more satisfaction in doing so (Namasaka, & Karario, 2013).

In Kenya, Physics, Chemistry and Biology science subjects are offered in its 8-4-4 curriculum (Kenya Institute of Education [KIE], 2002). Many students do not do well at KCSE as shown in table 1. A student is required to choose at least two sciences upon transition from form two to form three. However, during this transition many students drop Physics leading to low enrolment in the subject. Performance in Physics in Koibatek Sub-County in Baringo County has been very low. Table 2 shows performance in Biology, Chemistry and Physics in KCSE in Koibatek Sub-County from 2010 to 2014.

Table 2

Candidates Science Mean Scores for Koibatek Sub-County for the Years 2010 to 2014

Year	Subject	No. of Candidates	Mean Score (maximum = 12)
2010	Biology	1128	4.90
	Physics	483	4.95
	Chemistry	1203	4.11
2011	Biology	1449	4.85
	Physics	521	4.95
	Chemistry	1292	3.79
2012	Biology	1564	5.43
	Physics	532	4.96
	Chemistry	1504	4.14
2013	Biology	1645	4.04
	Physics	560	4.34
	Chemistry	1662	3.24
2014	Biology	1634	5.10
	Physics	562	4.81
	Chemistry	1613	4.28

Source: Koibatek Sub-County Education Office (2014)

The number of students doing Physics is very low compared to Chemistry and Biology. Although Physics sometimes lead in the three sciences, its performance is still below average in the Sub-County. Effective Physics instruction should be able to change students' way of thinking about Physics.

In an attempt to achieve this, various contemporary researches in education and psychology have come out with epistemologies, theories and pedagogies like constructivism and meaningful learning theories, and advanced organizers (Ausubel, 1968), metacognition (Flavell, 1979), creativity and process skills (Abungu et al., 2014), Gowin's Vee (Gowin, 1981) and concept maps (Mutai, 2015; Novak & Gowin, 1984).

These researches have shifted Physics education from building the knowledge capacity to improving thinking skills and creativity through conceptual understanding (Bigozzi, et al., 2018). Thus the use of socio-constructivist perspective and meaningful learning theory has offered a window of hope in the teaching and learning of various topics in Physics and science in general. Students should be made to understand the Physics world as made up of coherent structure of concepts which are interlinked together (Ausubel, 1968; Novak & Gowin, 1984). Gowin's Vee is a very useful teaching and learning tool which has been extensively used in many countries like USA (Mutai, 2015; Novak & Gowin, 1984), Finland (Ahlberg, 1993), Australia (Afamasaga, 2004), and South Africa (Ramahlape, 2004) among others in bringing about meaningful learning.

This study aims at finding out the effects of Gowin's Vee teaching strategy on form two Physics students' conceptual understanding and motivation in learning Hooke's law in Physics, advantages and challenges faced by Physics teachers in using this strategy in secondary schools within Koibatek Sub-County. This is because Hooke's law is a topic which needs a lot of practicals and calculations and the students have been performing poorly in Physics at KCSE. It has also been identified as one of the difficult areas according to the Kenya National Examinations Council Examination (KNEC, 2013) newsletter. Therefore this topic needs a strategy which carries the learners step by step in order for them to get the concepts right so that meaningful learning can be realized. Gowin's Vee teaching strategy is better than other methods of teaching because of its twelve epistemological elements starting from world view to the value of the answer at the end of a question. It is also easy to follow the V- diagram.

1.2 Statement of the Problem

Sustainable Development Goals and vision 2030 was hatched in Stockholm, Sweden during United Nations Conference on Human Environment in 1972. The title was 'Transforming the world'. This was a United Nations (UN) initiative for the 2030 agenda for sustainable development, which was adopted in 2015 at the UN summit by the world's head of state and

government. It has 17 agenda and one of them is quality education which is expected to make Kenya a fully industrialized country by the year 2030. Attainment of the industrialization status lays in acquisition of appropriate science education particularly the role of Physics education. However, there is a concern among all stakeholders about the continuous poor performance of secondary school students at KCSE in Physics nationally. Also in Koibatek Sub-County the performance has been poor from 2010 to 2014.

This could be attributed to the failure by teachers to use appropriate teaching methods and motivation of learners accordingly. Use of Gowin's Vee is known to improve students' conceptual understanding of various subjects. The effects of Gowin's Vee teaching strategy on conceptual understanding and motivation in Physics in Koibatek Sub-County has not been established and documented. It is against this background that this study is designed to investigate the effects Gowin's Vee teaching strategy on motivation and conceptual understanding of Physics. This may help students improve in their conceptual understanding and increase their motivational level in Physics which will be expected to improve performance in the subject.

1.3 Purpose of the Study

This study was to determine the effects of Gowin's Vee teaching strategy on students' conceptual understanding and motivation to learn Physics in co-educational public secondary schools.

1.4 Specific Objectives of the Study

This study was guided by the following objectives;

- (i) To investigate the effects of using Gowin's Vee teaching strategy on secondary school students' conceptual understanding in Physics.
- (ii) To investigate the effects of using Gowin's Vee teaching strategy on secondary school students' motivation to learn Physics
- (iii) To examine the challenges encountered by Physics teachers when teaching using Gowin Vee teaching strategy.

1.4 Research Question

The study attempted to answer the question, what are the challenges encountered by Physics teachers when teaching using Gowin Vee teaching strategy?

1.5 Hypotheses

The following hypotheses were tested:

Ho1: There is no statistically significant effect in conceptual understanding between students taught using Gowin's Vee and those taught using regular methods in Physics.

Ho2: There is no statistically significant effect in the level of motivation between students taught using Gowin's Vee and those taught using regular methods in Physics.

1.6 Significance of the Study

The results of the study were expected to contribute to the expansion of knowledge in the field of Physics education towards improving the students' conceptual understanding of Physics concepts and motivation to learn Physics. It is also expected to provide a solution to continuous poor performance in Physics at KCSE level. The findings are also expected to contribute to the government's effort to sustainable development achieving vision 2030 by equipping learners with technological skills related to physics education.

1.7 Scope of the Study

The study was conducted in public co-educational secondary schools in Koibatek Sub-County, Kenya. The study examined the effects of Gowin's Vee teaching strategy on students understanding and motivation to learn physics. It focused on the topic Hook's Law and involved only form two students. The study covered a period of 4 weeks.

1.8 Assumption of the Study

It was assumed that the responses provided by the respondents were a true record of their independent and unbiased opinion and views.

1.9 Definition of Terms

Challenge: It is something new and difficult which requires great effort and determination to do it. In this study it means difficulties faced by Physics teachers in the experimental groups.

Conceptual Understanding: This is knowledge about a topic acquired in an integrated and meaningful manner (Novak, 1976). In this study it is used to mean ability of students to connect relationship between concepts, principles and theories in Gowin Vee depicted by level of scores attained by a student in Physics conceptual understanding achievement test in Physics.

Effects: These are changes which are a result or consequence of an action or other cause, result of something or the ability to bring about a result. In this study it is the result of using Gowin's Vee teaching method.

Gowin's Vee: This is a V – shaped representation with two sides namely the theoretical (thinking side) on the left and methodological (doing side) on the right. The left hand side outlines the theory, principles, constructs and relevant concepts that constitute the prior knowledge of the learner (what the learner knows). The right hand side outlines; value claims, knowledge claims (facts), transformations and records that show how to carry out a learning task for example an experiment in order to answer the focus question. It provides a structure for an experiment or study, ensuring a strong theoretical and conceptual basis and solid analysis. It is a thorough way of representing knowledge about a subject. In this study it a useful diagram for planning and carrying out a study or an experiment, and for evaluating reports.

Hooke's Law: This is a principle of Physics that states that the force needed to extend or compress a spring by some distance is proportional to that distance. That is where is a constant factor characteristic of the spring, its stiffness. In this study it is the concept used to enable students to discover the relationship between force and extension of an elastic material.

Motivation: This is the act of making somebody want to do something, especially something that involves hard work and effort according to Oxford advanced learner's dictionary 8th edition. In this study it refers to how Gowin's Vee encourages the students to learn Physics.

Regular Teaching Methods: These are normal teaching methods used by Physics teachers such as lecture, discussions, demonstrations and laboratory experiment.

Teaching Strategy: This refers to methods used to help students learn the desired course contents and be able to develop achievable goals in the future. Teaching strategies identify the different available learning methods to enable them to develop the right strategy to deal with the target group identified. In this study it refers to a teaching method.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter reviews literature related to the study. These areas are; importance of Physics education, regular methods of teaching Physics, Gowin's Vee as a method for teaching, conceptual understanding, motivation, challenges encountered by Physics teachers, theoretical framework of the study and conceptual framework.

2.2 Importance of Physics Education

Physics is one of the fields of knowledge that underlies the physical universe and applies constantly to people's everyday lives. Physics seeks to explain the reasons why matter acts the way it does and to describe the way matter interacts with other matter from subatomic particles to galaxies in the heavens (Mutai, 2015). It can be as basic as the conversion of electrical energy to heat to make the morning coffee or as complex as plotting a space shuttle flight from Earth into orbit. Even though some concepts are initially difficult to grasp, the reward in terms of satisfaction and knowledge can make all the effort worth it. For example the study of Physics enables us to understand the physical world because it is through Physics that we seek solutions to issues like composition of matter, forces that hold particles of a solid together and what makes the sky to be blue (Okere, 1996).

Advances in technology are often based on discoveries in Physics and inventions based on a new interpretation of existing Physics knowledge (Bortfeld & Jeraj, 2011). For example, Wilhelm Rontgen discovered X-rays more than a century ago, and X-ray machines are now a piece of medical equipment taken completely for granted, designed and perfected by Physicists and engineers working off the initial research. In the first half of the 20th century, Enrico (1944) and Bodansky (2007) studied existing knowledge on nuclear fission and experimented until they achieved the first nuclear chain reactions which lead to the development of nuclear energy plants, which nowadays produce electricity for homes and businesses worldwide.

Physics is related to other subjects and its tenets actually apply to a wide variety of fields. For example, medical students need to know some basic Physics to understand how blood and air flow in the body, taking into account concepts such as pressure, velocity of flow and changes in resistance to flow (Jillian, 2009). Physics is also integral to engineering and is generally relevant for all the sciences. Many people are scared of studying Physics because it has a

reputation as a difficult subject. Specific aspects of Physics that many people find daunting include the need to understand different mathematical equations and graphs and then be able to translate those concepts into real life (Ambrose et al., 2010). While there may be easier subjects out there, one of the values of studying Physics is that it is intrinsically challenging and therefore also extremely rewarding when a student understands it. The Cornell University Physics Teacher Education Coalition says that the best place to learn Physics is through formal education, as the concepts are much harder to grasp in self-directed learning (Fafunwa & Aisku, 1982).

2.3 Regular Methods of Teaching Physics

These are normal teaching methods used by Physics teachers. These methods include; lecture, discussion, project work, demonstration, class experiments and field work teaching methods.

2.3.1 The Demonstration Method

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 (Fred, 2009). During demonstrations, students are kept active, can arouse interest and enthusiasm for the learning science, suitable when handling equipment with high risks of danger and clarify what might otherwise be vague and meaningless (Abungu et al., 2014). The students can get actively involved through questioning as the demonstration progresses, recording, observations and discussing the results (Omondi, 2019). Teacher demonstrations can be used to explain an experimental set before the students begin to set up their own apparatus for individual or group activities. According to Namasaka (2013), this method is especially useful when the apparatus and materials to be used are not enough for the whole class. It is also good for verification of observed phenomena or trend of data. However, the major disadvantage of this method is that it cannot be effective if the teacher does not involve pupils appropriately during the demonstration (Kigo, 2017).

2.3.2 Lecture Method

This involves giving factual information with very little or lack of participation from the learners or an oral presentation of organized thoughts and ideas by a speaker (Okere & Wachanga, 2014).

This method is considered outmoded due to a number of reasons that include failure to offer training for the attainment of scientific skills, content taught is quickly forgotten and boring

especially if lengthy and if the teacher lacks appropriate communication skills (Salandanan, 2008). However, this method is most effective for transmission of a wide content in a given time. In spite of this criticism, this method is still very useful as an instructional technique as long as it is used appropriately (Oluoch, 1982). Oluoch argues that it is an economic way of transmitting information to a large number of pupils because it does not need a lot of facilities. It also enables the teacher to present information in a logical and coherent order in a short time (Ndirangu, 2018).

2.3.3 Discussion Method

This method allows students to share their ideas. The role of the teacher is to guide the discussion.” non-directive teaching removes the teacher from his usual role as information dispenser, confirmation provider and limit setter (Maloy & LaRoche, 2010). It can be used at the beginning of a topic to ascertain students’ preconceived notions of the subject matter or towards the end of a topic by presenting students with a new situation and asking them to explain it in terms of what they have just learned. However, discussion in groups might not have much value unless it is followed by presentation of reports (Omondi, 2019).

Discussion can be done in small manageable groups or as a whole class. If discussion is done in small groups then there is need for a group leader to guide the discussion and one to write the main points to be presented in a report. The topic of discussion should be made clear to the group members or class prior to the sessions. To make the discussions meaningful, students should be encouraged to present their work in a plenary session (Mutai, 2015).

Discussion as a method is accredited for among other merits; widening the learners thinking, building self-confidence, providing feedback, ensures active participation of the learners, make students to be more tolerant and broad-minded, provide a cooperative means of bringing facts together, develops communication skills (Abungu et al., 2014). It also creates class cohesiveness and develops students’ independence from the teacher. However, discussion as a method is known to discourage weak students and encourage laziness in subject teachers. It is also time consuming (Graham et al., 2012).

2.3.4 Class Experiment Method

This involves teaching/learning activities conducted by the students under the guidance/supervision of the teacher (Namasaka, 2009). According to Abungu et al. (2014) the experimental activities aids in capturing students' attention, they also enhance development of learners' attitudes towards science and creativity. This is because during experiments teachers provide students either singularly or in groups, with materials and apparatus as well as the instructions to be followed in performing the activities. Experiments provide learners with the opportunity to demonstrate what has been learnt in the lectures thus boosting students' understanding of the physical laws and concepts.

According to Hohn (1996) two basic skills are required in order for students to carry out practical work safely and successfully. They include ability to read instruments such as thermometers accurately and correct use of equipment and apparatus. Hohn further suggests that successful practical work requires the following: Preparation before practical period, trying out of activities to make sure that the materials used will give expected results, clarity of the instructions (simple and clear language), effective guidance and supervision by the teacher, the teacher to establish a link between the practical work and the concept to be learnt, the teacher to brief learners on any precautions to be taken to ensure their safety and that of the equipment (Kigo, 2017). Although this method is expensive, lack of laboratory facilities should not be taken as an excuse to limit practical work (Mutai, 2015; Shiundu & Omulando, 1992; Wachanga, 2002) since some facilities can be improvised.

2.3.5 Fieldwork (Excursion)

An excursion involves the taking of a group of students to a specific place for a specific purpose (Kazmina et al., 2020). Fieldwork results from a need to illustrate the natural development or technological application of certain topics dealt with in the classroom. It provides students with first hand evidence of scientific phenomena and how they impact on everyday life (Biehler, 1978). Students' interest in Physics may be stimulated and it provides an opportunity to integrate school activities with community life. Some of the places where fieldwork/excursion can be done include, power stations, factories, research laboratories, Radar stations at Jomo Kenyata International Airport (JKIA), radio stations and water falls (Okere 1996).

To avoid a situation where students reduce a field trip to sightseeing, the teacher needs to plan well by specifying the objectives, learning activities, evaluation and follow up activities. The teacher needs to prepare a detailed worksheet or questionnaire and give clear instructions to students beforehand in order for them to focus on key areas of the study (Agango, 2014).

2.3.6 Project Work

The project method is a teacher-facilitated, collaborative approach in which students acquire and apply knowledge and skills to define and solve realistic problems using a process of extended inquiry (Muriithi et al., 2013). It is also referred to as Project-Based Learning (PBL) as it involves making actual projects by the students. Markham (2011) describes project based learning as integrating knowing and doing. Students learn knowledge and elements of the core curriculum, but also apply what they know to solve authentic problems and produce results that matter. Projects are student-centred, following standards, parameters and milestones clearly identified by the teacher. Students have control over the planning, refining, presenting and reflecting on the project.

Through projects, students are engaged in innovation and creativity, carrying out project work at secondary school level, creates a foundation for further studies, prepares students for Kenya Science and Engineering Fair (KSEF). The Fair was created as means to stimulate interest and proficiency in the sciences (Esokomi, 2019). Students with outstanding projects are selected to participate at national levels; it forms the basis for science, technology and innovation: the core idea of project based learning is that real-world problems capture student's interest and provoke serious thinking as the students acquire and apply new knowledge in problem solving (Sands, 2011). This is required for science, technology and innovation. Science, technology and innovation is a paramount driving force for socio-economic development; it facilitates the achievement of millennium development goals through sustained and enhanced socio-economic growth, (Markham, 2011). Technology also enhances project based learning. With technology, teachers and students can connect with experts, partners, and audiences around the world, and use tech tools to find resources and information, create products and collaborate more effectively.

Engineering is also through project work, the creative application of scientific principles to design or develop structures, machines, apparatus, or manufacturing processes (Graham et al., 2012). Project work arouses interest and curiosity among the learners, allows for the application

of knowledge from a wide range of topics in solving a particular problem, enables learners to interact with the environment, practice a range of science process skills, tackle real-life problems and interact socially among themselves (Muriithi et al., 2013).

Killerman (1996), outlines a combination of the following steps and science process skills in project work; observation, identification of a problem, discussion, formulation of a hypotheses, design of the investigation, data gathering, data analysis, making deductions, report writing and presentation. Whatever the case, the teacher should make sure that students have sufficient background information before they embark on project work (Bortfeld & Jeraj, 2011). Teacher supervision and guidance are important pre-requisites for successful project work. Since a variety of methods can be used in teaching, the main issue is how teachers should organize their teaching in order to maximize learning. Many critics of education insist that the most important goal of a school is to teach children how to think and solve problems. Construction of knowledge is a process that surpasses simple memory explanations (Killerman, 1996; Lorayne, 1989; Sands, 2011; Silva, 1992).

2.4 Gowin's Vee as a Method for Teaching

In 1984 Novak and Gowin introduced two constructivist heuristics (Novak, 1990), concept map which is a tool for helping students to understand the meaning of knowledge, and the knowledge Vee diagram, a tool to help students understand the structure as well as meaning of knowledge. The Gowin's Vee heuristic, apart from including the concepts in the left hand side, it includes activities in the right hand side of its V-structure. These enable the learner to understand the nature of scientific knowledge as being both theoretical and practical (Novak & Gowin, 1984). The theoretical side consists of world view, philosophy, theory, principles, constructs and concepts. The methodological side includes records, transformations, knowledge claims and value claims. At the tip of the Gowin's Vee diagram are events or objects to be studied which interact with both sides in order to achieve the answer to the focus question (Novak & Gowin, 1984). Figure 1 shows Gowin's Vee heuristic with a description of all the twelve epistemological elements.

Figure 1

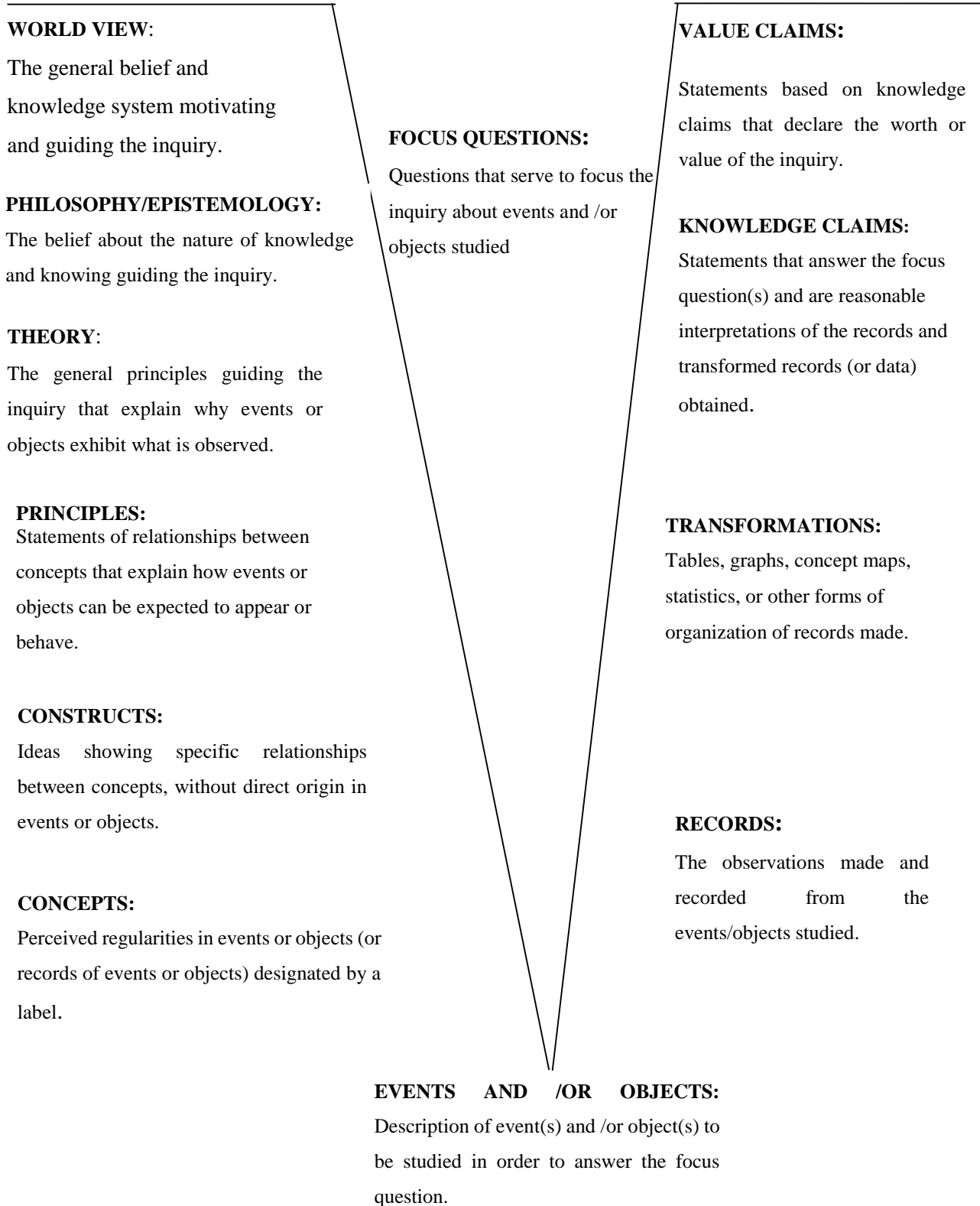
Gowin's Vee Heuristic diagram with a description of the twelve Epistemological Elements

Conceptual/Theoretical

(Thinking)

Methodological

(Doing)



As shown in figure 1, the Vee map has two sides, the left and right. The left hand side represents the theory and is referred to as the conceptual side. It outlines the philosophy, theories, principles and concepts that guide learners in selecting or constructing objects or events to be observed in the learning process (Kuada, 2012). The right hand side represents the methodology, often referred to as methodological side. The right side highlights the knowledge and value claims as well as data recording and transforming procedures. Placed in the middle of the Vee map is the focus question and events or objects to be observed in the learning process are at the bottom. The central idea in using a Vee map is that every element shown is interdependent with every other element on the Vee (Namasaka, 2009). Vee maps concentrate students' attention on the focus question, the events to be observed and direct students to interpret results in terms of relevant knowledge. The fundamental assumption is that knowledge is not absolute, but rather it is dependent upon the concepts, theories and methodologies by which we view the world. This assumption is supported by several views of epistemology (Ameyaw & Kyere, 2019).

Vee maps foster interplay between conceptual and methodological elements and the resultant knowledge or value claims. The knowledge claims are integrated into an individual's cognitive meaning frameworks. Concerned with the apparent inability of students in science laboratories to place their work in a larger context, Gowin began in the 1970s to develop a process that would help students make those crucial learning connections. The Vee heuristic was developed to illuminate the structure of, as well as help students construct knowledge. It emphasizes the structure of, and interplay between the theoretical and methodological dimensions of knowledge (Ameyaw & Kyere, 2019).

Gowin's Vee (Gowin, 1970, 1981), has 12 epistemological elements. The structure of knowledge is in two parts: conceptual and methodological. Gowin chose to use the "V" for the form of his heuristic simply because it has two sides, a center and an apex. The left or conceptual side of Vee in figure 1 is composed of philosophies, theories, principles and concepts; those constructs that provide the foundation or context for further learning. Philosophy, although we don't often think of it in everyday science or science education, underlies all that we do. Gowin described philosophy as the belief about the nature of knowledge and knowing which guide inquiry.

Subordinate to philosophy is theory that is described as “logically related sets of concept permitting patterns of reasoning leading to explanations” (Novak & Gowin, 1984). Note that the description in the figure differs from that here; this is done to provide for a wider understanding of the concepts.

Theories contain one or more principles or constructs which are “ideas which support reliable theory, but without direct referents in events or objects” (Novak & Gowin, 1984.). They in turn are supported by concepts which Gowin describes as “signs or symbols signifying regularities in events and shared socially”. It is the conceptual side which provides the meaning of, and foundation for, the methodology and is also the side which has been traditionally overlooked by both students as well as some teachers. The focus question in the center of the Vee is based on the conceptual side and must clearly address an issue specific to the left side. The apex, especially, points to the events and objects which “are at the root of all knowledge production” (Novak & Gowin, 1984). Events and objects are the activities and materials which comprise the normal laboratory experience and have as their immediate foundation the focus question (Novak et al., 1983). Although not stated explicitly, Gowin chose to use events and objects in lieu of “materials and methods” to ensure that those epistemological elements would not be confused with some named elements of the positivists’ scientific method.

Moving up the right side are the results of the events and objects, first of which is the record or specific results of the experience. They in turn can be transformed to a more useable format such as graphs or statistical analyses which in turn can be used to create knowledge claims in which new generalizations answer the focus question. At the top of the methodological side, and supported by the elements below it, are the value claims which identify the worth of the knowledge claims or place them in the context of the underlying theory. Such worth in the context of the underlying theory is the purpose of Kuhn’s (2012) “normal science”. Note the “interaction” arrow connecting the conceptual and methodological sides; it is this which calls to the attention of the student and teacher, the connections between knowing and doing. The Vee functions in helping students see the interactions between theory, methods and results. In its use, the Vee functions much like an advanced organizer in that it enhances the organization strength of the cognitive structure. This study will apply Gowin’s Vee in teaching form two students Hooke’s law and find its effects on conceptual understanding and motivation (Njoroge et al., 2014).

2.5 Conceptual Understanding

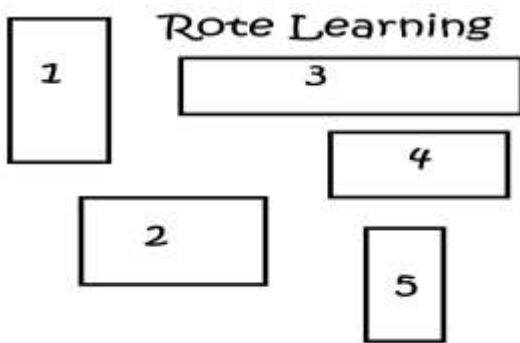
Concepts are packages of meaning; they capture regularities, patterns or relationships among objects, events and other concepts (Novak, 1996). According to the social constructivist approach, instructors have to adapt to the role of facilitators and not teachers (Amineh, 2015; Bauersfeld, 1995). The linearly separable concepts require fewer violations of the prior knowledge than the non-linearly separable concept. This explanation is also supported by later studies (Pazzani & Silverstein, 1990; Wattenmaker et al., 1986) that suggest a non-linearly separable concept consistent with prior knowledge is easier to learn than a linearly separable concept that violates prior knowledge. Concepts are understood by establishing relationships with prior knowledge (Demirbas & Ertugrul, 2014).

But what are the kinds of relationships which help lend meaning to new concepts? Meaningful learning of some kind can occur when appropriate links are made to any of a variety of kinds of relevant prior knowledge. Rote learning is where one memorizes something without full understanding and does not know how the new information relates to the other stored knowledge. In the traditional teaching the teachers' main focus is on memorization (rote learning). According to Safdar (2013), rote learning is not meaningful in the process of internalization. It is arbitrary and verbatim in nature. It stays close to the cognitive structure of the learner but does not get integrated there. Hence as a result the learner exhibits a non-successful learning set (Safdar & Shah, 2014).

At the end of a learning experience, a student can assess his/her own learning outcomes by using two basic kinds of tests: 'retention tests', which seek to evaluate if the student remember what was taught, and 'transfer tests', which the student must apply what has been learned to a novel situation (Mayer, 1995). If a student has not learned, he/she would have poor retention and poor transfer performance. If student has learned in a rote way, he/she probably have good retention, but would not know how to transfer. If student learned in a meaningful way, it is likely that the student would have both good retention and good transfer (Safdar & Shah, 2014). For example, let's say we learn 5 facts in a Physics course in a term by rote learning, figure 2 shows the stages of rote learning from 1-5 as separate items.

Figure 2

Diagrammatic explanation of stages of Rote Learning

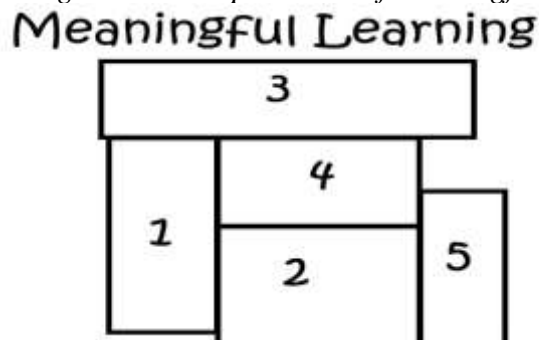


The 5 facts (labeled 1-5) are stored in memory as separate items although in real life they are related to each other. When the student rote-learned these facts, the brain stored them as distinct, unrelated knowledge that can only be recalled individually (one fact at a time). When this student recalls one fact the other 4 facts are not recalled (or activated) at that moment. In other words, thinking about fact 5 does not lead the student to think about facts 1-4 (Ausubel 2000). The meaning of learning is explained further in the subsequent paragraphs.

When meaningful learning occurs the facts are stored in a relational manner (Figure3). That is, the brain stores them together because they are related to each other (Demirbas & Ertugrul, 2014). Now, when one fact is recalled, the other facts are also recalled at that moment (or shortly thereafter). In other words, recalling fact 5 activates the memory for facts 2 and 4, and this in turn leads to recalling facts 1 and 3. This phenomenon is called the spread of activation. This is the gist of meaningful learning. Problem-solving for this student would be easier than for the student who rote-learned the same 5 facts (Sharma & Chawla, 2018).

Figure 3

Diagrammatic explanation of meaningful learning.



Ausubel (1968) says that “Meaningful learning takes place if the learning task is related in a non-arbitrary and non-verbatim fashion to the learner’s existing cognitive structure”. Ausubel

believes that “learning should progress deductively from the general to the specific, and not inductively, as Bruner recommended (from specific to general). He supports the use of direct instructional methods (lecture), and argues that large bodies of knowledge are best obtained through this type of learning.” What are the obstacles to conceptual understanding? (Safdar, 2013). It is helpful to think in terms of obstacles to initial acquisition of conceptual understanding and obstacles to retention of that understanding (Feltovich et al., 2012). Understanding is quite the opposite of memorization in that acquisition is what is difficult; retention is relatively easy (Hilgard et al., 1953).

Since acquisition is mainly a matter of relating the new knowledge to appropriate prior knowledge must indeed have been acquired already. Second, the appropriate prior knowledge must be "activated" that is, it must be brought to mind. Third, the proper relationship between the new knowledge and the prior knowledge must be learned. The more links created with relevant prior knowledge, the greater the depth and/or breadth of understanding. Once conceptual understanding has occurred, retrieval problems are relatively rare. To achieve meaningful learning, Kolb (1983) and Akella (2010) observed that there is a ‘natural’ learning cycle that follows these four stages when students undertake to learn something on their own.

The starting point is concrete experience; we then make observations and reflections on that experience. The third step involves using abstract concepts and generalizations to make sense of the reflections, which leads on to testing the implications derived from the abstraction in new situations (Safdar, 2013). However, if some piece of meaningful knowledge is not used for a long time, it can undergo what Ausubel (2000) calls "obliterative subsumption". To the extent that conceptual knowledge is subsumed under a broader, more inclusive representation of it, lack of use can result in the more detailed refinement being merged back into the subsumer from which it sprang, becoming indistinguishable from it. The more similar it is to its subsumer, the more quickly it is learned, but the more quickly it can also be forgotten. By making relationship among concepts, understanding can be measured using rote memorization because understanding cannot be directly observed Omondi (2019). It can only be inferred from various observable behaviors.

There are observable behaviors for each of the kinds of relationships. They include contextualizing, comparing and contrasting, analyzing, instantiating, analogizing and so forth (Bransford et al., 2000). For causal understanding, they include such things as explanation

(making an inference), prediction (describing an implication), and solution (solving a problem) (Safdar, 2013). This study will investigate the effect of Gowin's Vee on conceptual understanding of Hooke's law by two students.

2.6 Motivation to Learn Physics

Motivation is the act of making somebody wants to do something, especially something that involves hard work and effort (Fretz, 2015). Motivation has driving elements intensity, direction and persistence that enhance achievement. Intensity enables a person to work very hard, direction gives the way forward towards achievement of the target goal, and persistence enables an individual to wait as long as to achieve the goal. David and Anderzej (2010) posit that motivation is a cognitive decision making intended to make behavior with the aim of achieving a specific goal through initiation and supervision. Motivation can either come from within the student (intrinsic) or from outside (extrinsic). A child who is intrinsically motivated performs a task because of the joy that comes from learning new materials. Motivating students is important, without it, teachers have no point of entry.

But it is engagement that is critical, because the level of engagement over time is the vehicle through which classroom instruction influences student outcomes. For example, engagement with reading is directly related to reading achievement (Fretz, 2015; Guthrie, 2001; Guthrie & Wigfield, 2000). When students are academically motivated, their teachers often become professionally motivated, working hard to provide students with worthwhile educational experiences and finding more satisfaction in doing so (Ryan & Deci, 2020). Intrinsically motivated students set and work towards their own goals, undertaking tasks that they find both interesting and personally satisfying. They do not have to be pressured or coerced into completing their freely chosen tasks. Learners can be intrinsically motivated or extrinsically motivated. Learners tend to be intrinsically motivated when they perceive themselves as being both competent and self-determining (Levesque et al., 2004). The behaviour of students who are intrinsically motivated is internally regulated, meaning that those learners do not let other people or external events unduly influence them (Matusitz & Martin, 2013).

Extrinsically motivated students do not perceive themselves as being competent or self-determining. Their behaviour is externally regulated, meaning that other people and external events play a large role in determining their decisions and behaviour (Chua & Koestner, 2008; Fretz, 2015). For example, when students feel incompetent, their attention is often turned

outward towards those individuals they perceive as being more competent than they are. Thus rather than focusing on the task at hand and the satisfaction inherent in doing a good job on it, externally motivated students focus on what their teacher will think of them if they do not do a good job, how they can get help from the person sitting next to them, what sort of reward will be available if they do a good job, how they can make the student who always gets A grades look bad and what sort of punishment will be delivered if they do not do a good job.

Deci and Ryan (2020) gave another definition of a motivated student. A motivated student does not see any relationship between their own academic behaviour and what happens to them in school. If their teacher calls on them in class and they answer a question correctly, they are likely to attribute that success to luck or the easiness of the question and when they do poorly on an exam or quiz, they see no connection between the fact that they did not study and their grade on the test (Hargreaves, 2012). In the eyes of these motivated students, the results of the examination or quiz were predetermined; it was something that no amount of studying could have changed. They believe that their school successes are attributable to external, uncontrollable factors like easy test or lucky guess and thus, no reason to put out any effort or energy. Deci and Ryan (2020) three motivational orientations are best viewed as being at least somewhat situationally determined according to (Kigo, 2017). That is, individuals are not always intrinsically motivated or always extrinsically motivated.

Some individuals are motivated in school environment but highly motivated, albeit extrinsically, in work environments where they can earn money for their efforts. Teachers should be careful not to make sweeping orientations as flexible and fluid psychological structures, influenced by environmental factors; there is room for teachers to have an effect for good or bad on their students' academic motivation. Kigo (2017) suggests that promoting intrinsic interest in learning is much more complicated because when students do not perceive themselves as being competent in a given academic environment, opportunities to be self-determining lead only to decrements in their motivation.

This means that intrinsic motivation results when perceived competency and perceived control come together simultaneously (Deci & Ryan, 2020). The teachers' goal is to increase their students' intrinsic motivation in academic environments. However, intrinsic motivation is a situationally determined psychological state and as such no student can be in perpetual state of intrinsic motivation (Deci & Ryan, 2020). Motivation is highly complex phenomenon (Bajwa

et al, 2010; Jackson et al., 2009). It influences and is influenced by a large number of factors in one's environment (Part & Steers, 1991). The study of motivation is concerned with why individuals think and behave as they do (Mullin, 1999; Wagner, 1999; Weiner, 1992). Teachers face a lot of frustrations in trying to motivate weak students. Teachers ought to understand that everything they do in the classroom has a motivational influence on students' attitude.

This includes the way information is presented, the kind of activities teachers' use, the ways teachers interact with students, the amount of choice and control given to students and the opportunities for students to work alone or in groups (Fretz, 2015). Students react to who teachers are, what they do and how comfortable they feel in the classroom. This is because motivation is a function of what motivation researchers Deci and Ryan (2021) describe as natural needs for control, competence, and belonging that exist in all of us. Teachers can feel overwhelmed, when faced with students who are de-motivated to learn (Orodho, 2012). The task of teaching thus become less daunting when teachers realize that they can boost student motivation by first, making positive changes to the learning environment such as developing a setting in which learners work to encourage them to give their best efforts.

According to Montoya et al. (2008) and Rubin (2012), learning is a social activity and the interpersonal relationships are a central motivation for most learners. The teacher can therefore boost student motivation through selection and development of learning activities such as; encouraging active student participation in the learning process, using motivating 'real-life' examples for review, quiz or test items, structuring work period so that more difficult activities are in the middle with easier tasks at the start and end, allowing students to set their own pace for completing work, use humour and keeping miscellaneous work supplies on hand for students to borrow (Williams & Williams, 2011). When learners perceive learning to be interesting, fun, personally involving, meaningful and relevant and the context supports and encourages personal control, motivation to learn and self-regulation of the learning process occur naturally (McCombs & Whisler, 1989; Ridley, 1991).

That is, in situations the learner perceives as interesting or related to personal goals that can be pursued in self-determining ways, the learner is caught up in the activity and directs attention to accomplishing the personal goal. The learner may not even be consciously aware of being self-motivated and self-regulatory (Lens et al., 2002). A crucial assumption regarding the nature of the learner concerns the level and source of motivation for learning. According to

Von Glasersfeld (1989) sustaining motivation to learn is strongly dependent on the learner's confidence in his or her potential for learning. These feelings of competence and belief in potential to solve new problems are derived from first-hand experience of mastery of problems in the past and are much more powerful than any external acknowledgment and motivation (Lambros, 2013).

This links up with Vygotsky's "zone of proximal development" (Vygotsky 1978) where learners are challenged within close proximity to, yet slightly above, their current level of development. By experiencing the successful completion of challenging tasks, learners gain confidence and motivation to embark on more complex challenges. Many teachers agree that practical work should be done to create interest and motivate students in science lessons (Koballa & Glynn, 2013). Similarly students justify the use of practical work on the grounds of interest and motivation and often enter a science class with the expectation that normally they will be doing a practical activity. A scientist's work involves 'doing experiments, which requires a set of skills and techniques to be mastered. Observation and measurement skills need to be developed along with techniques for the safe and systematic manipulation of apparatus (Koballa & Glynn, 2013; Lynch, 1987; Woolnough & Allsop, 1985).

2.7 Challenges Encountered by Physics Teachers when using Govin's Vee Teaching Strategy

Scholars in Physics education have made quite a deliberate effort to improve the way Physics is taught in order to try and eliminate the perception that Physics is difficult. This perception is very common not only among secondary school students but also among undergraduate science teachers (Chiappetta et al., 2002). For many students, Physics is a subject that is perceived to be difficult and that should be dropped as fast as possible (Lyons 2005; Semela, 2010). One problem with regular method of teaching Physics lies in the presentation of materials (Gok], 2018). Serious teachers should teach with their content in the mind and their students at heart (Bhatt, 2012).

What all great teachers have in common is the love for their subject and an obvious satisfaction in arousing this love in their student and ability to convince them that what they are being taught is deadly serious. It is however possible that consistent low academic achievement may lead to discouragement and consequently negative attitude. The complex nature of classroom

inquiry leads to a host of problems. For example, teachers may not share similar instructional goals for science teaching (Abell, 2000; Southerland et al., 2003).

Teachers may experience frustration when students do not accomplish subject matter goals or when students do not develop inquiry skills (Smith & Anderson, 2012; Southerland et al., 2003) teachers may find it difficult to construct experiences, discussions and assessments that help students question and expand their ideas about scientific knowledge (Hammer, 2000; Smith & Anderson, 2012) and significant progress is hard to achieve without socio-emotional and cognitive challenges for the teacher. Furthermore, students (and teachers) may become frustrated and less successful when asked to make evidence-based claims and build collective models (Smith & Anderson, 2012; Southerland et al., 2003). Or they may become resistant when asked to put forth the effort necessary to integrate authoritative knowledge with evidence-based knowledge (Smith & Anderson, 2012; Southerland et al., 2003).

According to Bullough and Pinnegar (2001), and Ovens and Fletcher (2014), self-study involves the investigation of weaknesses with one's teaching. Self-study research addresses the growing dissatisfaction about the value of traditional approaches in education (Korthagen & Kessels, 1999) by developing a deeper understanding of the nature of teaching and a greater satisfaction in that work (Loughran, 2002). Another challenge to teaching science through inquiry was developing a student-centered classroom. Within the context of a student-centered classroom, teaching students appropriate scientific terminology means allowing them to use their own terms first, and later helping to replace students' terms with scientific ones (Sands, 2011). The teacher provides a personal experience in which students can attach meaning to the new terms. The importance of mathematics can be seen from the fact that students who have mathematical difficulties do not have any guarantee of success in teaching and learning Physics; in other words, students who do not have sufficient mathematical ability, will certainly have weak physical ability (Chiu, 2015; Hudson & McIntire, 1977; Pietrocola, 2008). Without knowledge of mathematics, it is impossible to attain good knowledge of Physics.

However, in the reality the phenomenon is that Physics teachers spend a great deal of time to teach students about mathematics earlier and quicker since they have not mastered mathematics well, whereas mathematics is a prerequisite in teaching and learning Physics (Retnawati et al., 2018).

The complaint frequently conveyed by Physics teachers is that students are not been able to apply the knowledge that they attain in mathematics into the Physics class (Retnawati et al., 2018). In addition, mathematics is often considered as the cause of students' failure in teaching and learning Physics; students have not understood Physics well because they have weakness in their concept of mathematics (Pietrocola, 2008). Therefore, several experts consider that the fundamental ability in mathematics provides greater opportunity to achieve success in teaching and learning Physics. This situation then will be the one that has forced Physics teachers to teach mathematics first (Sands, 2011). As a consequence, Physics teachers have greater challenges than do mathematics teachers. In addition, Physics curriculum demands Physics teachers to teach several contents that have been more challenging (Chiu, 2015). It is this heavier load that becomes the difficulty and the stress on Physics teachers' part if mathematics curriculum does not support Physics curriculum and if mathematics teachers have not taught the contents that support Physics teaching and learning process.

Chiu (2005) underlined five challenges that Physics teachers encounter in implementing the Physics teaching and learning process prior to teaching the mathematics curriculum to the students, namely:

- (i) Political challenge: the national curriculum emphasizes the higher political policy rather than the high education policy
- (ii) Social challenge: there have been plenty of interventions in education
- (iii) Scientific challenge: the borders between the subjects and the knowledge have increased in schools
- (iv) Justice challenge: there has been inequality in the learning opportunity
- (v) Teaching challenge: the burdens of Physics teachers have increased because of the urgency to teach mathematics and of the mathematics teachers' confusion in re-teaching the learning materials that have been studied in Physics.

If the mathematical competency is necessary for solving the physical problems, then it will be wiser to teach mathematics first (Nahson et al., 2009). Teaching and learning that train many abilities, for example train the mathematics ability first and then train Physics abilities and skills cause teachers to work too hard, especially teachers also have the task of carrying out the assessment. Teachers' difficulties in carrying out such complex learning require long time (Retnawati et al., 2017), and cause difficulties in conducting assessment (Retnawati et al.,

2016). Bajah (1993) identified inadequate laboratory facilities and exposure to be responsible for the unsteady state of Physics teaching in Nigerian Secondary Schools.

According to Millican et al. (2005) Physics is an experimental subject. The teaching of Physics without learning materials will certainly result to poor performance. According to Bhatt (2012) provision of necessary facilities in schools will provide a challenging environment for students to learn and for effective teaching by the teachers. On the other hand Chiu (2015) says that lack of adequate facilities such as textbooks, ill-equipped classrooms, laboratories, workshops and library are among the probable causes of students' poor performance in examinations. Smyth and Hannan (2006) found that teachers experience and instructional facilities have also been found to shape Physics take up. A study conducted by Retnawati et al. (2018) showed that having no science laboratories or inadequate equipment in science laboratories in schools affect teachers attitudes towards the aims of science experiments in a negative way. Science experiments are inseparable and indispensable parts of learning experiences.

2.8 Theoretical Framework of the Study

This study was based on Novak and Gowin (1984) Meaningful Learning Theory (MLT) based on David Ausubel's meaningful learning principles that incorporate "concept maps" and knowledge Vee diagrams to represent meaningful relationships between concepts and propositions. Both instruments help in processing, become conceptually transparent in terms of information and also facilitate the cognitive process of new meanings construction. The constructivist theory would therefore provide theoretical basis for the study. The constructivist epistemology asserts that knowledge resides in individuals and is constructed from within (Dennick, 2014; Driver & Oldham, 1986). This means that prior knowledge is crucial in the learning process because it makes understanding of new knowledge easier. The implication of this is that teachers have a role of helping students to learn how to learn.

In the light of this, when the teaching method (Gowin's Vee strategy) is used, effective and meaningful learning is likely to take place. Constructivist theory of instruction is helpful in classifying the relevant aspects of the educative events Dennick, (2014). In an educative event, teachers and learners share meanings and feelings so as to bring about a change in the human experience. This theory stresses the centrality of the learner's experience in learning. Ausubel's learning theory places central emphasis on the influence of students' prior knowledge on subsequent meaningful learning. Philosophers such as Brown (1979), Gowin (1970, 1981),

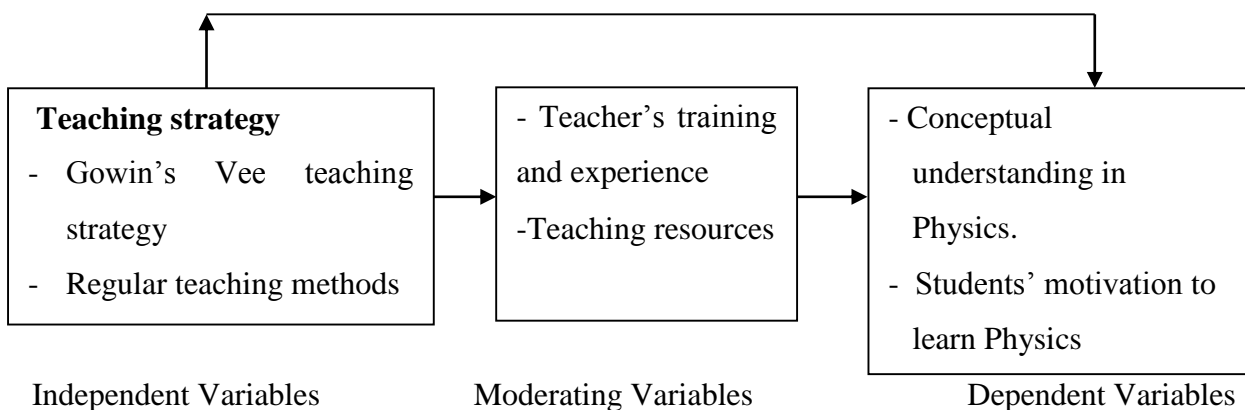
and Toulmin (1972) feel that knowledge is constructed from experience using concepts as stepping stones (Driver & Oldham, 1985; Fosnot, 1996; Pines & West, 1986).

2.9 Conceptual Framework

The concepts that guided this study are as outlined in the conceptual framework shown in the Figure 4.

Figure 4

Conceptual Framework showing the Basic Concepts



In the conceptual framework teaching using Gowin's Vee teaching strategy and teaching using regular methods forms the independent variables. Gowin's Vee is a new method expected to make students understand concepts while regular methods like discussions, lecture, demonstrations etc have been used by teachers for a long time but the performance has been low. Influence of motivation and students' conceptual understanding in Physics forms the dependent variables. These variables are the end results after using the new teaching method. To control the moderating variables, trained teachers in the experimental schools selected and co-educational secondary schools with almost the same level in KCPE performance and resources was used (Dennick, 2014; Driver & Oldham, 1986).

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Introduction

This chapter covered the research design, study location, study population, sample and sampling techniques, instruments, validity of the research instruments, reliability of research instruments, data collection procedures and data analysis.

3.2 Research Design

In this study Solomon-four non-equivalent control group design was used as shown in figure 5. According to Fraenkel and Wallen (2009) Solomon-Four is suitable in experimental and Quasi-experimental research because it can control all the threats to internal validity. This design is adopted because under school arrangement the students have already been assigned classes and cannot be randomly constituted during the study. This cannot be authorized in the schools since it will affect the laid down criteria for which they were initially constituted. Figure 5 shows structure of Solomon four non-equivalent control group design.

Figure 5

Solomon four non-equivalent control group design (Cohen & Manion, 1990)

Group 1(E ₁)	O ₁	X	O ₂

Group 2(C ₁)	O ₃	–	O ₄

Group 3(E ₂)	–	X	O ₅

Group 4(C ₂)	–	–	O ₆

Key

.....= No randomization is done

X = treatment

O₁ & O₃ = pretest results

O₂, O₄, O₅ & O₆ = Posttests results

There are two experimental groups E₁ and E₂ and two control group C₁ and C₂. One of the experimental group E₁ and one control group C₁ received the pre-test while the other experimental group E₂ and control group C₂ were not pre-tested. At the end of the study, all the groups were post-tested simultaneously. Most of the threats to internal and external validity

were addressed by this design. Sensitization was addressed by having one of the experimental and one control group pre-tested. The reactive effect was controlled by ensuring that the subjects under the study were not made aware that they are in an experimental situation. The schools that acted as control groups were selected at a far distance from the experimental groups in order to prevent any contamination during inter-school activities.

3.3 Study Location

The study was carried out in Koibatek Sub-County. This Sub-County is in Baringo County and located in the south western part of the County. It is situated to the north of Nakuru, borders Kericho to the North West. The Sub-County is to the west of Laikipia, south of Elgeyo Marakwet. There has been consistent low performance in Physics in Koibatek Sub-County for a long time and also no study had been done on the effects of Gowin’s vee teaching strategy on secondary school students’ conceptual understanding and motivation in Physics.

3.4 Study Population

Koibatek Sub-County has 33 public secondary schools. It has 4 divisions namely: Eldama Ravine, Torongo, Mumberes and Esageri. The total number of form two students in Koibatek Sub-County who were doing Physics was 2041 and the teachers were 35. The 24 co-educational secondary schools are distributed in the divisions as shown in the table 3.

Table 3:

Distribution of Accessible population by Divisions

Division	Students	Teachers
Eldama Ravine	1626	24
Esageri	225	5
Mumberes	100	4
Torongo	90	2

The target population was the secondary school Physics students in Koibatek Sub-County. The accessible population was the Form two Physics students in 24 co-educational secondary schools in the study area. The form two students were purposively selected for the study because the topic of Hooke’s law is taught in form two; the students were also fairly exposed to the Physics subject and almost choosing subjects at the end of form two.

3.5 Sampling Procedures and Sample Sizes

Four co-educational secondary schools out of 24 schools were purposively selected. This is because of the research design which uses Solomon-four non-equivalent control group design. The four schools were equivalent in terms of resources and performance in national examination therefore formed the study sample. Co-educational secondary schools were selected so as to control gender issues. This was done by checking their background performance including KCPE entry marks. Two co-educational secondary schools were chosen in Eldama Ravine division since it has many schools, one from Esageri division and one from Mumberes division. To get the sample size from the four schools one class was used then the results were generalized to other classes and schools. The number of students per class was expected to be 45 that mean a total of 180 students. However, four classes were selected randomly in each of the four schools. They were grouped into: $E_1=30$, $E_2=36$, $C_1=40$ and $C_2=32$ giving a total of 138 students. Correlational designs require at least 30 participants and experimental, quasi-experimental, and causal-comparative designs require at least 15 participants per group (Onwuegbuzie & Leech, 2007).

3.6 Instrumentation

A Physics Conceptual Understanding Achievement Test (PCUAT) was used to measure students' conceptual understanding in the topic of Hooke's law. This is an achievement test constructed by the researcher. It consisted of four test items. The questions covered Hooke's law. Each question was answered by filling in the twelve epistemological elements of the Gowin's Vee. The students incorporated the applications of the topic under value claims which is the last element of the Gowin's Vee. The twelve epistemological elements were each assigned a mark according to Gowin's Vee scoring criteria (Novak & Gowin 1984). For Physics students' motivation, a 35 item 5-Likert scale questionnaire adopted from Cooper and Sandi-Urena (2009) was given to students by the Physics teachers in the selected secondary schools.

The 5-Likert scales are; SA-Strongly Agree, A-Agree, U-Undecided, D-Disagree, SD-Strongly Disagree. For positive questions the scoring was be; SA-5, A-4, U-3, D-2, SD-1 and for negative questions it was SD- 5, D-4, U-3, A-2 and SA-1.

3.6.1 Validity of the Instruments

Validity of an instrument is a measure of the extent to which the instrument measures what it is meant or expected to measure (Mugenda & Mugenda, 2003). Secondary school Physics teachers and lecturers in charge of students' supervision of postgraduate students from Egerton University Department of Curriculum, Instruction and Educational Management validated the content of the questionnaire to ensure relevancy and accuracy. The lecturers and Physics teachers in the selected co-educational secondary schools were able to go through the instruments to check any corrections before being used.

3.6.2 Reliability of the Instruments

According to Mugenda and Mugenda (2003), reliability of an instrument is a measure of the extent to which a research instrument yields consistent results or data after repeated trials in the study. According to Murray (2010), pilot testing of instruments is important because it helps to identify ambiguities of the items and vague questions for improvement. Pilot testing of the instruments was conducted before the main study. For this purpose one co-educational secondary school from Mogotio Sub-County with similar characteristics to those under study but not included in the sample was used. Cronbach's alpha was used for PSMQ while that of PCUAT was calculated using the Kuder Richardson KR 21 formula.

Cronbach's alpha formula

$$\alpha = \left(\frac{k}{k-1} \right) \left(1 - \frac{\sum_{i=1}^k \sigma_{yi}^2}{\sigma_x^2} \right)$$

k - Refers to the number of scale items

σ_{yi}^2 - Refers to the variance associated with item i

σ_x^2 - Refers to the variance associated with the observed total scores

From the above formula the researcher found the reliability of the instrument to be 0.88 which is acceptable for the study.

Kuder-Richardson Reliability Coefficient KR21 formula

$$KR_{21} = \frac{K}{K-1} \left[1 - \frac{\bar{X}(K-\bar{X})}{K(\sigma^2)} \right]$$

KR21 - Estimated reliability of the full-length test

K - Number of items

σ^2 - Variance of the whole test (standard deviation squared)

\bar{X} - Mean score on the test

The researcher found the reliability of the instrument for PCUAT to be 0.94. The threshold value to be accepted in this study is 0.7 and higher (Fraenkel & Wallen, 2009).

3.7 Data Collection Procedures

To carry out this research the researcher received authorization letter from Egerton University Faculty of Education and Community Studies at Njoro through Graduate School. The researcher obtained research permit from the National Commission for Science, Technology and Innovation (NACOSTI) to carry out the research study. The permit was presented to Baringo County Director of Education who gave authorization letter to carry out research in Baringo County. The letter was then presented to the principals of the five schools to seek their permission to carry out research in their respective schools.

The researcher gave pre-test to students in the experimental group E_1 and control group C_1 . Training of Physics teachers on the use of Gowin's Vee took one week. These were teachers who taught in the experimental group E_1 and E_2 . They were provided with Gowin's Vee teaching guide. The teachers used two weeks to train students using Gowin's Vee. This ensured that the students familiarized themselves with the Gowin's Vee before using. Teaching using Gowin's Vee strategy in the topic of Hooke's law proceeded for another two weeks. Finally, post-testing was done using PCUAT and PSMQ by all the four groups. Care was taken to ensure that the control and experimental groups do not meet to prevent contamination. Data was also collected by the researcher qualitatively through an interview on challenges faced by the teachers during teaching using Gowin's Vee teaching strategy.

3.8 Data Analysis

This study uses Solomon four non-equivalent control group design. It contains four groups which required careful process of data analysis. Mostly, the data analysis combines various analyses in order to verify the effect of treatment. Therefore, this study first computed standard deviations and means of each score. One way ANOVA was used to test the hypotheses at 0.05 significance α -level respectively. ANOVA gives indication of existence of significant difference among the groups in the Solomon four. However, it does not indicate the pattern of difference between the means. In order to analyze the patterns of difference between means, ANOVA analysis was followed by post hoc analysis which involved comparing a pair of means at a time. Scheffe multiple comparison test was used. This gives the significant difference of the means using student distribution called p values at $\alpha=0.05$ significance level. Secondly, t-

tests was carried out to test whether the means of the pre-tests were statistically significant at $\alpha=0.05$ significance level. Qualitative data was organized in themes pertinent to the study objectives and summarized using frequencies and percentages.

Table 4:

Summary of Data Analysis

Hypothesis	Independent Variable	Dependent Variable	Analysis Technique for Quantitative data
Ho1: There is no statistically significant effect in conceptual understanding between students taught using Gowin's Vee and those not exposed to it, in the topic of Hooke's law in Physics.	Gowin Vee teaching strategy. Regular teaching methods.	Conceptual understanding In Physics learning	Mean Standard deviation One way ANOVA, t-test
Ho2: There is no statistically significant effect in the level of motivation between students taught using Gowin's Vee and those not exposed to it, in the topic of Hooke's law in Physics	Gowin's Vee teaching strategy. Regular teaching methods.	Students motivation to learning Physics increases	Mean Standard deviation One way ANOVA, t-test.

3.9 Ethical Consideration

Ethics is concerned with defining norms of conduct which distinguish between acceptable and unacceptable behaviour (David & Resrik, 2011). Indicators of ethical behaviour include; honesty, objectivity, integrity, carefulness, openness, respect for intellectual property, confidentiality, responsible publication, non-discrimination, legality and human subjects' protection. Ethics demands that a researcher must seek the consent of the subjects in studies that involve human beings, and put in place mechanisms that ensure that their safety, privacy, are respected and treated equally (Hammersley & Traianou, 2012). Within a research context, ethical considerations are the guidelines that ensure researchers' behaviours are within the acceptable norms (Parveen & Snowkat, 2017).

This study attempted to ensure that the ethical considerations were observed by explaining to the students the purpose of the study and seeking their consent to participate in it. The students were also informed of their right not to provide answers to the questions they were not

comfortable with and withdraw from the study when they felt so. During the study, the students were treated with respect and equally. They were also assured that all the information given would be treated with confidentiality and anonymity. This was achieved through use of codes, controlling access to data files by use of pass words and reporting only aggregated data. Data provided by the respondents were not tampered with to suit the researcher's opinion and the findings of the study were solely based on the study data. Plagiarism was minimized by listing in the reference all sources cited in the thesis.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

The results and discussions of the study are presented in this chapter. The chapter begins by examining the entry behavior of the groups before the commencement of the study. It then establishes the difference in students' achievement in Physics by teaching method. The chapter also explores the difference in students' motivation to learn Physics by teaching strategy. Finally, discusses the challenges encountered by Physics teachers in the experimental groups and also advantages when teaching using Gowin's Vee teaching strategy.

4.2 Pre-Test Analysis

The entry behavior of the subjects were established before the commencement of the programme by pre-testing groups E1 and C1 on Physics Conceptual Understanding Achievement Test (PCUAT) and Physics Motivation Questionnaire (PSMQ). Pre-testing helps the study to identify the characteristics of the subjects at the beginning of a programme. This was to make sure that the groups used in the study had similar characteristics and same entry level before administering of the treatment (Borg & Gall, 1989). The information gathered during the pre-test helps the researcher to come up with valid and objective conclusions about the population at the end of the study (Luvanya, 2013). During the pre-test analysis, the students pre-test mean scores of the groups on Physics conceptual understanding and motivation were compared by teaching strategy. To test whether the groups were similar a t-test was used. The results of the comparison by teaching strategy are shown in Table 5

Table 5:

T-test Results of the Pretest Scores on PCUAT

Group	N	Mean	SD	df	t-value	p-value
	30	14.40	6.18	68	.330	.743
C1	40	13.95	5.22			

The results in Table 5 show that the Physics conceptual understanding pre-test mean score (M = 13.95, SD = 5.22) of C1 was not significant different from that (M = 14.40, SD = 6.18) of E1 at the 0.05 level, $t(68) = 0.330$, $p > 0.05$. This means that the two groups were similar before the commencement of the teaching strategy as measured by Physics conceptual understanding pre-test mean scores. Given that the E1 and C1 had comparable characteristics on Physics

conceptual understanding, they were considered suitable for the study as they were drawn from a stable population.

The motivation pre-test scores were also analysed before commencement of the study. This involved comparing the mean score of E1 with that of C21 as presented in Table 6.

Table 6

T-test Results of the Pre-test Motivation Scores on PSMQ

Group	N	Mean	SD	df	t-value	p-value
E1	30	2.27	0.59	68	.854	.396
C1	40	2.15	0.58			

The results in Table 6 show that the Physics motivation pre-test mean score ($M = 2.15$, $SD = 0.58$) of C1 was not significant different from that ($M = 2.27$, $SD = 0.59$) of E1 at the 0.05 level, $t(68) = 0.854$, $p > 0.05$. This means that the two groups were similar before the commencement of the teaching strategy as measured by Physics motivation pre-test mean scores. Given that the E1 and C1 had comparable characteristics on Physics motivation questionnaire, they were considered suitable for the study as they were drawn from a stable population.

4.3 Comparison of Physics conceptual understanding achievement between students taught using Gowin’s Vee and those taught using regular methods

The first hypothesis tested whether there was no significant difference in Physics conceptual understanding between students taught using Gowin’s Vee and those taught using regular methods. The Physics conceptual understanding posttest mean scores was used to determine the differences among the groups; E1, C1, E2 and C2 that took part in the study. The post-test means scores and their standard deviations are summarized in Table7.

Table 7

Students’ Physics Conceptual Understanding Post-test Mean Scores and their Standard Deviations

Group	N	Mean	SD
E1	30	22.90	4.99
E2	36	22.33	5.02
C1	40	15.70	7.25
C2	32	11.22	4.58

An examination of the scores in Table 7 reveal that the mean scores of experimental groups E1 (M = 22.90, SD = 4.99) and E2 (M = 22.33, SD=5.02) were higher than those of the control groups C1 (M = 15.70, SD = 7.25) and C2 (M = 11.22, SD = 4.58). The ANOVA test was used to establish whether the difference among the mean scores were significantly different or not. This shows that the experimental groups had higher mean scores than the control groups. The experimental groups were taught using Gowin’s Vee teaching strategy while control groups were taught using regular methods. It can therefore be deduced from the results that the treatment improved the mean score of the experimental group hence conceptual understanding of Hooke’s law in form two Physics. This means that Gowin’s Vee teaching strategy is better than the regular methods in teaching of Physics.

4.4 Comparison of Students’ Physics Conceptual Understanding Post-test Mean Scores by Teaching Strategy

To find out whether there was any significant difference in the means among the groups the one-way ANOVA test was used. The results are shown in Table 8.

Table 8

Analysis of Variance (ANOVA) of the Posttest Scores on PCUAT

Scale	Sum of Squares	df	Mean Square	F-value	p-value.
Between Groups	3079.170	3	1026.390	31.951	.000
Within Groups	4304.569	134	32.124		
Total	7383.739	137			

The results of the ANOVA test in Table 8 show that the difference among the mean scores of E1, C1, E2 and C2 were significant at the 0.05 level in favour of the experimental groups, $F(31.951) = 0.000, p < 0.05$. The results of ANOVA test therefore indicate that there is a statistically significant difference in conceptualization of Hooke’s law topic in Physics between students taught using Gowin’s Vee teaching strategy and those taught using regular teaching methods. The results in Table 8 did not reveal where the differences were given that it involved 4 groups thus the need for further analysis. Further analysis was conducted to reveal where the differences were. The Scheffe’s multiple comparison test was used. The results of the tests are shown in table 9.

Table 9*Scheffe's Pair Wise Comparison of the Post-test Scores on PCUAT for the Four Groups*

Pair	Mean Difference	Std. Error	P-value.
E1 - C1	7.20	1.37	.000*
E1 - C2	11.68	1.44	.000*
E2 - C1	6.63	1.30	.000*
E2 - C2	11.11	1.38	.000*
C1 - C2	4.48	1.34	.013*

The results in table 9 indicates that the difference in the Physics mean scores between pairs E1-C1 ($p=.000$), E1-C2 ($p=.000$), E2-C1 ($p=.000$), E2-C2 ($p=.000$) and C1-C2 ($p=.013$) were statistically significant. However the difference between E1-E2 ($p=.983$) was not statistically significant. The difference between C1-C2 ($p=.013$) could be attributed to administrative issues in C2. The results show that the experimental groups (E1 and E2) performed better than the control groups given that the groups were similar at the commencement of the treatment. The improved performance of the experimental groups was attributed to the effects of the Gowin's Vee teaching strategy. This shows Gowin's Vee teaching strategy can enhance the conceptualization of Physics concepts better than regular teaching methods. The following table 10 shows the Physics achievement pre-test and post-test mean scores, standard deviations and mean gains by teaching using Gowin's Vee strategy.

Table 10*Students' Physics Achievement Pre-test and Post-test Mean Scores, Standard Deviations and Mean Gains by Teaching Strategy*

Group	Pretest			Posttest			Gain
	N	Mean	SD	N	Mean	SD	
E1	30	14.40	6.18	30	22.90	4.99	8.50
C1	40	13.95	5.22	40	15.70	7.25	1.75

Table 10 shows the mean gain ($M = 8.50$) of E1 was higher than that ($M = 1.75$) of C1. These results indicate that the achievement of students exposed to Gowin's Vee teaching strategy greatly improved as compared to their counterparts taught using conventional methods. The t-test was used to establish whether the mean gain of the two groups was statistically significant. Table 11 below shows the differences in mean gain for E1 and C1.

Table 11*Differences in mean gain of E1 and C1*

Group	N	Mean	SD	df	t-value	p-value
E1	30	8.50	7.67	68	3.379	.001
C1	40	1.75	8.69			

The results of the t-test reveal that the difference between the mean gain (M = 8.50) of E1 was significantly different from that (M =1.75) of C1, $t(68) = 3.379, p < 0.05$. Given that E1 and C1 were similar at the point of entry, the major improvement in learning outcomes of E1 was attributed to the treatment.

4.5 Comparison of motivation to learn Physics between students taught using Gowin’s Vee and those taught using regular methods in Physics.

All the groups did post-test to show the motivation level of the experimental and control groups. Table 12 shows the mean of each group.

Table 12*Posttest Results of Motivation of Experimental and Control Groups.*

Group	N	Mean	SD
E1	30	4.53	0.41
E2	36	4.23	0.39
C1	40	3.46	0.72
C2	32	3.35	0.70

An examination of the scores in Table 12 reveal that the mean scores of experimental groups E1 (M = 4.53, SD = 0.41) and E2 (M = 4.23, SD=0.39) were higher than those of the control groups C1 (M = 3.46, SD = 0.72) and C2 (M = 3.35, SD = 0.70).

Examinations of the results reveal that the experimental groups were more motivated than the control groups. In order to find out whether the difference among the groups was statistically significant, the ANOVA test was used to establish whether the difference among the mean scores were significantly different or not. Table 13 shows the F-value using one way ANOVA.

Table 13*Analysis of Variance (ANOVA) of the Post-test Scores on PSMQ*

Scale	Sum of Squares	df	Mean Square	F-value	p-value
Between Groups	33.061	3	11.020	32.383	.000
Within Groups	45.602	134	.340		
Total	78.664	137			

The results of the ANOVA test in Table 13 show that the difference among the mean scores of E₁, C₁, E₂ and C₂ were significant at the 0.05 level in favour of the experimental groups, $F(32.383) = 0.000$, $p < 0.05$. The results in Table 12 did not reveal where the differences were given that it involved 4 groups thus the need for further analysis. Further analysis was conducted to reveal where the differences were. The Scheffe multiple comparison test was used as shown in table 14

Table14*Scheffe's Multiple Comparison Test for Motivation*

Pair	Mean Differences	Std. Error	P-value.
E1 - E2	0.31	0.14	.214
E1 - C1	1.07	0.14	.000*
E1 - C2	1.18	0.19	.000*
E2 - C1	0.77	0.13	.000*
E2 - C2	0.87	0.14	.000*
C1 - C2	0.11	0.14	.892

The difference between E₁-E₂ (0.21) and C₁-C₂ (0.89) were not statistically significant.

The results show that the experimental groups (E₁ and E₂) were more motivated than the control groups given that the groups were similar at the commencement of the treatment.

The motivation of the experimental groups was attributed to the effects of the Gowin's Vee teaching strategy. This shows Gowin's Vee teaching strategy can motivate Physics students.

The mean gain analysis was done for motivation by checking the pre-test and post-test. The results are shown in table 15 below.

Table 15*Mean Gain Analysis*

Group	Pretest			Posttest			Gain
	N	Mean	SD	N	Mean	SD	
E ₁	30	2.27	0.59	30	4.53	0.41	2.26
C ₁	40	2.15	0.58	40	3.46	0.72	1.31

The differences in mean gains for motivation was done using t-test as shown in table 16

Table 16*Differences in Mean Gain for Motivation*

Group	N	Mean	SD	df	t-value	p-value
E ₁	30	2.26	0.60	68	4.512	.000
C ₁	40	1.31	1.03			

The results of the t-test reveal that the difference between the mean gain ($M = 2.26$) of E₁ was significantly different from that ($M = 1.31$) of C₁, $t(68) = 4.512$, $p < 0.05$. Given that E₁ and C₁ were similar at the point of entry, the major improvement in learning outcomes of E₁ was attributed to the treatment. The results in the table 14 indicates that the difference in the Physics mean scores between pairs E₁- C₁ ($P=.000$), E₁-C₂ ($P=.000$), E₂-C₁ ($P=.000$), E₂-C₂ ($P=.000$) were statistically significant .

4.6 Challenges encountered by Physics teachers when teaching using Gowin's Vee teaching strategy

The third objective was to examine the challenges encountered by Physics teachers in the experimental groups when teaching Physics using Gowin's Vee teaching strategy.

The teachers in E₁ and E₂ were interviewed by the researcher after teaching Hooke's law using Gowin's Vee teaching strategy. An interview schedule containing 9 questions was used by the researcher to find out the challenges.

4.6.1 Thematic analysis

Question one

When training you on how to teach Physics using Gowins vee teaching strategy, was the method new to you?

Teacher 1

Gowin's vee teaching strategy was new to me and therefore took time for me to understand especially when it is related to the topic of Hooke's law.

Teacher 2

Yes, the teaching method was new to me even during my course in the university I never came across this concept.

Question two

Which specific areas in the Vee diagram were a bit difficult to teach?

Difficult areas

Table 17

Difficult areas in the Vee diagram

Teacher	World view	Principle	Construct	Philosophy	Events	Concept	Value claim
1	√	√	√	-	√	-	√
2	√	-	√	√	-	-	√

Key

√ - difficult

- Not difficult

Teacher 1

The areas which were a bit difficult were: world view, principles, constructs, events and value claim.

Teacher 2

World view, philosophy, constructs and value claim

Question three

Was the lesson material well covered in the amount of time given?

Teacher 1

The topic was supposed to take fourteen lessons, about three weeks but it took four weeks because the learners took time to understand the Vee diagram.

Teacher 2

It took a bit longer because the learners were not able to relate easily the twelve epistemological elements with the questions asked.

Question four

How was the teacher- student interaction during the lessons?

Teacher 1

At first the learners were tense but in the subsequent lessons the learners were able to enjoy the lessons and the teacher- student interaction was good.

Teacher 2

The teacher-student interaction was very good especially when the students learnt that the format for answering questions was the same throughout.

Question five

Were you able to get adequate instructional materials for teaching the topic?

Teacher 1

Yes I got all the materials needed.

Teacher 2

Yes, although the spiral springs were few, the students per group were crowded, but all was well.

Question six

How was the overall class atmosphere during the lessons?

Teacher 1

The class overall atmosphere was good though some learners missed classes due to fees challenges.

Teacher 2

The learning atmosphere in the class was quite good. We were able to finish the term well.

Question seven

Were the learners able to identify the focus question?

Teacher 1

Yes, because the focus question is at the center of the Vee diagram

Teacher 2

Yes, the focus question is the one asked in every question.

Question eight

Which of the 12 epistemological elements was difficult for the students to answer during the post-test?

Teacher 1

The difference between the constructs and principles was confusing the learners, the learners were not able to differentiate claim value and knowledge claim.

Teacher 2

The world view, transformations, knowledge value and claim value. In transformations the learners experienced problems since graph work was being introduced to them. The learners were not also able to know where to put the answer between knowledge value and value claim.

Question nine

Which other challenges did you face during your teaching using this method?

Teacher 1

The topic of Hooke's law is in chapter seven of form two; skipped other topics and taught Hooke's law which was ahead.

Teacher 2

- He was behind the syllabus since he had just started form two work but Hooke's law is among the last topics in form two.
- The V diagram took a lot of space, the diagram takes one page

From the interview above it shows that Gowin's Vee teaching strategy has less challenges compared to the regular teaching methods.

4.7 Advantages of Gowin's Vee teaching strategy

In the interview the researcher also wanted to find out the advantages of the Gowin's Vee teaching strategy. The following one question was used by the researcher to find out the advantages of Gowin's Vee teaching strategy in experimental schools.

Question ten

What are some of the advantages of Gowins Vee teaching strategy over regular teaching methods?

Teacher 1

- (i) Gowin's Vee teaching strategy is easy to use since it uses the same format in answering questions
- (ii) Improves the performance of the students
- (iii) The learners can be able to incorporate all the 12 epistemological elements in a systematic way.
- (iv) The learners can be able to know the value of the answer they get in knowledge claim
- (v) This method is suitable for answering questions which needs calculations, plotting of graphs and analysis

The learners can score some marks even if they don't do well at the transformation element.

Teacher 2

- (i) Ensure students learn more effectively from the lesson by increasing the chances of linkage occurring between theoretical knowledge and learning outcomes gained from the lesson.
- (ii) The teacher found the Vee-map easy to implement
- (iii) The teacher remarked that as soon as the blank Vee-map was distributed to students' they commenced filling immediately.
- (iv) The teacher commented that he believed that the Vee-map improved the overall effectiveness of the lessons. He said it made students to select an appropriate focus question and that it emphasized the conclusion of the question asked.
- (vi) Teacher found the Vee-map to be a useful summary tool for each lesson.

From the interview there are more advantages when Gowin's Vee teaching strategy is used in teaching Physics than regular methods.

4.8 Discussion of the Results

The above results were discussed in the following order. First, the results of the pre-test and how the pre-test results contributed to the study were done. Secondly, the results of the tests of hypotheses of PCUAT examination and PSMQ questionnaire in relation to the objectives of the study were done. Finally the literature review compared with the existing context in the field was done.

4.8.1 Results of the Pre-tests

The pre-test was done to ensure that the control groups and experimental groups had similar characteristics before treatment was administered. Consequently, PCUAT mean scores were

pretest E1= 14.40 and pre-test C1=13.95 which have a slight variation. Similarly PSMQ mean scores were pre-test E1=2.27 and pretest C1=2.15. The t-test results of pre-test PCUAT mean scores for groups E1 and C1 in Table 6 showed a non-significant difference between the two groups, $t(68)=.330$, $p = .743$ and the results of PSMQ, $t(68) = 0.854$, $p = 0.396$. The four groups were randomly assigned to experimental and control groups and they were similar before treatment and therefore suitable for the study (Cook, 2015).

4.8.2 Results of PCUAT

The first objective of this study was to investigate the effects of using Gowin's Vee teaching strategy on secondary school students' conceptual understanding in the topic of Hooke's law in Physics. The performance of the students was analyzed using one way ANOVA. The F-ratio $F(31.951) = 0.00$, $p < 0.05$. Also the post hoc analysis using Scheffe multiple comparison test indicated positive and significant increment in performance after treatment. This led to the rejection of the hypothesis and hence Gowin's Vee teaching strategy was found to be effective in improving students' conceptual understanding.

The performance of students in the control groups was average and significantly less compared to those of experimental groups. This showed that they could not demonstrate full understanding of the Hooke's law concepts. These findings are in agreement with Novak et al. (2005) when stated that rote learning occurs when the learner makes no effort to relate new concepts and propositions to prior relevant knowledge his/her possesses and Novak (1998) who said that such information learned by rote in the absence of connections with previously acquired frameworks is largely forgotten.

The many strategies of learning science influence understanding and performance only to a certain limit (Mintrez et al., 2005) which agree with Gowin's Vee teaching strategy. Effective Physics instruction should be able to change students' way of thinking about Physics. In an attempt to achieve this, various contemporary researches in education and psychology have come out with epistemologies, theories and pedagogy like constructivism and meaningful learning theories (Getha-Eby et al., 2015), metacognition (Flavell, 1979), creativity and process skills (Okere, 1996), advanced organizers (Ausubel, 1968), Gowin's Vee (Bohecker et al., 2016) and concept maps (Novak & Gowin, 1984) among others.

These have shifted Physics education from building the knowledge capacity to improving thinking skills and creativity through conceptual understanding. Thus the use of socio-constructivist perspective and meaningful learning theory has offered a window of hope in the teaching and learning of various topics in Physics and science in general. Students should be made to understand the Physics world as made up of coherent structure of concepts which are interlinked together (Ausubel, 1968; Novak & Gowin 1984). Vee diagramming helps learners to do better on tests requiring problem-solving skills, and their performance increases with time as they get more experienced in using Vee diagrams (Novak & Gowin, 1984; Wandersee, 1990). One effective way to facilitate meaningful learning is to use concept mapping and Vee diagrams together (Özsoy, 2004). This concurs with the findings.

V-diagram enhanced laboratory applications were found to have more positive effects on students' achievement and retention levels when compared to teaching carried out through laboratory method (Evren & Sülün, 2010). The student groups that have been taught through the use of concept maps and V- diagrams are more successful than those who have been taught by the lecture method. Furthermore, misconceptions and incomplete knowledge were not found in the group that used concept maps and V-diagrams (Bahar & Özatlı, 2010).

Vee maps provide a framework that allows learners to conceptualize their previous knowledge as they develop meaningful learning, utilizing the Vee map to guide their thinking throughout the process of experimentation. This agrees with Gowin's Vee teaching strategy. Previous research has shown that the use of Vee maps as a formative assessment tool positively affects students' content knowledge (Thoron & Myers, 2011). It is evident that in a majority of situations students commence laboratory activities unsure of their aim and the procedure they are going to carry out.

Further, they apparently have no understanding that experimentation is one way of forming knowledge (Moreira, 1980; Novak & Gowin, 1984). Vee-maps (Gowin & Novak, 1984) are one way of making laboratory work more meaningful. Vee-maps concentrate students' attention on the focus question, the event to be observed, and direct students to interpret results in terms of their prior knowledge. This process assists students to obtain an overall view of the laboratory exercise and to see how theory is linked to experimental work. Cobern (1991) described a worldview as "the foundational belief, i.e., presuppositions, about the world that support both common sense and scientific theories". Practical work is designed to enable the

student to discover and understand the theory. This agrees with the findings of the study. The other two meaningful learning tools; concept maps and advanced organizers, were developed on conceptual and theoretical framework of the new knowledge that the student must learn.

However, they do not address relationships between activities and concepts required in order to acquire the knowledge being sought (Gowin 1981). Gowin's Vee offers a solution to this by combining both the theoretical knowledge to be learned with the activities to be performed in one unit of a Vee. Gowin's Vee is a very useful teaching and learning tool which has been extensively used in many other countries like USA (Novak & Gowin, 1984), Finland (Ahlberg, 1993), Australia (Afamasaga, 2004), Venezuela (Ramírez et al., 2008) and South Africa (Ramahlape, 2004) among others in bringing about meaningful learning. Gowin's Vee teaching strategy addresses the relationship between the activities and the concepts. When using the Gowin's Vee in the teaching and learning process it is important that the learner starts by filling in the focus question under investigation at the center of the Gowin's Vee, then writes down any of the activities, procedures, descriptions, apparatus, objects and events needed in order to answer the focus question.

In the conceptual side the learner indicates the theories, principles, constructs (formulae) and concepts used in the study (Afamasaga, 2004). Records section, in the methodological side, the learner fills in data in tables or audio-visual form. In the transformation section the learner analyzes the data using graphs, calculations and charts. The answer to the focus question is written under the knowledge claims section. Finally, the relevance and importance of the knowledge attained is written under the value claims. After filling in all the sections of the Gowin's Vee, the learner relates both sides which lead to conceptual understanding of the scientific knowledge sought. Therefore the learners retain the knowledge for a long time and reproduce it at any time using the basic structure of a Gowin's Vee teaching strategy. This makes the learning process meaningful (Novak & Gowin, 1984).

The results have demonstrated that Govin's Vee strategy enhances understanding of concepts and performance. This is in harmony with the findings of a study conducted by Ongowo et al. (2011) which established that strategies which engaged students in learning activities such as Govin's Vee boosts learners understanding and performance. The findings agree with those of Uside et al. (2013) which showed that the low enrolment in Physics was due to poor performance and inappropriate teaching methods among other factors. Many students also

perceive the subject as difficult as demonstrated by Musasia et al. (2012). Consequently, many opt out of the subject despite its importance (Abungu et al., 2014).

Many teachers in Kenya use regular teaching methods which are teacher dominated learning process (Changeiywo & Wambugu, 2008; Kiboss, 2002). There is no relating of new content to the learners environment so as to create meaning to the learner. This reduces learning into rote memorization of facts (Alvarez & Risco, 2007). These findings can solve the problem by using Gowin's Vee teaching strategy. As Driver (1987) reaffirms, in the regular methods, there is a lot of emphasis on absoluteness of the content where students are supposed to just accept the content given to them. Ausubel (1963, 1968), Alvarez and Risco (2007) and Gowin and Novak (1984) have stressed the need to use meaningful learning strategies so that the already existing knowledge of the learner is related to the new knowledge and wrong conception of the learner is clarified. The regular methods need to be replaced with Gowin's Vee teaching strategy.

The application of the use of Vee-mapping was reported by Kinchin (2018). For almost three decades Gowin's Vee teaching strategy has been employed to help students and teachers understand better how to "unpack" knowledge in documents in biology and mathematics (Keleş & Özsoy, 2017), and to construct knowledge (Novak, 1979; Novak & Gowin, 1984). This research and the research of others have shown that these tools can be effective in facilitation of meaningful learning (Mintzes, 1998; Mintzes et al., 2000; Novak, 1990; Novak & Wandersee, 1990). This agrees with the findings of the study. These studies have shown that it is not easy to move science and mathematics instruction from the traditional approaches emphasizing rote memorization to patterns where meaningful learning predominates. The tools are no panacea or "magic bullet," but they can be effective.

In fact, this task is typically so difficult that I believe the research evidence suggests the use of learning tools such as concept maps and Vee diagrams are essential to achieve high levels of meaningful learning by a high percentage of students. The fundamental challenge to "conceptual change teaching" is therefore to help learner's understand how they must choose to modify their concept and propositional hierarchies and to provide instruction that is "conceptually transparent" to the learners (Novak, 1992).

4.8.3 Results of PSMQ

The second objective was to determine the effects of Gowin's Vee teaching strategy on students' level of motivation in the topic of Hooke's law in Physics. PSMQ 35 item 5-Likert scale questionnaire was used. The test of the null hypothesis produced an F-ratio of $F(32,383) = 000, p < 0.05$. Also post hoc analysis using Scheffe multiple comparison test showed higher means in experimental groups' posttest mean scores. The treatment was deemed effective and the null hypothesis was rejected. Then the Gowin's Vee teaching strategy improved students' level of motivation. The elements in the Gowin's Vee diagram can be interpreted to suit any educational level and curriculum content as long as the basic structure remains. Therefore, during this study the Gowin's Vee teaching strategy was made to suit the level of the learner and Kenyan secondary school curriculum. For instance, in secondary school level the world view and philosophy elements of the Gowin's Vee teaching strategy can be left out (Keleş & Özsoy, 2017).

Novak (1998) prediction that it may take several decades before the Gowin's Vee teaching strategy is fully utilized in the teaching and learning process. Gowin's Vee can be applied for teaching since it summarizes the 12 epistemological elements at once according to the findings. Many researchers have acknowledged the importance of the Gowin's Vee and emphasized that its use should not take too long before it is utilized. This is because of its power to capture and facilitate the thinking process of the learner (Piyush & Robert, 2006). The role of the Gowin's Vee has not been fully realized in Kenya. This is supported by Namasaka et al. (2013) that there is need to use Gowin's Vee teaching strategy in Kenya since it has potential to improve students' motivation and does not depend on gender.

Self-regulation refers to the processes whereby students create and sustain thoughts and actions that are intentionally oriented towards goal attainment (Silva et al., 2018). Williamson (2015) further defined self-regulated learning behavior by the degree to which students are "metacognitively, motivationally, and behaviorally active participants in their own learning process". While learning strategies are necessary to developing conceptual understanding, being motivated to use them to achieve academic goals is equally, if not more, important. De Barba et al. (2016) provide the most comprehensive theory for explaining how the value components in an expectancy/value framework motivate learners to achieve. They established that expectancy and task value were the two most important predictors of achievement behavior.

The findings of the study need to be used for teaching in secondary schools in Kenya. The literature review of Horton et al. (1993) found only three studies (Schroeder et al., 2018) that explored the effect size of concept mapping on student attitudes. However, in none of the studies was attitude defined in terms of specific motivational components for example self-efficacy, control beliefs, or task value, which affects motivation to engage in a task. Additionally, while many educational researchers (Ames & Archer, 1988; Dweck & Elliott, 1983; Meece et al., 1988; Pintrich, 1989; Pintrich & Garcia, 1991; Pintrich et al., 1993; Pintrich & Schrauben, 1992; Risemberg & Zimmerman, 1992; Schunk, 1994; Zimmerman, 1990) have examined the role that motivation plays in relation to employment of cognitive learning strategies, no one has empirically investigated the role that motivation plays in affecting the depth of students' conceptual understanding as a result of using concept mapping.

Studies on Physics education have shown that such reasons as low level of interest and motivation about Physics classes, inability to attribute meanings to abstract concepts, misuse or inaccurate usage of concepts related to scientific thoughts and beliefs, false usage of concepts related to the models and theories as well as the previous thoughts and beliefs are the main reasons that make concepts difficult to learn (Caymaz & Aydin, 2019; Duit, 1992; Eryilmaz & Tatli, 2000). The findings of the study motivate the learners to learn Physics.

The aim of the Physics curriculum, which has been revised in Turkey recently, is to improve scientific literacy in students as well as increasing the level of their interest in Physics, motivating students towards inquiry, using scientific knowledge and methods to explain an event and creating awareness about the nature of science (Ministry of National Education [MONE], 2013). The reasons why students had difficulties in learning the topics in Physics curriculum were identified as follows: mechanical learning without understanding the topic, the deficiencies of the students in numerical expressions, the insufficiency of the periods allocated, the knowledge deficiencies and misconceptions of the past learning experiences, lack of motivation, inappropriate level of teaching for the students, inclusion of abstract concepts in the "Modern Physics" unit (Wosilait et al., 1998). This problem can be solved by use of Gowin's Vee teaching strategy.

In other countries, gender differences led to the under representation of women in the field of science as cited in the paper of Glynn et al. (2007). Mattern and Schau (2002) found that women showed substantially low motivation to participate in science classes and in pursuing science

careers. Klein and Hodges (2001) conducted two studies about college students that together resulted to suggest that there are motivational differences between men and women which are not due to simple differences of abilities. The findings did not show any gender differences in motivation of the learners. Gowin's Vee can motivate students to learn, therefore, students with high motivation to learn are likely to take care of their education, engage in any activities, and try to learn the concepts (Korur & Eryilmaz, 2018). When students have lack of motivation there can also be lack of intention and satisfaction, and this lack of motivation results in a decrease in their achievement (Brophy, 2010; Gagne & Deci, 2005; Sweet & Guthrie, 1996).

The motivation of students is one of the paramount factors that affect the learning process. If teachers give suitable feedback to the students on their level, initiate students' interest, make them understand the importance of the content, and have students share their ideas in classroom discussions, then the students' motivation increases as well as their achievement (Glynn & Koballa, 2006; Smith & Schmidt, 2012). The findings of the study can also be applied to meta-analyses of motivation and learning, and predicting students' behaviour.

Moreover, it is emphasized that referring to the situation in which the learning process takes place might help to understand the correlation between motivation and learning in greater detail (Krapp & Hengstenberg 1996; Schiefele et al., 1993; Schiefele & Schreyer, 1994). Taking into account that more and more German high-school students lose interest and take the earliest chance to omit Physics (Baumert et al., 1987) and to close the gap between a cognitive and an emotional-motivational view and to focus on the interrelation between both components of learning. This project tries to use a new development of psychological theory and apply it to the specific subject matter and situations of learning Physics at school. In the last two decades theory and research have been concerned with the relation between motivation and learning.

McTigue et al. (2019) present a summary of different studies related to this topic. Three components characterizing the interference of motivation and learning processes and the related experimental settings are known: the motivational states of the student, the learning environment in which the learning process takes place and the measuring of the results of a learning process as indicators of learning. This agrees with the findings on motivation.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Introduction

This chapter contains summary, conclusions, implications and recommendations made from the findings of the study whose purpose was to investigate the effects of Gowin's Vee teaching strategy on secondary school students' conceptual understanding, motivation in the topic of Hooke's law in Physics syllabus, challenges and advantages of using Gowin's Vee in teaching Physics.

5.2 Summary of major findings

Due to low performance in Physics at the secondary school level the researcher carried out this study to determine the effects of Gowin's Vee teaching strategy on secondary school students conceptual understanding, motivation in the topic of Hooke's law in Physics syllabus, challenges and advantages of Gowin's Vee teaching strategy. This was done to find out whether the use of Gowin's Vee teaching strategy would enhance the performance in Physics at KCSE. A Physics conceptual understanding achievement test (PCUAT) on Hooke's law topic in form two Physics syllabus was set and administered to the students in the four groups of the study. The PCUAT scores provided data for analysis. The researcher used the mean, standard deviation, t-test, post hoc analysis and one-way ANOVA to analyze the data obtained. One-way ANOVA test was carried out to determine whether there was any statistical significant difference in conceptualization of Hooke's law topic between the students taught using Gowin's Vee method and those taught using regular methods.

- (i) The conceptual understanding of students in experimental groups was high compared to control groups. The results showed a statistically significant difference. The research was carried out to test for statistically significant conceptual understanding of the Hooke's law topic when Gowin's Vee teaching strategy was used
- (ii) The motivation of students was generally high in experimental groups compared to control groups. Results showed a statistically significant difference. The t-test was also carried out to test for statistically significant motivation difference in conceptualization of the Hooke's law topic when Gowin's Vee was used.
- (iii) The results indicated that the difference was statistically significant. An interview was also carried out by the researcher to find out the challenges faced by Physics teachers in experimental groups when teaching using Gowin's Vee teaching strategy. The

advantages of Gowin's Vee were also found out from the Physics teachers which were more than the challenges stated. This shows that the teaching method was successful.

5.3 Conclusions

From the findings of the study, the researcher made the following conclusions:-

- (i) The use of Gowin's Vee teaching strategy improves students understanding of Physics concepts better compared to their counterparts taught using regular teaching methods.
- (ii) The use of Gowin's Vee teaching method motivates students to learn Physics compared to those taught using regular teaching methods.
- (iii) The use of Gowin's Vee teaching strategy has fewer challenges.

5.4 Implications of the study

This study has given rise to some important findings which are very useful to the teaching and learning of Physics, biology, mathematics and chemistry in secondary schools. The study established that Gowin's Vee statistically improved students' conceptual understanding and motivation in the topic of Hooke's law in form two Physics. This makes it a very useful teaching tool which should be utilized in the teaching and learning in secondary schools in Kenya. Therefore it has implications on the educational stakeholders, teachers and students in the secondary schools. In Physics lessons the teachers and students should be able to use Gowin's Vee teaching strategy to teach/ learn the topic of Hooke's law and other topics. This tool assists the learners in retention and transfer of concepts hence there is conceptual understanding. This tool assists learners to understand the structure of scientific knowledge by giving a summary of the scientific knowledge using theories, philosophy, principles and concepts together with the activities being used hence they achieve high conceptual understanding.

Gowin's Vee teaching strategy statistically improved students' level of motivation. Therefore the students are able to plan, monitor and evaluate their own learning process since they are more motivated in Physics. This tool not only improves the learning of Physics but also chemistry, biology and mathematics.

This tool also has more advantages and therefore it is advisable to be used. Thus the science teachers and curriculum developers should consider Gowin's Vee teaching strategy as a useful tool in the teaching and learning of sciences in secondary schools in Kenya.

5.5 Recommendations

The findings of the study showed that the Gowin's Vee teaching strategy improves conceptualization of Physics concepts and motivation. It builds up meaningful learning and therefore it is important for teachers to use this method for teaching and learning purposes. This can translate to improved performance in KCSE. Based on the findings of the study, the researcher makes the following recommendations:

- (i) Physics teachers should use this Gowin's Vee teaching strategy in secondary schools since it improves conceptual understanding in their subjects.
- (ii) Physics teachers should use Gowin's Vee teaching strategy in secondary schools since it improves learners' motivation.

5.5.1 Recommendations for Further Research

The findings of the study have shown that the use of Gowin's Vee teaching strategy improves conceptual understanding of Physics concepts. The scope of the study was however limited. The researcher makes recommendations for further research in the following areas:-

- (i) Challenges faced by students when Gowin's Vee teaching strategy is used in sciences on secondary school students in Kenya.
- (ii) Research on Gowin's Vee teaching strategy for a long duration so that that better results can be achieved
- (iii) Research on Gowin's Vee teaching strategy with increased sample size
- (iv) Research on Gowin's Vee teaching strategy with increased number of topics instead of one topic.

REFERENCES

- Abell, S.K. (2000). From professor to colleague: Creating a professional identity as collaborator in elementary science. *Journal of Research in Science Teaching*, 37(6), 548–562.
- Abungu, H.E., Okere, M.I. & Wachanga, S.W. (2014). The effect of science process skills teaching approach on secondary school students' achievement in chemistry in Nyando District, Kenya. *Journal of Educational and Social Research*, 4(6), 359-359.
- Afamasaga-Fuata'i, K. (2004). Concept maps & vee diagrams as a tool for learning new mathematics topics, concept maps: Theory, methodology, technology procedures. Paper presented at the First International Conference on Concept Mapping. <http://cmc.ihmc.us/papers/cmc2004-271.pdf> (13.02.2008).
- Agango, C. O. (2014). *Influence of interactive teaching methods on achievement in mathematics among preschool children, in Nyang'oma zone, Muhoroni district, Kenya* (Unpublished PhD thesis). Nairobi University.
- Akella, D. (2010). Learning together: Kolb's experiential theory and its application. *Journal of Management & Organization*, 16(1), 100-112.
- Alvarez, M.C & Risko, V. J. (2007). *The use of Vee diagrams with third graders as a metacognitive tool for learning science concepts*. Paper presented at the department of teaching and learning, Tennessee State University.
- Ambrose, S. A., Bridges, M. W., DiPietro, M., Lovett, M. C., & Norman, M. K. (2010). *How learning works: Seven research-based principles for smart teaching*. John Wiley & Sons.
- Ameyaw, Y. & Kyere, I. (2019). Mapping biological concepts: Concept-vee maps an improver of students' performance in photosynthesis. *International Journal of Innovative Science Engineering and Technology*, 6, 169-181.
- Ames, C. & Archer, J. (1988). Achievement goals in the classroom: Students' learning strategies and motivation processes. *Journal of educational psychology*, 80(3), 260-269.
- Amineh, R.J. & Asl, H.D. (2015). Review of constructivism and social constructivism. *Journal of Social Sciences, Literature and Languages*, 1(1), 9-16.
- Andersen, T.J. & Nielsen, B.B. (2009). Adaptive strategy-making: The effects of emergent and intended strategy modes. *European Management Review*, 6, 94-106.
- Ausubel, D. (1978). In defense of Advance Organizers: A reply to the critics. *Review of Educational Research*, 48, 251-257.

- Ausubel, D.P. (1963). *The Psychology of Meaningful Verbal Learning*. Grune and Stratton.
- Ausubel, D.P. (2000). *The Acquisition and Retention of Knowledge*. Kluwer.
- Ausubel, D.P. (1977). Facilitation of meaningful verbal learning in the classroom. *Educational Psychologist*, 19-37.
- Ausubel, D.P. (1968). *Educational Psychology: A cognitive view*. Holt, Rinehart & Winston.
- Ausubel, D.P. (1960). The use of Advance Organizers in the learning and retention of meaningful verbal material. *Journal of Educational Psychology*, 51, 267-272.
- Ausubel, D., Novak, J. & Hanesian, H. (1978). *Educational Psychology: A cognitive view* (2nd Ed.). Holt, Rinehart & Winston.
- Ausubel, D.P. & Robinson, F.G. (1969). *School Learning: An introduction to educational psychology*. Holt, Rinehart and Winston.
- Bajwa, S.J.S., Viridi, S.S., Bajwa, S.K., Ghai, G.K., Singh, K., Rana, C.S. & Puri, A. (2010). In depth analysis of motivational factors at work in the health industry. *Industrial Psychiatry Journal*, 19(1), 20 -31.
- Baumert, J., Schmitz, B., Sang, F. & Roeder, P.M. (1987). The compatibility of promoting and minimising divergence in the classroom. *Zeitschrift für Entwicklungspsychologie und Pädagogische Psychologie*, 19(3), 249–265.
- Bhatt, B.D. (2012) *Modern methods of teaching concepts and techniques*. Uttarakhand
- Biehler R.F. (1978). *Psychology Applied to Teaching* (3rd ed.). Houghton Mifflin Company.
- Bigozzi, L., Tarchi, C., Fiorentini, C., Falsini, P. & Stefanelli, F. (2018). The influence of teaching approach on students' conceptual learning in physics. *Frontiers in Psychology*, 9, 2474.
- Bodansky, D. (2007). *Nuclear energy: principles, practices, and prospects*. Springer Science & Business Media.
- Bohecker, L., Vereen, L.G., Wells, P.C., & Wathen, C.C. (2016). A mindfulness experiential small group to help students tolerate ambiguity. *Counselor Education and Supervision*, 55(1), 16-30.
- Borg, W.R. & Gall, M.D. (1989). *Educational research: An introduction* (5th ed.). Longman.
- Bortfeld, T. & Jeraj, R. (2011). The physical basis and future of radiation therapy. *The British Journal of Radiology*, 84(12), 485-498.
- Bransford D., Brown L. & Rodney R. (eds). (2000). *How People Learn: Brain, mind, experience and school*. National Academy Press.
- Brophy, J. (2013). *Motivating students to learn*. Routledge.

- Bullough, R.V. & Pinnegar, S. (2001). Guidelines for quality in autobiographical forms of self-study research. *Educational Researcher*, 30(3), 13–21.
- Caymaz, B. & Aydin, A. (2019). The effect of common knowledge structuring model on students' conceptual understanding. *Kastamonu Education Journal*, 27(5), 1955-1960.
- Chiappetta, E.L. & Koballa, T.R. (2002), *Science instruction in the middle and secondary school*. Mervil Prentice Hall.
- Chiu, M. (2015). The challenge of learning physics before mathematics: A case study of curriculum change in Taiwan. *Research in Science Education*, 46(6), 767-786. Doi <https://doi.org/10.1007/s11165-015-9479-5>.
- Chua, S.N., Koestner, R. (2008). A Self-determination theory perspective on the role of autonomy in solitary behaviour. *The Journal of Social Psychology* 148 (5): 645–647.
- Coburn, W.W. (1991). *World view theory and science education research, NARST monograph number 3*. National Association for Research in Science Teaching.
- Cook, T.D. (2015). Quasi-experimental design. *Wiley Encyclopedia of Management*, 1-2.
- Dale H.S. (2007) *Motivation in education: Theory, research, and applications*. Prentice Hall.
- David, A. & Anderzej, A. (2010) *Organisational behaviour* (7th ed.). Pearson.
- David, B & Resnik, J.D. (2011). What is Ethics in Research and why is it Important? *National Institute of Environmental Health Science: Your Environment your Health*. <http://www.niehs.nih.gov>.
- De Barba, P.G., Kennedy, G.E. & Ainley, M.D. (2016). The role of students' motivation and participation in predicting performance in a MOOC. *Journal of Computer Assisted Learning*, 32(3), 218-231.
- Deci, E.L., Koestner, R. & Ryan, R.M. (2001). Extrinsic and intrinsic motivation in education: Reconsidered once again. *Review of Educational Research*. 71(1), 1-27.
- Demirbas, M. & Ertugrul, N. (2014). A study on preschoolers' conceptual perceptions of states of matter: A case study of Turkish students. *South African Journal of Education*, 34(3), 72-81.
- Dennick, R. (2014). Theories of learning: Constructive experience. In *An introduction to the study of education* (pp. 50-77). Routledge.
- Driver, R. & Oldham, V. (1986). A constructivist approach to curriculum development. *Studies in Science Education*, 13, 105-122.
- Dweck, C.S. & Elliot, E.S. (1983). Achievement motivation. In E.M. Hetherington (Ed.), *Socialization, personality, and social development* (pp. 643-691). Wiley.

- Eryilmaz, A. & Tatli, A. (2000). Metu students' misconceptions about mechanics. *Hacettepe University Faculty of Education Journal*, 18 (18).
- Esokomi, S. N. (2019). Perceived influence of participation in non-formal curricular activities on secondary school students' perception and achievement in Physics in Vihiga County of Kenya (Unpublished PhD thesis). Maseno University.
- Evren, A. & Sülün, Y. (2010). The effect of teaching animal physiology through "V-Diagrams" on students' success and retention level. *Procedia-Social and Behavioral Sciences*, 2(2), 4285-4292.
- Fafunwa A.B. & Aisku, J.U. (1982). *Education in Africa: A comparative survey*. George Allen Unwin.
- Feltovich, P.J., Spiro, R.J. & Coulson, R.L. (2012). Learning teaching, and testing for complex conceptual understanding. In *Test theory for a new generation of tests* (pp 193-230). Routledge.
- Fermi, E., Franck, J., Hogness, T.R., Jeffries, Z., Mulliken, R.S., Stone, C.A. Thomas, D. (1994). *Prospectus on nucleonics*. National Archives Record Group77, Harrison Bundy Files.
- Flavell J. (1979). *Metacognition and cognitive monitoring: A new area of cognitive developmental enquiry*. *American Psychologist*, 34, 906-911.
- Fosnot, C.T. (1996). *Constructivism: A Psychological Theory of Learning*. In C.T. Fosnot (Ed.), *Constructivism: Theory, perspectives and practice* (pp. 8-33), Teachers College Press.
- Fraenkel, J.R. & Wallen, N.E. (2006). *How to design and evaluate research in education*. McGraw-Hill.
- Fretz, J.R. (2015). Creating optimal learning environments through invitational education: an alternative to control oriented school reform. *Journal of Invitational Theory and Practice*, 21, 23-30.
- Gagné, M. & Deci, E.L. (2005). Self-determination theory and work motivation. *Journal of Organizational behavior*, 26(4), 331-362.
- Getha-Eby, T.J., Beery, T., O'Brien, B. & Xu, Y. (2015). Student learning outcomes in response to concept-based teaching. *Journal of Nursing Education*, 54(4), 193-200.
- Glynn, S. M. & Koballa, T. R. (2006). Motivation to learn in college science In J. J. Mintzes & W.H. Leonard (Eds.), *Handbook of college science teaching* (p. 25-32). NSTA Press.

- Glynn, S. M., Brickman, P., Armstrong, N. & Taasobshirazi, G. (2011). Science motivation questionnaire II: Validation with Science majors and non-science majors. *Journal of Research in Science Teaching*, 7(12), 113-127.
- Gok, T. (2018). The evaluation of conceptual learning and epistemological beliefs on physics learning by think-pair-share. *Journal of Education in Science Environment and Health*, 4(1), 69-80.
- Graham, S., Bollinger, A., Olson, C.B., D'Aoust, C., MacArthur, C., McCutchen, D. & Olinghouse, N. (2012). *Teaching elementary school students to be effective writers: A practice guide*. What Works Clearinghouse.
- Guthrie, J. T. & Wigfield, A. (2000). *Engagement and Motivation in Reading*. In M. Kamil, R. Barr, P. Mosenthal & D. Pearson, (Eds.), *Handbook of Reading Research II,I* (pp. 403-422). Longman.
- Hammersley, M. & Traianou, A. (2012) Ethics and Educational Research, British Educational Research Association. <https://www.bera.ac.uk/wpcontent/uploads/2014/02/Ethics-and-Educational-Research.pdf>.
- Hammer, D. (2000). *Teacher inquiry*. In J. Minstrell and E. van Zee (Eds.), *Inquiring into inquiry learning and teaching in science (pp. 184–215)*. American Association for the Advancement of Science.
- Hargreaves, D. (2012). *The challenge for the comprehensive school: culture, curriculum and community*. Routledge.
- Hilgard, E. R. & Irvine W. (1953). Rote memorization, understanding, and transfer: an extension of Katona's card-trick experiments. *Journal of Experimental Psychology* 46 (4), 288-292.
- Hohn, R. L. (1996). *Classroom learning & teaching*. Longman Publishers Ltd.
- Horton, P.B., McConney, A.A., Gallo, M., Woods, A.L., Senn, G. J. & Hamelin, D. (1993). An investigation of the effectiveness of concept mapping as an instructional tool. *Science Education*, 77(1), 95-111.
- Hudson, H.T. & McIntire, W.R. (1977). *Correlation between mathematical skills and success in Physics*. *American Journal of Physics*, 45(5), 470-471.
- Jackson, G. & Hudson, A. (2009). *Engaging all Young People in Meaningful Learning after 16, A survey*. EHRC.
- Jillian, O. (2009). *Jacaranda Physics: Importance of studying physics*. EBook plus.

- Kazmina, L., Makarenko, V., Provotorina, V. & Shevchenko, E. (2020). Innovative technologies in vocational tourist-excursion education. In *E3S Web of Conferences* (Vol. 210, p. 12002). EDP Sciences.
- Kehinde, A. & Emmanuel, M. (2011). Concept mapping teaching strategy and Secondary Students' attitudes towards Physics. *Journal of African Educational Research Network*, 11(2), 232-244.
- Keleş, Ö. & Özsoy, S. (2017). Pre-service teachers' attitudes toward use of Vee diagrams in general physics laboratory. *International Electronic Journal of Elementary Education*, 1(3), 124-140.
- Kenya National Examinations Council (KNEC) (2014). The 2013 *Kenya Certificate of Secondary Education Examination Report*. KNEC.
- Kiboss J.K. (2002). Impact of a computer-based physics instruction program on pupils' understanding of measurement concepts and methods associated with school science. *Journal of Science Education and Technology*, 11(2), 193-198.
- Kigo, J.K. (2017). Effect of science process skills advance organizer on secondary school Physics students' performance and motivation in electric circuits, Laikipia County, Kenya (Unpublished PhD thesis). Kabarak University.
- Killerman, W. (1996). Biology education in Germany: Research into effectiveness of different teaching methods. *International Journal of Science Education*, 18(3), 71-86.
- Kinchin, I.M. (2018). A species identification approach to concept mapping in the classroom. *Journal of Biological Education*, 14, 1-7.
- KNEC (2014). *The year 2013 KCSE Examination Report*. Kenya National Examination Council.
- Koballa Jr, T.R. & Glynn, S.M. (2013). Attitudinal and motivational constructs in science learning. In *Handbook of research on science education* (pp. 89-116). Routledge.
- Kolb, D.A. (1983). *Experimental Learning: Experience as the source of learning and development*. Prentice Hall.
- Korb, K.A. (2015, June). *Writing a Research Proposal in Education*. Paper presented at the First Seminar of Nigerian Society of Educational Psychologists Plateau State Chapter, Jos, Nigeria.
- Korthagen, F.A.J. & Kessels, J.P.A.M. (1999). Linking theory and practice: Changing the pedagogy of teacher education. *Educational Researcher*, 28(4), 4-17.
- Korur, F. & Eryilmaz, A. (2018). Interaction between students' motivation and Physics teachers' characteristics: multiple case study. *The Qualitative Report*, 23(12).

- Krapp, A. (1999). Interest, motivation and learning: An educational-psychological perspective. *European journal of psychology of education, 14*(1), 23-40.
- Krapp, H.G. & Hengstenberg, R. (1996). Estimation of self-motion by optic flow processing in single visual interneurons. *Nature, 384*(6608), 463.
- Kuada, J. (2012). *Research methodology: A project guide for university students*. Samfundslitteratur.
- Kuder, G.F. & Richardson, M.W. (1937). The theory of the estimation of test reliability. *Psychometrika, 2*(3), 151–160.
- Kuhn, T. (2012). *The structure of scientific revolutions* (50th ed.). University of Chicago Press
- Lambros, A. (2013). Problem-Based Learning: From theory to practice. *Research on Education in Sciences through Learning Based on Problem Solving*. Wake Forest University, Winston-Salem, NC, USA.
- Lens, W., Simons, J. & Dewitte, S. (2002). From duty to desire: The role of students' future time perspective and instrumentality perceptions for study motivation and self-regulation. *F. Pajares et T. Urdan (Éds.), Academic motivation of adolescents, 221-245*.
- Levesque C., Zuehlke A. N., Stanek, L. R. & Ryan, R.M. (2004). Autonomy and competence in German and American university students: A comparative study based on self-determination theory. *Journal of Educational Psychology, 96*, 68–84.
- Lorayne H. (1989). *Memory Makes Money*. New American Library.
- Loughran, J. (2002). Understanding self-study of teacher education practices. In J. Loughran and T. Russell (Eds.). *Improving teacher education practices through self-study* (pp. 239–248). Routledge Falmer Press.
- Lyons, T. (2005). *The puzzle of falling enrolment in Physics and Chemistry courses: Putting some pieces together*. National Centre of Science, ICT, and Mathematics Education for Rural and Regional Australian Universities.
- Maloy, R.W. & LaRoche, I. (2010). Student-centered teaching methods in the History classroom: Ideas, issues, and insights for new teachers. *Social Studies Research & Practice, 5*(3), 91-105.
- Markham, T. (2011). *Project Based Learning*. Cambridge University Press.
- Mattern, N. & Schau, C. (2002). Gender differences in science attitude-achievement relationships over time among white middle-school students. *Journal of Research in Science Teaching, 39*(4), 324-340.

- Matusitz, J. & Martin, J. (2013). The application of self-determination theory to eating disorders. *Journal of Creativity in Mental Health*, 8(4), 499-517.
- Mayer, R.E. (1995). Cognitive Theory for education: What teachers need to know. In Lambert, N.M. & McCombs, B.L. (Eds.). *How students learn-reforming school through learner-centered education*. American Psychological Association (pp. 353–378).
- McCombs, B.L. (1991). Motivation and Lifelong Learning. *Educational Psychologist*, 26 (2), 117-127.
- McCombs, B.L. & Whisler, J.S. (1989). The role of affective variables in autonomous learning. *Educational Psychologist*, 24(3), 277-306.
- McTigue, E.M., Solheim, O.J., Walgermo, B., Frijters, J. & Foldnes, N. (2019). How can we determine students' motivation for reading before formal instruction? Results from a self-beliefs and interest scale validation. *Early Childhood Research Quarterly*.
- Meece, J.L., Blumenfeld, P.C. & Hoyle, R.H. (1988). Students' goal orientations and cognitive engagement in classroom activities. *Journal of Educational Psychology*, 3, 43-52.
- Millican, G., Richards, P. & Mann, L. (2005). The engineering link project: Learning about engineering by becoming an engineer. In Radcliffe, D., Humpries, J. (Eds.), *Proceedings of the 2005 ASEE/AaeE 4TH Global colloquim*, Sydney, Australia.
- Mintzes, J.J., Wandersee, J.H. & Novak, J.D. (Eds.). (2005). *Teaching science for understanding: A human constructivist view*. Academic Press.
- MONE (2013). Vocational and Technical Education Strategy Document and Action Plan 2014-2018. (General Directorate of Vocational and Technical Education).
- Moreira, M.A. (1980). A non-traditional approach to the evaluation of laboratory instruction in general Physics courses. *European Journal of Science Education*, 2(4), 441-448.
- Mugenda, O. & Mugenda, A. (2003). *Research Methods*. Acts Press.
- Murray, P. (2010). Modes of Production. In Albert J. Mills, Gabrielle Durepos, and Elen Wiebe (ed.), *Sage encyclopedia of case study research* 2(pp. 567-570). Thousand Oaks, Cal. and Sage Publications.
- Muriithi, E.M., Odundo, P.A., Origa, J.O. & Gatumu, J.C. (2013). Project method and learner achievement in physics in Kenyan secondary schools. *International Journal of Education and Research*, 1(7), 1-12.
- Musasia M.A., Abacha A.O. & Biyoyo, E.M. (2012). Effect of practical work in Physics on girls' performance, attitude change and skills acquisition in the form two-form three secondary schools' transition in Kenya. *International Journal of Humanities and Social Science*, 2(23), 151-163.

- Mutai, D. (2015). Effects of Gowin's Vee heuristic teaching strategy in secondary students and conceptual understanding and metacognition in moments in Bomet District. (Unpublished Masters thesis). Egerton University.
- Mutula, K. (2012, July 9). Upgrading and refurbishing of CEMASTEAs for quality delivery of Mathematics and Science Education in Africa: Message from the Minister of Education. *Daily Nation*, 32.
- Namasaka, F.W. (2009). Effects of concept and vee mapping strategy on students' motivation and achievement in Biology in secondary schools in Uasin-Gishu District, Kenya. (Unpublished Masters thesis). Egerton University.
- Namasaka F.W. & Kerario F.N. (2013). *Effects of Concept and Vee Mapping strategy on students' motivation in biology in secondary schools in Uasin-Gishu District, Kenya*, (Unpublished Thesis) Egerton University.
- Novak, J.D. (1976). Understanding the learning process and effectiveness of teaching methods in the classroom, laboratory and field. *Science Education*, 60, 493-512.
- Novak, J.D. (1990). Concept maps and vee diagrams: Two metacognitive tools for science and mathematics education. *Instructional Science*, 19, 29-52.
- Novak, J.D. (2010). *Learning, creating, and using knowledge: Concept maps as facilitative tools in schools and corporations* (2nd ed.). Routledge, Taylor-Francis.
- Novak, J.D. & Gowin, D.B. (1984). *Learning how to learn*. Cambridge University Press.
- Novak, J.D., Gowin, D.B. & Johansen, G.T. (1983). The use of concept mapping and knowledge vee mapping with junior high school science students. *Science education*, 67(5), 625-645.
- Omondi, K.O.K. (2019). Effects of advance organizers on students' achievement and attitude towards learning Biology in secondary schools in Kilifi County, Kenya (Unpublished PhD thesis). Egerton University.
- Oluoch, P. (1982). *Essentials of Curriculum Development*. Elimu Bookshop Ltd.
- Ongowo, R.O, Keraro, F.N. & Okere, M.O. (2011). Concept mapping: An interactive teaching strategy that enhances active learning and students' achievement in Biology. *Journal of Education & Pedagogy*, 3(20), 1 – 12.
- Onwuegbuzie, A.J. & Leech, N.L. (2007). Sampling designs in qualitative research: Making the sampling process more public. *The Qualitative Report*, 12(2), 238-254.
- Ovens, A. & Fletcher, T. (2014). Doing self-study: The art of turning inquiry on yourself. In *Self-study in physical education teacher education* (pp 3-14).

- Özsoy, N. (2004). Using concept maps and Govin's vee diagrams as a teaching and learning tools on the unit of functions. *Gazi Eğitim Fakültesi Dergisi*, 24, 15-24.
- Parveen, H. & Snowkat, N. (2017). *Research Ethics*. [https:// www.researchgate.net / publication /318912804](https://www.researchgate.net/publication/318912804).
- Pazzani M. & Silverstein. G. I. (1990). *Learning from examples: The effects conceptual roles*. Paper presented during proceedings of the Twelfth Annual Conference of the Cognitive Science Society (pp. 221-228). Erlbaum.
- Pazzani. M., Dyer, M. & Flowers, M. (1986). *The Role of Prior-causal Theories in Generalization*. Proceedings of the National Conference on artificial intelligence (pp. 545-550). Morgan Kaufmann.
- Pei, M. & Kasper, S. (2003). *Lessons from the past: The American record of nation-building*. Carnegie Endowment for International Peace Policy Report.
- Pietrocola, M. (2008). Mathematics as structural language of physical thought. In M. Vicentini & E. Sassi (Eds.). *Connecting research in Physics education with teacher education, Volume 2*. International Commission on Physics Education.
- Pines, A.L. & West, L. (1986). Conceptual understanding and science learning: An interpretation of research within a sources-of-knowledge framework. *Science Education*, 70, 583-604.
- Pintrich, P.R. & DeGroot, E. (1990). Motivational and self-regulated learning components of classroom academic performance. *Journal of Educational Psychology*, 82, 33-40.
- Pintrich, P.R. & Garcia, T. (1991). Student goal orientation and self-regulation in the college classroom. In M.L. Maehr & P.R. Pintrich (Eds.), *Advances in motivation and achievement: Goals and self-regulatory processes 7*(pp. 371-402). JAI Press.
- Pintrich, P.R. & Schrauben, B. (1992). Students' motivational beliefs and their cognitive engagement in classroom tasks. In D. H. Schunk & J. Meece, (eds.), *Student perceptions in the classroom: Causes and consequences* (pp. 149-183), Lawrence Erlbaum Associates.
- Pintrich, P.R. (1989). The dynamic interplay of student motivation and cognition in the college classroom. In C. Ames & M. Maehr (Eds.) *Advances in motivation and achievement: Motivation-enhancing environments*, (pp.117-160). JAI Press.
- Pintrich, P.R., Marx, R.W. & Boyle, R.A. (1993). Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. *Review of Educational research*, 63(2), 167-199.

- Ramírez, M.M., Aspée, M., Sanabria, I. & Tellez, N. (2008). *Mathematical modeling of physical phenomena with the use of Gowin's vee and concept maps*. In Canas, A.J, Reiska, P. & Novak, J.D. (Eds.), Paper Presented on the 3rd International Conference on Concept Mapping University of Tachira, San Cristobal, Venezuela.
- Reeve, J. (2012). *Understanding motivation and emotion*. All Star Publishing.
- Retnawati, H., Arlinwibowo, J., Wulandari, N.F. & Pradani, R.G. (2018). Teachers' difficulties and strategies in Physics teaching and learning that apply in Mathematics. *Journal of Baltic Science Education*, 120, 1-17.
- Retnawati, H., Munadi, S., Arlinwibowo, J., Wulandari, N.F., Sulistyaningsih, E. (2017). *Teachers' difficulties in implementing thematic teaching and learning in elementary schools*. *The New Educational Review*, 48(2), 201-212.
- Retnawati, H., Hadi, S. & Nugraha, A.C. (2016). Vocational high school teachers' difficulties in implementing the assessment in curriculum in Yogyakarta Province of Indonesia. *International Journal of Instruction*, 9(1), 74-89.
- Ridley, D.S. (1991). Reflective self-awareness: A basic motivational process. *Journal of Experimental Education*, 60(1), 31-48.
- Rubin, M. (2012). Social class differences in social integration among students in higher education: A meta-analysis and recommendations for future research. *Journal of Diversity in Higher Education*, 5(1), 22-30.
- Ryan, R.M. & Deci, E.L. (2020). Intrinsic and extrinsic motivation from a self-determination theory perspective: Definitions, theory, practices, and future directions. *Contemporary Educational Psychology*, 61, 101-860.
- Safdar, M. (2013). Meaningful learning and rote learning in physics: A comparative study in city Jhelum (Pakistan). *Middle Eastern & African Journal of Educational Research*, 6, 60-77.
- Safdar, M., & Shah, I. (2014). Construction and validation of an instrument to measure the scientific attitude of the students, and attitude gain by the application of meaningful learning model of David Ausubel in teaching Physics. *Asian Journal of Education and e-Learning*, 2(1), 56-67.
- Salandanan, G.G. (2008). *Teaching Approaches & Strategies*. Goodwill Trading Co. Inc.
- Sands, T.D. (2011). *The relationship factor: Understanding the role and development of teacher-student relationships in middle school*. Liberty University.

- Sharma, M. & Chawla, S. (2018, May). *Using a concept map network based constructivist learning environment to design a learning system*. Paper presented at the International Conference on Information, Communication and Computing Technology in Singapore.
- Schiefele, U. & Csikszentmihalyi, M. (1995). Motivation and ability as factors in Mathematics experience and achievement. *Journal for Research in Mathematics Education*, 26 (2), 163-181.
- Schiefele, U. & Schreyer, I. (1994). *Intrinsic motivation of learning and learning. An overview of results of research*. *Zeitschrift für Pädagogische Psychologie*, 8(1), 29-38.
- Schiefele, U., Krapp, A., Wild, K.P. & Wintele, A. (1993). *A questionnaire concerning interest related to studying at the university*. *Diagnostica*, 39(4), 335-351.
- Schroeder, N.L., Nesbit, J.C., Anguiano, C.J. & Adesope, O.O. (2018). Studying and constructing concept maps: A meta-analysis. *Educational Psychology Review*, 30(2), 431-455.
- Semela, T. (2010). Who is joining Physics and why? Factors influencing the choice of Physics students among Ethiopian University. *International Journal of Environmental and Science*, 5, 319-340.
- Shiundu, S.J. & Omulando, J.S. (1992). *Curriculum: Theory and practice in Kenya*. Oxford University Press.
- Silva J. (1992). *The revolutionary mind – power programme*. Prentice Hall.
- Silva, W.F., Chiquillo-Rodelo, J. & Brito-Carrillo, C.J. (2018). Extrinsic factors and their association with the motivation and self-regulation of learning in engineering students. *Contemporary Engineering Sciences*, 11(20), 13-21.
- Smith, D.C. & Anderson, C.W. (2012). Appropriating scientific practices and discourses with future elementary teachers. *Journal of Research in Science Teaching*, 36, 755–776.
- Southerland, S. A, Gess-Newsome, J. & Johnston, A. (2003). Portraying science in the classroom: The manifestation of scientists' beliefs in classroom practice. *Journal of Research in Science Teaching*, 40, 669–691.
- Sulaiman, F. (2011). The effectiveness of Problem-Based Learning (PBL) online on students' creative and critical thinking in physics at tertiary level in Malaysia (Unpublished PhD thesis). University of Waikato.
- Sweet, A.P. & Guthrie, J.T. (1996). How children's motivations relate to literacy development and instruction. *The Reading Teacher*, 49(8), 660-669.

- Taasoobshirazi, G. (2007). Gender differences in physics: A focus on motivation. *Journal of Physics Education*, 4(3), 63-71.
- Thoron, A.C. & Myers, B.E. (2011). Effects of inquiry-based agri-science instruction on student achievement. *Journal of Agricultural Education*, 52(4), 175-187.
- Toulmin, S. (1953). *The philosophy of science, an introduction*. Hutchinson's University.
- Toulmin, S. (1972). *Human understanding Vol. 1: The collective use and evolution of concepts*. Princeton University Press.
- UNICEF (2015). Solution to energy and environmental problems: A statistical overview and exploration of the dynamics of change. UNESCO.
- Uside, O.N., Barchok, K.H. & Abura, O.G. (2013). Effect of discovery method on secondary school student's achievement in physics in Kenya. *Asian Journal of Social Sciences*, 2(3), 351-358.
- Von G.E. (1996). Introduction: Aspects of constructivism. In C. Fosnot (Ed.), *Constructivism: Theory, perspectives, and practice*, (pp.3-7). Teachers College Press.
- Vygotsky's, L. (1978). *Mind in Society: The development of higher psychological processes*. Harvard University Press.
- Wachanga, S.W. (2002). Relative Effects of Cooperative Class Experiment Teaching Method on Secondary School Students' Motivation to Learn Chemistry in Nakuru District, Kenya. *Zimbabwe Journal of Educational Research*, 14(3), 229-253.
- Wambugu, P.W. & Changeiywo, J.M. (2008). Effects of mastery learning approach on secondary school students' Physics achievement. *Eurasia Journal of Mathematics, Science and Technology Education*, 4(3), 293-302.
- Wattenmaker, W.D., Dewey, G.I., Murphy, T.D. & Medin, D.L. (1986). Linear separability and concept learning: Context, relational properties, and concept naturalness. *Cognitive Psychology*, 18, 158-194.
- Williams, K.C. & Williams, C.C. (2011). Five key ingredients for improving student motivation. *Research in Higher Education Journal*, 12(1). 32-41.
- Williamson, G. (2015). *Self-regulated learning: An overview of metacognition, motivation and behaviour*. Genevieve Williamson College of Education, Health and Human Development, University of Canterbury.
- Woolnough, B. & Allsop, T. (1985). *Practical Work in Science*. Cambridge University Press.
- Wosilait, K., Heron, P.R., Shaffer, P.S. & McDermott, L.C. (1998). Development and assessment of a research-based tutorial on light and shadow. *American Journal of Physics*, 66(10), 906-913.

APPENDICES

Appendix I: Physics Conceptual Understanding Achievement Test (PCUAT)

School..... Experimental group () Control group ()

The following is a Physics Conceptual Understanding Achievement Test under the topic of Hooke's law. You are requested to answer the questions carefully to the best of your knowledge.

Any information given will be treated with the confidentiality it deserves.

Instructions: Do NOT write your name anywhere in this paper.

This paper consists of **FOUR** questions occupying 4 pages

You are requested to answer all the questions in the spaces provided

1. A mass of 200g is suspended from the lower end of a spring. If the spring extends by 50cm and the elastic limit of the spring is not exceeded, calculate the spring constant? (5mks)
2. A metal cube suspended freely from the end of a spring causes it to stretch by 25.0cm. A 400g mass suspended from the same spring stretches it by 5.0 cm. If the elastic limit is not exceeded, find the weight of the metal cube. (8mks).
3. A spring of spring constant 73N/m produces an extension of 9mm when a certain force is applied to it. Find the magnitude of the force applied. (5mks)
4. The table below gives values of extension of a spiral spring against the various forces applied.

Force F (N)	0	1.0	2.0	3.0	4.0	5.0	6.0
Extension e (cm)	0	0.8	1.5	2.3	3.1	3.8	4.6

- (a) Plot a graph of force against extension (8mks)
- (b) Use the graph to determine the spring constant (4mks)

Thank you very much for answering the Questions

Appendix II: Students' Motivation to learn Physics Questionnaire (PSMQ)

SchoolExperimental group () Control group ()

The following is Physics Students' Motivation Questionnaire. The purpose of this questionnaire is to find out what you think about Physics course. Any information given will be treated with the confidentiality it deserves.

Instructions

- Do **NOT** write your name anywhere in this paper
- Read the items carefully and try to understand before choosing what you accept to be true.
- There is no right or wrong answer.
- Tick the letter that corresponds with how you feel towards the Physics course. Tick only one of the choices:

Strongly Disagree - SD, Disagree - D, Undecided - U, Agree - A, Strongly Agree - SA.

If you change your mind about the answer, you may cross it neatly and tick another one.

	How you feel towards the Physics course	SA	A	U	D	SD
1.	Fun					
2.	Rewarding					
3.	Satisfying					
4.	Interesting					
5.	Stimulating					
6.	Challenging					
7.	Frustrating					
8.	Boring					
9.	Time wasting					
10.	I often look forward towards Physics lesson					
11.	I regularly revise my Physics notes					
12.	I do perform well in Physics					
13.	I am satisfied with the way I am taught Physics					
14.	I hardly ask questions during Physics lesson					
15.	I feel there is no need for me to continue studying Physics					
16.	Our teacher is discouraging during Physics lesson					
17.	Physics knowledge do not relate to my daily life					

18.	My success in Physics is very important					
19.	I always manage to solve Physics problems on my own					
20.	I feel confident during Physics lesson					
21.	I do not enjoy Physics lesson					
22.	I practice solving Physics problems on my own					
23.	I hope to pursue a Physics career beyond my form 4 level.					
24.	I put into practice what I learn in Physics in my daily life experience.					
25.	I do expect to perform well in Physics after examination					
26.	Learning Physics is rewarding in real life					
27.	I always manage to connect experimental set-up in Physics practical					
28.	I feel relaxed during a Physics lesson					
29.	I do not understand what Physics is all about					
30.	I like Physics					
31.	I feel confident about the Physics course					
32.	I feel eager to learn the Physics course					
33.	I don't appreciate Physics					
34.	I doubt my ability to learn Physics					
35.	I am scared of Physics					

Thank you very much for taking your time to answer the Questions

Appendix III: Training Manual for Teachers and Students

Currently teachers use various methods of teaching. What I am proposing is not to dispense with these methods but to modify the approach by implementing a method of teaching which has a specific structure. This structure will achieve a number of things. It will:

- (i) Ensure students learn more effectively from the lesson by increasing the chances of linkage occurring between theoretical knowledge and learning outcomes gained from the lesson;
- (ii) Make it easier for teachers to identify essential prior knowledge students require before commencing the exercise.

The structure I propose to use is Gowin's Vee teaching method. If used correctly and efficiently the Vee will not occupy any more class time.

This method helps students understand the structure and process of knowledge construction.

The left side of the Vee is the conceptual or 'thinking' side and the right side is the methodological or 'doing' side. The conceptual framework is built up over time while the right side displays the constructions for the current problem. The teacher need to;

1. Assist learners to understand that this topic of Hooke's law involves observing of objects or events which we choose to observe as well as selecting or constructing objects (events) to be observed, being guided by our concepts, principles and theories.
2. Tell learners that during the lesson a question has to be answered. This is a focus question which describes the objects and main events of the investigation and indicates the kinds of records that will be collected.
3. Learners also need to understand that the question leads to the aim of that particular lesson and to be able to answer the question. The investigation involves thinking and doing exercises.
4. Thinking requires use of theoretical knowledge, which is categorized into four elements, namely:
 - i) Theory, which means the general principles guiding the investigation.
 - ii) Principles, which are statements of relationship between concepts that explain how events or objects are expected to appear or behave.
 - iii) Constructs, which ideas are showing specific relationships between concepts.
 - iv) Concepts, which are labeled ideas or regular events and objects.

5. Doing component refers to the method or procedure. Assist learners to understand that in respect to doing, they must consider the following;
 - i. Value claims, that is, a statement to show that what is being investigated is of value. Describes the significance or application of the knowledge gained in the investigation.
 - ii. Knowledge claims, which are statements based on reasonable interpretation of data or records that, answers the focus question. It is here that the student makes statements concerning what is claimed to be known about the focus question.
 - iii. Transformations, which refer to tables, graphs, concept maps and statistics among others.
 - iv. Records, which are observations made or recorded from the events or objects. They should be presented in an organized fashion, such as in tables, charts and graphs.
6. Arrange the elements of thinking component on the left hand side and those of doing on the right hand side. Place the focus question at the top middle position (that is; between the thinking side and the doing side). Put the events, at the bottom middle position.
7. Construct the Vee-map by drawing a Vee-shape, and then fill in the details under each element on both sides of the Vee-map. First you have to fill the left hand side in order to do the right because the left hand side tells you what you have to know. And the right hand side tells you how to do it and how to end it. Therefore the left hand side stuff is what you already know and you use that stuff on the left hand side to figure out the information on the right hand side. Ask learners to provide the details and give them some task of constructing a Vee-map, using a given focus question and events.

Appendix IV: Interview Schedule for Physics Teachers using Gowin's Vee Teaching Strategy

Interview schedule

1. Preamble
2. When training you on how to teach physics using Gowins Vee teaching strategy was the method new to you?
3. Which specific areas in the Vee diagram were a bit difficult to teach?
4. Was the lesson material well covered in the amount of time given?
5. How was the teacher- student interaction during the lessons?
6. Were you able to get adequate instructional materials for teaching the topic?
7. How was the overall atmosphere during the lessons?
8. Were the learners able to identify the focus question?
9. Which of the 12 epistemological elements was difficult for the students to answer during the post-test?
10. Which other challenges did you face during your teaching using this method?
11. What are the advantages of Gowins Vee teaching strategy over regular teaching methods?

Appendix V: Research Authorization (NACOSTI)



NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

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Ref. No. **NACOSTI/P/19/81394/28758**

Date: **3rd April 2019**

James Kipkemoi Kipkazi
Egerton University
P.O. Box 536-20115
NJORO

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on "*Effects of Gowin's Vee teaching strategy on secondary school students' conceptual understanding and motivation in the topic of Hooke's Law in physics in Koibatek Sub-County, Kenya*" I am pleased to inform you that you have been authorized to undertake research in **Baringo County** for the period ending **1st April, 2020**.

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

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


BONIFACE WANYAMA
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Baringo County.

The County Director of Education
Baringo County.

National Commission for Science, Technology and Innovation is ISO9001:2008 Certified

Appendix VII: Letter of Authorization from County Director of Education Baringo County

REPUBLIC OF KENYA



**MINISTRY OF EDUCATION
STATE DEPARTMENT OF EARLY LEARNING & BASIC EDUCATION**

**OFFICE OF THE COUNTY DIRECTOR
(BARINGO COUNTY).**

Our Email: countyedubaringo@gmail.com
Tel / Fax: 053/21282

P.O. BOX 664
KABARNET

REF: CDE/BAR/RESEARCH.GEN/VOL.II/145

18/04/2019

James Kipkemoi Kipkazi
Egerton University
P. O. Box 536 – 20115
Njoro

RE : RESEARCH AUTHORIZATION

Reference is made to your request letter Ref. No. NACOSTI/P/19/81394/28758 dated 03/04/2019 on the above subject.

I am pleased to inform you that you have been authorized to carry out research on *"Effects of Gowin's Vee teaching strategy on Secondary School Students' conceptual understanding and motivation in the topic of Hooke's Law in Physics in Koibatek Sub County, Kenya"* for a period ending **1st April, 2020**.

The authorities concerned are therefore requested to give maximum support so that this research is completed within schedule.

I take this opportunity to wish you well during this research in our county.

For: COUNTY DIRECTOR OF EDUCATION
BARINGO
P. O. Box 664 - 30400
KABARNET

John K. Biwott
For : County Director of Education
Baringo County

Appendix VIII Distribution of Co-educational secondary schools in Koibatek Sub-County

Distribution of co-educational secondary schools in Koibatek Sub-County

Eldama Ravine Division	Esageri Division	Numberes Division	Torongo Division
Arama High School	Kiplombe Sec. Sch.	Kamura Sec. School	Tugumoi
Benonin Sec. School	Lebolos Sec. School	Moi Highlands Sec. Sch.	Koibatek Sec. School
Bhakita Sec. School	Muserechi Sec. Sch.	Soi Mining Sec. Sch.	Tinet Sec. School
Kamelilo Sec. School	Sagat Sec. School	St. Mary's Boito Sec. Sch.	
Kapcholoi Sec. School	Solian Mixed Day		
Kipkuyang Sec. School			
Kiptuno Sec. School			
Maji Mazuri Mixed Day			
Uhuru Kabiyet Sec. Sch.			
Uzalendo High School			
Simotwet Sec. School			
Sinonin Sec. School			
Tolmo Sec. School			

Source: Koibatek Sub-County office

Appendix IX: Published Paper Abstract

Journal of Education and Practices
<http://journals.essrak.org/index.php/education>

Journal of Education and Practices
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EFFECTS OF GOWIN'S VEE TEACHING STRATEGY ON SECONDARY SCHOOL STUDENTS' MOTIVATION TO LEARN HOOKE'S LAW TOPIC IN KOIBATEK SUB-COUNTY, KENYA

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Abstract

The study sought to find out the effects of Gowin's Vee teaching strategy on secondary school students' motivation to learn Hooke's law topic in Physics in Koibatek Sub-County in Kenya. Gowin's Vee Teaching Strategy is a learning activity involving making a V – shaped representation with two sides: the theoretical and methodological. Data were collected in selected co-educational secondary schools in Koibatek Sub-County, Baringo County. Solomon four non-equivalent control group design was used. Two experimental groups were taught using Gowin's Vee as treatment and two control groups taught using regular teaching methods. The target population was all Physics students in public secondary schools in Koibatek Sub-County. Purposive sampling was used to select 138 students from four co-educational secondary schools which were randomly assigned to experimental and control groups. The instruments used were Physics Students' Motivation Questionnaire (PSMQ) to test students' motivation level. Validity of the instruments was determined by Egerton University lecturers in the Department of Curriculum, Instruction and Educational Management and experienced secondary school Physics teachers in the four selected secondary schools. Reliability of the instruments was established through a pilot test process which was undertaken on the sample of Physics students in a co-educational secondary school in Mogotio Sub-county. Estimation of reliability using Kuder Richardson KR 21 gave 0.94 for PCUAT while Cronbach's alpha coefficient gave 0.88 for PSMQ, which is above 0.7- the accepted value. This study is important in enhancing performance and quality of teaching Physics.

Keywords: Gowin's Vee teaching strategy, learning, motivation, physics

Introduction

Physics is the study of matter and energy and their interactions. Physics is important because it improves the quality of life of human beings and it develops solutions to both energy and environmental problems (United Nations Educational, Scientific and Cultural Organization [UNESCO, 1999]). Any breakthrough in science and technology is deeply rooted in the strength of science education (Kehinde and Emmanuel, 2011). It is in recognition of this importance of science that during the Fifth Ordinary Session of the Conference of Ministers of Education in Africa (COMEDAF V) held in April 2012 in Abuja, Nigeria, Centre for Mathematics, Science and Technology Education in Africa (CEMASTEA) was showcased as model 'Centre of Excellence' in the promotion of quality of mathematics and science education at the basic level in Africa (Mutula, 2012).