EFFECTS OF CONSTRUCTIVIST TEACHING STRATEGY ON STUDENTS' CONCEPTUALISATION OF ELECTROSTATICS IN SECONDARY SCHOOL PHYSICS IN NAKURU DISTRICT, KENYA

BY

David G. Ngatia

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DECLARATION AND RECOMMENDATIONS

DECLARATION

This is my original work and has not been presented before for any award of a Diploma or Degree in this or any other university.

Sign:................................Date: ....

David G. Ngatia

RECOMMENDATIONS

This work has been submitted with our recommendations as university supervisors.

Sign:..Date:..

Prof. M. Okere

Sign:..Date...

Prof. J. Changeiywo

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DEDICATION

Dedicated to my beloved wife Delphine,our two children Reagan and Melissa, and my mum Mary.

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ABSTRACT

Physics subject is very important for scientific and technological development of any society. However, teaching of physics in our secondary schools has been found wanting. This is clearly depicted by the poor performance in the subject both at the school level and in the national examinations. Consequently, there has been low enrolment in the subject in comparison to other sciences. There is therefore a need to look for new teaching strategies that may improve the physics performance in schools. One of the modern teaching strategies that has been found to enhance learning of science concepts is the constructivist teaching strategy. This study aimed to determine the effects of the constructivist teaching strategy on students' conceptualisation of the topic Electrostatics in the Form One physics syllabus. Solomon-four-group quasi-experimental design was used. The data were collected from four purposively sampled co-educational secondary schools within Nakuru district to ensure homogeneity in characteristics. The sample size of the study comprised 140 Form One students. Teachers in the experimental groups were trained by the researcher for one week on the use of constructivist teaching strategy. Those in the control groups used the Convention Teaching Methods and were only trained in the scoring of the Physics Achievement Test. A Physics Achievement Test (PAT) on the concept Electrostatics was developed and used for data collection. The instrument was pilot-tested in a co-educational secondary school in Nakuru district to ascertain its validity and reliability. A Cronbach's reliability coefficient alpha value of 0.8889 was obtained which is above the recommended threshold value of 0.70. Data were analysed using Analysis of Variance (ANOVA) and t-test. The hypotheses were tested at the significance level of alpha value of 0.05 using the computer Statistical Package for Social Sciences (SPSS) version 11.5. The findings of the study indicate that the use of constructivist teaching strategy enhances conceptualisation of the topic Electrostatics in physics better than the conventional teaching methods. The findings further indicate that there is no statistical significant gender difference in conceptualisation of the topic Electrostatics in physics when constructivist teaching strategy is employed. The findings of the study may greatly help the Ministry of Education, Teachers Training Colleges and Curriculum Developers to incorporate the constructivist teaching strategy in the physics curriculum in order to improve the performance of the subject. Finally recommendations and implication of these findings have been discussed.

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ABBREVIATIONS AND ACRONYMS

CTM	- Conventional Teaching Methods
CTS	- Constructivist Teaching Strategy
KCSE	- Kenya Certificate of Secondary Education
KIE	- Kenya Institute of Education
KNEC	- Kenya National Examinations Council
PAT	- Physics Achievement Test
SMASSE	- Strengthening of Mathematics and Sciences in Secondary Education

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Scientific and technological knowledge, particularly of physics is fundamental for socio-economic development of any society (Changeiywo, 2000). Physics as a science is central to the promotion of public's scientific knowledge about the physical world, sharpening of the logical thinking amongst the youth, technological advancement, promotion of scientific attitudes and in solving societal problems (Okere, 1996). Of all subjects in science, physics offers the greatest opportunity for discoveries of fundamental philosophical importance, since only through it can an understanding be gained of those primal forces which, to give only two examples at extremes of distance, govern the interaction of celestial bodies at billion of meter's separation and of nuclear constituents at about 10^{-15} meters separation (Dainton, 1972).

Kenya Institute of Education (1992) gives the following objectives for teaching physics in secondary schools. Firstly, to help the learner to discover and understand the order of physical environment. Secondly, to make the learner aware of the effects of scientific knowledge in everyday life through application to the management and conservation of the environment. Thirdly, for the utilization of resources and production of goods and to enable the learner acquire knowledge, to foster development. Finally, to prepare learners for further studies and vocational training.

However, there is an increasing student's apathy to science. Students see science and particularly physics as uninteresting and uninspiring (Siringi & Waihenya, 2002). This has resulted in continued poor performance in physics (Ramani, 2004) despite the fact that physics is among the key subjects expected to turn Kenya into an industrialized country by the year 2020 (Githua, 2002). The performance in physics has been poor and this has remained a matter of concern to the Ministry of Education Science and Technology. For example in the year 2003 Kenya Certificate of Secondary Education (KCSE) examination, the overall mean score for physics was 32.28 out of maximum score of 190 (Ramani, 2004). This is disregarding the fact that it is the bright students who opt to take physics as their optional subject (Siringi & Waihenya, 2002). Table 1 gives the physics performance in K.C.S.E between 1999 and 2002.

Table 1:
Performance in Physics in K.C.S.E in the Period 1999-2002

Year	Paper	Candidature	Maximum Score	Mean Score	Standard Deviation
1999	1A		70	26.43	17.46
	1B		80		
	2		40	16.63	7.27
	Overall	35,061	190	43.07	22.88
2000	1A		70	26.24	15.44
	1B		80		
	2		40	17.94	8.19
	Overall	40,061	190	43.81	21.94
2001	1		70	20.94	15.50
	2		80		
	3		40	14.56	7.17
	Overall	54,645	190	35.24	20.00
2002	1		70	24.61	18.05
	2		80		
	3		40	17.06	8.23
	Overall	54,180	190	41.55	24.80

Source: KNEC 2003, p63

Table 1 clearly shows the poor performance trend in physics between the year 1999 and 2002. Out of the maximum score of 190, the overall mean score for the subject in the year 1999, 2000, 2001 and 2002 was 43.07, 43.81, 35.24 and 41.55 respectively. This translates to an overall percentage mean score of less than 25%. The table also indicates a declining trend in the mean score between the year 2000 and 2002. This poor performance trend calls for urgent corrective measures if Kenya is to become industrialised by the year 2020(Githua, 2002)

The enrolment for physics has also been lower than for the other science subjects. Furthermore, more boys than girls opted for physics. Table 2 gives the comparison of the number of candidates enrolling for selected subjects between year 2001 and 2002.

Table 2:

Candidate Enrolment in Physics and Selected Subjects between 2001 and 2002

	2001		**2002**	
Subject	**Female**	**Male**	**Female**	**Male**
	No. of students	No. of students	No. of students	No. of students
Mathematics	89481	104334	91647	105471
Biology	85499	91525	87141	90241
Physics	16225	38425	15312	38868
Chemistry	84534	96862	87725	99536
Geography	48116	61354	46727	60165

Source: KNEC 2003, pii

From table 2, the number of students who sat for physics examination in the year 2001 was 54,650 out of the total student candidature of 193,815. This means that only 28% of the total number of candidates opted for physics that year. In the year 2002, 54,180 students sat for the physics examination against a total student population of 197,118. This translates to 27% of the total number of candidates that year. Table 2 therefore gives clear evidence that physics attracts the lowest number of students as compared to other science subjects. Moreover, the table indicate gender imbalance for the students who opted for physics. For instance, in the year 2002, only 15,312 girls opted for physics against 38,868 boys. This apparently depicts the picture that physics is more popular with boys than girls.

Odalo (2000) attributed one reason to the poor performance and low enrolment in physics to failure by the teachers to use strategies that captivate learners during instruction. Okere (1996) points out that the quest for better teaching strategies has been going on for a long time. According to Kiboss (1997), most of the teaching approaches practised in Kenyan schools are mainly expository and fact oriented making students to be passive. Kochhar (1992) argues that the best curriculum and the most perfect syllabus remain dead unless quickened into life by the right methods of teaching. Additionally, the traditional teaching method of the teacher as sole information-giver to passive students appears outdated. In one study (Resnick, 1987) on undergraduates in a large lecture hall setting, it was found that only 20% of the students retained what the instructor discussed after the lecture. Furthermore, an American Advancing of Science Project 2061 (1990) charges that the present curricula in science and mathematics are overstuffed and undernourished. They emphasize the learning of answers more than exploration of questions, memory at the expense of critical thought, bits and pieces of information instead of understanding in context, recitation over argument, reading in lieu of doing. They fail to encourage students to work together, to share ideas and information freely with each other, or to use modern instruments to extend their intellectual capabilities.

One proposed solution for this problem is to prepare students to become good adaptive learners who should be able to apply what they learn in school to the various and unpredictable situations that they might encounter over the course of their lives (Yager, 1991). Obviously, the traditional teacher-as-information giver, textbook guided classroom has failed to bring about the desired outcome of producing thinking students. A much-heralded alternative is to change the focus of the classroom from teacher dominated to student-centred using a constructivist teaching strategy. Taking into account the poor performance in physics, there is therefore a need to improve the teaching of the physics subject (Ramani, 2004).

In order to guide the students, the teacher must not only have a model of the students' present conceptual structures but also an analytical model of the adult conceptualisation towards which his guidance is to lead (Glasersfeld, 1989). To achieve this, constructivist teaching strategy has in the recent past been recommended. According to Okere (1996), constructivist view of learning and teaching is very relevant to the teaching of most concepts in physics, which sometimes prove to be too difficult for the students. Good and Brophy (1995) explain the constructivist model of learning as the one that emphasizes students development of knowledge through active discussion process that link new knowledge to prior knowledge. This is as opposed to the transmission model of learning where the teachers act as a sender of fixed body of content to the learners who act as recipients. In constructivist view, pupils are seen as agents in their own learning. What they come to know arises through active construction of concepts in making sense of their experiences (Denvir, 1984). This construction process is important because unless the students build their own representation of new learning, it will be retained as relatively meaningless and inert rote memory (Good & Brophy, 1995). According to Driver (1989) and Okere (1996), constructivist teaching strategy could enhance the understanding of scientific concepts by learners since it involves construction of meanings based on learners' prior experience.

In this study, the researcher aimed at determining the effects of using the constructivist teaching strategy on students' conceptualisation of Electrostatics topic in Form One physics syllabus. According to KNEC Report (2001), this was one of the poorly performed areas. The researcher was therefore interested in determining whether the use of constructivist teaching strategy would reverse this poor performance and encourage enrolment in the physics subject.

1.2 Statement of the Problem

Physics subject is very important for technological development of any society. Its applications transverse many fields such as Engineering, Medicine, Automobiles, Information Technology and Aviation to mention but a few. However, the students' performance in physics in the Kenya Certificate of Secondary Education (K.C.S.E) Examinations has been poor. Girls' performance in the subject has been poorer than for boys. Some students are able to memorise the taught ideas for examination purposes but have difficulty applying them in everyday life situations.

One reason attributed to the poor performance in physics and other science subjects is failure by the teachers to use teaching strategies that enhance learning. constructivist teaching strategy is one of the strategies recommended by educators to enhance learners' conceptualisation of scientific concepts. However, its effects as a teaching strategy have not been investigated in Nakuru District. This study intended to fill the gap by applying the constructivist teaching strategy in teaching of the Electrostatics topic in physics to Form One students in Nakuru district and determining its effects on the conceptualisation of the topic.

1.3 Purpose of the Study

The purpose of this study was to investigate the effects of using constructivist teaching strategy on students' conceptualisation of Electrostatics topic in Form One physics syllabus. The study aimed at improving the performance in physics and encouraging more students to enrol for the subject due to its importance in their future careers.

1.4 Objectives of the Study

In order to achieve the stated purpose, the following objectives guided the study:

(i) To determine whether the use of constructivist teaching strategy has any effect on students' conceptualisation of Electrostatics topic in physics, in comparison with the conventional teaching methods

(ii) To determine whether there is any statistical significant gender difference in conceptualisation of Electrostatics topic in physics when constructivist teaching strategy is used.

1.5 Hypotheses of the Study

To achieve the objectives of the study, the following null hypotheses were tested:

Ho1: There is no statistically significant difference in conceptualisation of Electrostatics topic in physics between the students taught using constructivist teaching strategy and those taught using conventional teaching methods.

Ho2: There is no statistically significant gender difference in conceptualisation of Electrostatics topic in physics when taught using constructivist teaching strategy.

1.6 Significance of the Study

The results of this study are likely to provide information on the effect of using constructivist teaching strategy in conceptualisation of physics concepts. This may in turn translate into improvement of performance in physics. The findings may also greatly help physics teachers, Quality Assurance and Standards Officers in the Ministry of Education and curriculum developers in coming up with strategies and instructional materials that will make the teaching of physics concepts easier and interesting to the students. The teachers will be alerted to the function of prior learning and extant concepts in the process of learning new materials, by stressing the importance of understanding as a goal of physics instruction and by fostering pupils' engagement in lessons.

The findings are likely to make educators aware of the human dimension of science: its fallibility, its connection to culture and interests, the place of convention in scientific theory, the historicity of concepts and the complex procedure of theory appraisal. The teacher training colleges and universities may greatly benefit from the findings, which may help them to train teachers with the effective strategies to use when teaching scientific concepts.

1.7 Scope of the Study

The study was carried out in Nakuru district. The physics concept covered in this study was Electrostatics I. This involved the study of stationary, electrical charges in line with the KIE Form One physics syllabus. The effect of using constructivist teaching strategy on conceptualisation of the Electrostatics topic by Form One students in Nakuru district was determined. The study also aimed to determine whether there was any significant difference in conceptualisation of Electrostatics topic between boys and girls when constructivist teaching strategy was used

1.8 Limitations of the Study

The sample size of the study comprised only form one students in four co-educational secondary schools within Nakuru district. The findings could therefore be generalized to schools within Nakuru district. The topic covered in the study was Electrostatics I. The result of the study may thus be limited in generalizing to other physics topics.

1.9 Assumptions of the Study

The following assumptions were made in the study:

i). The form one students' attitude towards Physics had not been negatively influenced

ii). The teachers involved in the experimental groups taught according to the proposed strategy and those in control groups taught using conventional methods.

iii). There were no disruptions of the schools programmes during the period of the study.

1.10 Definition of Terms

The following terms were operational in this study:

Conceptualisation: This is the general understanding of an idea or a concept. It also means the act of cognitively forming an idea or a concept. In this study, it referred to the ability of the learners to understand and form ideas about the concept of Electrostatics. This was reflected by learners' ability to answer correctly questions related to the concept of Electrostatics in a Physics Achievement Test (PAT).

Constructivism: it refers to a philosophy of learning founded on the premise that, by reflecting on our experiences, we construct our own understanding of the world we live in. Constructivism is an approach to teaching and learning based on the premise that cognition (learning) is the result of "mental construction." In other words, students learn by fitting new information together with what they already know. Constructivists believe that learning is affected by the context in which an idea is taught as well as by students' beliefs and attitudes.

Constructivist Teaching Strategy (CTS): This refers to a teaching strategy, which holds the view that learning outcomes depend not only on the learning environment, but also on what the learners already know. The learner therefore construct meaning by generating links between their existing knowledge and the new materials they are taught. In this study, it referred to the teaching strategy that would involve learners' construction of meaning about the concept Electrostatics by considering their prior knowledge about charges.

Conventional Teaching Methods (CTM): It refers to regular methods of teaching. In this study, it referred to methods of teaching which are not learners' centred and which do not take into considerations learners' prior knowledge about concepts. In these methods, teachers serve as pipeline and seek to transfer their thoughts and meanings to the passive students. There is little room for student-initiated questions, independent thought or interaction between students. The goals of the learner are to regurgitate the accepted explanations or methodology expostulated by the teacher.

Electrostatics: This refers to a physics concept that involves the study of stationary electrical charges. The charges are either positive or negative.

Physics Achievement Test (PAT): This is a set of physics questions on the topic Electrostatics. It was used as a measure of students' conceptualisation of the Electrostatics topic.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter deals with literature review which includes the aims of teaching physics in Kenya, the meaning of processes of teaching and learning in science; theories of learning in science education; methods of teaching in science, the constructivist teaching strategy, the constructivist teaching strategy and achievement in sciences; gender and performance in sciences and finally, the theoretical and the conceptual frameworks of the study.

2.2 Aims of Teaching Physics in Kenya

Physics subject is important since it helps people to know more of nature thus giving them greater power over their own destiny. Osborne (1972) suggested that physics encourages the formation of scientific attitudes relevant to developing society. Shaffer (1972) also contends that knowledge of physics has produced industry tools and devices and new forms of transport, as well as new means of destruction. Thus, physics has affected thought in other spheres and through technology has revolutionized peaceful industry and methods of war. It has shaped history and therefore should be part of education at the secondary and other levels of education.

The Kenya secondary school physics syllabus is designed in line with the general objectives of education to offer varied experiences that may lead to an all round mental, social and moral development of the student (KIE, 1992). The syllabus portrays the nature of physics as body of knowledge about the physical environment, as a method of study and as a way of reasoning (Okere, 1996).The syllabus emphasizes both the understanding of the fundamental scientific concepts and principles and the experimental approach of investigation.

The following are the objectives for teaching physics in secondary schools in Kenya.

i) Help the learner to discover and understand the order of the physical environment.

ii) Make the learner aware of the effects of scientific knowledge in everyday life through application to the management and conservation of the environment.

iii) Enable the learner acquire knowledge and skills for solving problems

iv) Enable the learner to reason critically in any given situation.

v) Inculcate in learners a willingness to co-operate in using scientific knowledge to foster development in society.

vi) Prepare the learners for further studies or vocational training (K.I.E, 1992, p- 27).

Okere (1996) has highlighted the following as the aims of teaching physics. Firstly, Physics is taught for promotion of public scientific knowledge about the physical world. SMASSE (2004) agrees with this view by indicating that physics enables the learners to make sense of their world by helping them restructure their ideas in useful ways. The learners should build coherent scientific perspective that they can relate with what they learn and to the world in which they live. The second aim for teaching physics is for sharpening of logical thinking amongst the youth. Schaffer (1972) notes that, the study of physics allows objective thinking and the association of cause with effect to replace superstition and belief in magic. Teaching of physics helps foster and develop an individual with a scientific way of thinking (SMASSE, 2004). Thirdly, physics is taught for technological advancement since it is applicable in everyday situations; for promotion of scientific attitudes and for solving societal problems. Okere (1996) stresses that the physics we teach should be that which is relevant to societal needs.

From the foregoing discussion, the importance of physics as a subject is vividly brought in the limelight and it is imperative that it should be taught in schools. This study was concerned about how well the concept of Electrostatics could be understood by students in line with the aims of teaching physics, when constructivist teaching strategy is applied.

2.3 Teaching Process in Science

The term teaching has been defined differently by different authors (Keraro, 2002). Teaching is more than standing before a class and applying a few specific techniques. It is not merely presenting textbook information and then testing the student's ability to repeat it. Teaching is not a mechanical process. It is an intricate, exacting and challenging job (Kochhar, 1992; Vaidya, 2003). Stewart (1979) view teaching as all those teachers' activities that are aimed at helping learners to learn. Shiundu and Omulando (1992) define teaching as a professional activity in which one creatively and imaginatively uses himself and knowledge to promote learning of others. Sutton (1980) explains the role of a teacher as being first that of a diagnostician who tries to describe the learners' private concept and secondly a provocateur who tries to change and or extend this concept. According to Kochhar (1992), the teacher plays the role of guiding the learner and promoting the learners' development. He further sees teaching as an art and points out that as a sculpture is to a block, education is to the human soul. The teacher unconsciously moulds the child entrusted to him/her and modifies him/her accordingly.

Teaching of science involves organization of learning experiences in a way that will facilitate students' learning (Novak, 1981). Osborne and Freyberg (1990) give the teachers' role as a motivator, experimenter and researcher. According to Driver (1989), the science teacher's task involves helping students to organize their own learning experiences successfully and in a way that make sense to them. Hammacheck (1995) argue that the teachers' basic task is to present the subject matter in ways that encourage learners to make sense of it by relating it to what they already know.

According to constructivist view, teaching is any activity that is aimed at providing experience, interaction and negotiation of meanings of concepts amongst learners (Okere, 1996). Bartlett (1932) argue that teaching is an activity that activates learners existing cognitive structure or constructs new ones to subsume the new input. The teacher's role is to see that almost all students in one way or another construct their own meanings while acquiring knowledge. The pupils then link and inter-link concepts, which help them, construct new knowledge. Knowledge is therefore constructed and reconstructed progressively. Constructivism thus becomes the new philosophy in teaching and learning of science (Vaidya, 2003). The teacher acts as a facilitator of the learning process by arranging conditions of learning appropriately. He also helps children in evaluation of their individual learning or understanding. Science teachers should therefore develop scientific and technical capabilities in order to cope up with requirements of the content in science that is changing rapidly in our times.

Constructivist teaching requires a shift in thinking in which the underlying assumptions about what knowledge is, about how people learn, and about what is important are different. One can grow from a traditional view of teaching in which one seeks to control one's subject area and students to becoming comfortable with a subject area that is less predictable and more ambiguous. This enables one to make the shift in thinking that may be necessary to be a constructivist teacher. Lester and Onore (1990) explain the idea that our beliefs about teaching and learning affect our classroom practice, as well as our ability to change our practice. Support for this idea comes from Kelly's (1991) personal construct theory.

Lester and Onore (1990) indicate that teachers' personal beliefs about teaching (their construct systems) account for the kinds and extents of change that teachers are able to make. We view our situation through the lens of our personal construct system. Our beliefs about teaching and learning account for how we think and act as teachers. Specifically, teachers' definitions of what knowledge is, how people acquire it, and how we determine whether knowledge has been acquired account for the degree and kind of change teachers will experience.

Kelly (1991) devised personal construct theory, which proposes that, like scientists, we continually hypothesize about experience; formulating expectations based on a template of reality we have created through experience and reflection. We come to believe something through accumulated experience about it and then interpret experience according to those beliefs. These hypotheses, or personal constructs, may be modified with new experiences, but some are continually reinforced and confirmed, until, over time, they may actually shape experiences whereas when they were developing, experience moulded them. It is for this reason, Saunders (1992) believe that beliefs and practices about schooling are so difficult to change. He suggests that we need to examine the constructs or beliefs that influence our decisions about teaching and learning in order for change to occur. He believes that by changing our beliefs about teaching and learning, we are able to change our practice.

Smith (1993) suggests that the main construct affecting a teacher's ability to teach in a constructivist way is the belief that knowledge is not constructed by human beings. And so teachers would need to make a shift in thinking and change what they believe about knowledge in order to really change their teaching. Gredler (1997) proposes that genuine learning or change comes not from disregarding all prior learning in order to relearn, but from questioning or reassessing our existing beliefs about the world. Change can occur through having experiences that present and represent alternative systems of beliefs and trying to find a place for new experiences to fit into already held beliefs.

Reflecting on one's teaching practice contributes to one's ability to cross the bridge in terms of the way one thinks and believes about teaching. This enables him or her to move, for example, from a transmissional instructional practice to a constructivist one. Reflection, Mezirow (1990) explains, involves a critique of the assumptions on which our beliefs have been built, and through reflection, our perspectives are transformed. Yager (1991) notes that teachers are often trained to use various models of teaching and evaluation yet are not taught to be critical of the assumptions that underlie these models. He advises that teachers must be more than technicians but transformative intellectuals engaging in a critical dialogue among themselves and with the pupils.

The underlying assumptions about teaching and learning of a constructivist and a nonconstructivist teacher are quite different. Changing the gimmicks we use to teach in the classroom without changing the way we think about teaching and learning is, according to Cobb (1994), insufficient to change our practice. A complete rethinking of what teaching and learning are is necessary if we are to really change what happens in the classroom. A crucially important aspect of a teacher's job is watching, listening, and asking questions to students in order to learn about them and about how they learn so that teachers may be more helpful to students. Calkins (1986) notes that there is a thin line between research and teaching.

At the same time that we teach children, they also teach us because they show us how they learn; we just have to carefully watch them and listen to them. This kind of watching and listening may contribute to a teacher's ability to use what the classroom experience provides to help him or her create contextualized and meaningful lessons for small groups and individuals. The ability to observe and listen to one's students and their experiences in the classroom contributes to his or her ability to use a constructivist teaching strategy. Paradoxically, a constructivist teaching strategy contributes to one's ability to observe and listen in the classroom. Thus, the process is circular.

Understanding science concepts is a creative act. Students construct their own knowledge of science concepts and therefore should be actively involved in the science lesson. Constructivist instruction provides an experiential base for learning science content. From the above definitions, it is quite clear that the learner prior knowledge and experience are relevant bases for teaching science. This is supported by constructivist views of teaching (Osborne & Freyberg, 1990; Driver, 1989). In this study learner prior knowledge and experiences about charges were used in helping them understand the concept of Electrostatics.

2.4 Learning Process in Science

Teaching and learning are closely intertwined and you cannot talk of one without talking of the other. Learning in science is typically a difficult task for students and this is unlikely to change because of the complex structure of science (Hammacheck, 1995). Instead of reading or discovering the book of nature, scientists impose constructs and concepts on observed natural phenomena to organize and to understand them better (Driver, Asoko, Leach, Mortimer & Scott, 1994). Driver *et al* (1994) argue that the complexity in science lies in the study of the constructs advanced to explain natural phenomena rather than in the phenomena themselves. Carey (1989) state that exploration of the history and philosophy of science and inclusion of newer models of learning from cognitive psychology have prompted the science education community to focus on student learning in science and, as a result, have begun to change the view of teaching science from a transmission model to one of student construction of knowledge.

Central to constructivism is its conception of learning. Glasersfeld (1995) argues that: "From the constructivist perspective, learning is not a stimulus-response phenomenon. It requires self-regulation and the building of conceptual structures through reflection and abstraction". Fosnot (1996) adds that "Rather than behaviours or skills as the goal of instruction, concept development and deep understanding are the foci. For educators, the challenge is to be able to build a hypothetical model of the conceptual worlds of students since these worlds could be very different from what is intended by the educator (Glasersfeld, 1996).

In this paradigm, learning emphasizes the process and not the product. How one arrives at a particular answer, and not the retrieval of an 'objectively true solution', is what is important. Learning is a process of constructing meaningful representations, of making sense of one's experiential world. In this process, students' errors are seen in a positive light and as a means of gaining insight into how they are organizing their experiential world. The notion of doing something 'right' or 'correctly' is to do something that fits with "an order one has established oneself" (Glasersfeld, 1987, p. 15). This perspective is consistent with the constructivist tendency to privilege multiple truths, representations, perspectives and realities. The concept of multiplicity has important implications for teaching and learning. For instance, mathematics and science are viewed as systems with models that describe how the world might be rather than how it is. These models derive their validity not from their accuracy in describing the world, but from the accuracy of any predictions which might be based on them.

Direct transmission models of student learning began to lose favour because of their inability to explain some important intellectual achievements, such as, creativity, decision making and problem solving ability (Yager, 1991). Our thinking about learning in science has gradually changed because of developments in learning psychology and epistemology. Cognitive psychologists began to describe mental functions of students during learning; and, philosophers moved away from positivist and empiricist attempts to establish truths toward a constructivist view of knowledge building (Novak, 1981).

Driver and Bell (1986) emphasize that learning is a responsibility of individual learner. According to them, learning takes place not only through the taking in of new information but also involves organization and imaginative restructuring of the conceptions or framework, which learners already have. Good and Brophy (1995) explain the construction model of learning as the one that emphasizes students' development of knowledge through active discussion processes that link new knowledge to prior knowledge.

According to the D'Amico and Schmid (1997), meaningful learning occurs when students create ideas from the existing information. They further argue that one person's knowledge cannot be transferred exactly to another because knowledge, in part is the result of personal interpretation. A learner builds knowledge structures from personal experiences. Okere (1996) indicates that learners construct meaning from input by processing it through existing cognitive structures and then retaining it in long-term memory. This is done in ways that leave the input open to further processing and possible reconstruction. The learning outcomes depend not only on learning environment but also on the state of the learners (Driver, 1984).

Furthermore, it is argued that the responsibility of learning should reside increasingly with the learner (Glasersfeld 1989). Social constructivism thus emphasizes the importance of the learner being actively involved in the learning process, unlike previous educational viewpoints where the responsibility rested with the instructor to teach and where the learner played a passive receptive role. Glasersfeld (1989) emphasizes that learners construct their own understanding and that they do not simply mirror and reflect what they read. Learners look for meaning and will try to find regularity and order in the events of the world even in the absence of full or complete information. Ausubel (1963) asserts that meaningful learning occurs when new knowledge is consciously linked by the learners to existing knowledge in cognitive structures.

Social constructivist scholars view learning as an active process where learners should learn to discover principles, concepts and facts for themselves, hence the importance of encouraging guesswork and intuitive thinking in learners (Gredler, 1997). In fact, for the social constructivist, reality is not something that we can discover because it does not pre-exist prior to our social invention of it. Wood (1998) argues that reality is constructed by our own activities and that people, together as members of a society, invent the properties of the world.

Other constructivist scholars agree with this view and emphasize that individuals make meanings through the interactions with each other and with the environment they live in. Knowledge is thus a product of humans and is socially and culturally constructed (Ernest, 1996; Gredler, 1997). Vygotsky (1978) agrees that learning is a social process. He further states that learning is not a process that only takes place inside our minds, nor is it a passive development of our behaviours that is shaped by external forces and that meaningful learning occurs when individuals are engaged in social activities.

Vygotsky (1978) also highlighted the convergence of the social and practical elements in learning by saying that the most significant moment in the course of intellectual development occurs when speech and practical activity, two previously completely independent lines of development, converge. Through practical activity a child constructs meaning on an intrapersonal level, while speech connects this meaning with the interpersonal world shared by the child and her/his culture.

Constructivism is a view of learning based on the belief that knowledge is not a thing that can be simply given by the teacher at the front of the room to students in their desks. Rather, knowledge is constructed by learners through an active, mental process of development; learners are the builders and creators of meaning and knowledge. Constructivism draws on the developmental work of Piaget (1977) and Kelly (1991). Twomey (1989) defines constructivism by reference to four principles: learning, in an important way, depends on what we already know; new ideas occur as we adapt and change our old ideas; learning involves inventing ideas rather than mechanically accumulating facts; meaningful learning occurs through rethinking old ideas and coming to new conclusions about new ideas which conflict with our old ideas. A productive, constructivist classroom, then, consists of learner-centered, active instruction. In such a classroom, the teacher provides students with experiences that allow them to hypothesize, predict, manipulate objects, pose questions, research, investigate, imagine, and invent. The teacher's role is to facilitate this process.

Piaget (1977) asserts that learning occurs by an active construction of meaning, rather than by passive recipience. He explains that when we, as learners, encounter an experience or a situation that conflicts with our current way of thinking, a state of disequilibrium or imbalance is created. We must then alter our thinking to restore equilibrium or balance. To do this, we make sense of the new information by associating it with what we already know, that is, by attempting to assimilate it into our existing knowledge. When we are unable to do this, we accommodate the new information to our old way of thinking by restructuring our present knowledge to a higher level of thinking.

Similar to this is Kelly's theory of personal constructs (Kelly, 1991). Kelly proposes that we look at the world through mental constructs or patterns, which we create. We develop ways of construing or understanding the world based on our experiences. When we encounter a new experience, we attempt to fit these patterns over the new experience. For example, we know from experience that when we see a red traffic light, we are supposed to stop. The point is that we create our own ways of seeing the world in which we live; the world does not create them for us.

Education is fundamentally about students, teachers and processes of teaching and learning, most often in classrooms. Driver (1984), writing of constructivism in science education, place strong emphasis on respect for students' personal conceptions, and their influence on the development of scientific conceptions. She draws attention to the dialectical relationship between conceptions and perceptions, "Conceptions guide perceptions, and perceptions develop conceptions". The point is made that not only do students' conceptions "provide science instruction with information that is necessary to guide students to scientific conceptions" but they also "reveal important aspects of the nature of scientific knowledge". Thus the fallibility of scientific knowledge is emphasized, while simultaneously we have a recognition of particular scientific conceptions to which students need to be guided. A pedagogical process in such guiding involves the use of cognitive conflict.

Glasersfeld (1996) emphasizes both the aims and value of this "constructivist approach", and its failings. "Students often do not see the cognitive conflict, although it is obvious from the teacher's point of view". A 12-year old's investigation into the melting of ice illustrates his point. She believes that ice covered by wool will melt faster than ice covered by aluminum foil, since the wool will warm the ice. When she sees the ice in aluminum foil melting first, she puts this down to conditions in the experiment, rather than being challenged by conflicting evidence. Her personal conceptions are too strong to be shaken by one conflicting experience. The teacher needs to guide the student to learn the scientific conception that ice melts faster in aluminum foil.

It is evident from the foregoing discussion that the learning of science is an active process, which involves construction and negotiations of meanings through interaction of the learner with the environment and linking it with the existing cognitive structure. In this study learners were required to construct the meaning of the concept of charges by linking it with their prior everyday life experiences.

2.4.1 Cognitive Structural View of Learning Science

According to cognitive theorists, intake of information from the environment is active and systematic rather than passive and controlled by cue stimuli (Okere, 1996). Learning involves active cognitive processing of information rather than mere stimulus- response association. Bruner (1964) argues that we are constantly bombarded with stimulation to all our senses more than we can process at the same time. Hence we attend selectively to the stimulus input that is most important or interesting.

Cognitive theorists view learning as the organization of experience into cognitive structures (Chauhan, 1978). Cognitive theorists conclude that verbal learning can be effective and efficient if the instruction pertains to potentially meaningful material. To be logically meaningful, learning materials need to be non-arbitrary and substantively relatable; the relevant ideas or concepts must be within the realm of the student understanding (Ausubel, 1968).

Cognitive theories of learning differ from behavioural theories of learning in several ways, but both behavioural theories of learning and cognitive theories of learning are predicated on an objectivist view. Objectivists' views of learning have an underlying assumption that when studying a topic, we should all gain the same understanding. Underlying this assumption would be a belief that reality (and knowledge) is external to the knower (Ausubel, 1968). Generally speaking, then, in both behavioural and cognitive learning environments, it is believed that information can be transmitted from one person to another. However, unlike in a behavioural learning environment where the focus of learning is on observable behaviours, in Cognitive Information Processing Theory, the learner is a processor of information. Learning occurs when information from the environment is inputted, processed, stored in memory, and outputted as a learned capability.

The constructivist perspective is clearly different from earlier views of education that presumed we could put or pour information directly into a student's head. In constructivism, real learning can occur only when the learner is actively engaged in operating on, or mentally processing, incoming stimuli. Furthermore, the interpretation of stimuli depends upon previously constructed learning. Nothing here should be taken to imply that the mental processing involved in learning is necessarily conscious. In fact, much, perhaps even most, of the learning we do is subconscious. Thinking or learning about the process of learning, rather than the material being learned, is often called a meta-cognitive process (Chauhan, 1978).

Cognitive science has undertaken the study of the mental processes used to acquire, store, process, and use knowledge. Essential to any such study is a theory of learning and cognition. As a theory of epistemology, constructivism plays a central role in cognitive science, a role akin to that of causality for the physical sciences. Like causality, constructivism provides no specific answers, but rather, frames the questions and the acceptable forms of answers (Bruner, 1964)

Cognitive psychology has provided a basis for constructivist teaching. Piaget (1971) was one of the early contributors to this research. He suggested that new experiences are received through existing knowledge, a process of assimilation and accommodation. Learners construct knowledge as they attempt to bring meaning to their experiences. Glaserfield (1995) was another contributor of constructivist research. He explains that constructivism is a theory of rational knowing. Learners construct knowledge themselves on the basis of subjective experiences. In this study learners cognitively processed the concept of charges and organized experiences from experiments they conducted into their cognitive structures.

2.4.2 Discovery Learning Theory in Science

Bruner (1964) was influential in defining Discovery Learning. According to him, discovery learning uses psychology as a base. Discovery learning is an approach to instruction through which students interact with their environment-by exploring and manipulating objects, wrestling with questions and controversies, or performing experiments (Ormrod, 1995). In other words, Discovery learning is an inquiry-based, constructivist learning theory that takes place in problem solving situations where the learner draws on his or her own past experience and existing knowledge to discover facts and relationships and new truths to be learned. Students interact with the world by exploring and manipulating objects, wrestling with questions and controversies, or performing experiments (Bruner, 1964). As a result, students may be more likely to remember concepts and knowledge discovered on their own (in contrast to a transmissionist model). Models that are based upon discovery learning model include: guided discovery, problem-based learning, simulation-based learning, case-based learning, incidental learning, among others.

The idea is that students are more likely to remember concepts they discover on their own. Teachers have found that discovery learning is most successful when students have prerequisite knowledge and undergo some structured experiences (Roblyer, Edwards & Havriluk, 1997). Bruner (1964) points out that much learning that is meaningful is developed through discoveries that occur during exploration motivated by curiosity. True learning involves figuring out how to use what you already know in order to go beyond what you already think (Bruner, 1983). He further argues that discovery learning leads to development of problem solving skills, an increase in students' confidence about their learning abilities and an ability to adapt in the real world. He emphasizes activities that encourage students to search, explore, analyse or otherwise actively process input rather than respond to it. He contends that if foundations of learning are well laid, concepts so formed can be applied to discover new meanings and knowledge. As such the pupil discovers the intended content on his own, as he discovers several facts and concepts from the environment in his day-to-day living.

Bruner (1967) rejects expository mode of teaching in which the teacher teaches his lessons by organizing his content and materials. He argues that this mode makes students to receive knowledge passively. Instead, he prefers the hypothetical mode is which: -

(i) The pupil is not a passive listener or a bench bound listener.

(ii) The pupil participates in a major way in the development of the lesson.

(iii) The pupil has his own ideas on the topic, which he cares to develop further with his teacher. In case he goes ahead in his thinking, the teacher then becomes another resource person.

(iv) The pupil develops general problem solving skills which enable him work on his own.

(v) The pupil gets intrinsic rather than extrinsic satisfaction from his work.

(vi) The pupil is naturally aided in the development of his memory, which is meaningful rather than rote in nature. He is thus in a position to recall information whenever he needs it. (Bruner, 1967, p50)

Okere (1996) agrees with him and points out that Bruner's ideas are quite applicable in physics education in line with one of the objective of teaching physics, which is to guide the students to discover knowledge and analyse situations (KIE, 1992). Discovery learning is most noticeable in problem solving situations. The learner calls on their past experience and prior knowledge to discover the new information or skills. It is a personal, internal, constructivist-style learning environment. "Emphasis on discovery in learning has precisely the effect on the learner of leading him to be a constructionist, to organize what he is encountering in a manner not only designed to discover regularity and relatedness, but also to avoid the kind of information drift that fails to keep account of the uses to which information might have to be put" (Bruner, 1964). In this study, learners were guided to discover the basic law of charges by performing experiments involving charges.

2.5 Methods of Teaching Science

The method of teaching science means the process of delivering knowledge or transmitting specific skills to pupils by the teacher with the aim of making pupils comprehend and be able to apply the content and process of science (SMASSE, 2004; Vaidya 2003). The science curriculum in most developing countries, tend to be dominated by external examinations and generally students study solely under the pressure of the examinations and the teachers in their turn overstrain themselves zealously for the same. Consequently the methodology of teaching science has been found wanting. It has been found that physics teachers, for example, rarely use any variety in their teaching method such as teaching in a wider setting, discovery approach to science teaching, use of problem-solving procedure and teaching through individual and small group projects. Care needs to be given to develop educational research on methods. Educational systems must become less rigid and more must be done to encourage initiative, creativity and experimentation to achieve high standards (Vaidya, 2003). If science teaching is to improve, the teachers must be more aware of the alternatives of teaching facts through rote memory geared to the lowest, level of reflection. Teachers need to have some vision of their students' potential to perform at higher levels and the potential teachers have to raise their students' expectations as well. A review of possible alternatives to what is the prevalent method of science teaching seems appropriate. In this study, the strengths of various methods of teaching were integrated in the constructivist teaching strategy to enhance learning. The following are methods of science teaching that are worthy of review (SMASSE, 2004).

2.5.1 The Lecture Method

A lecture is an oral presentation of organized thoughts and ideas by the teacher to the students (Okere, 1996). In many classrooms in the developing countries, lecturing is the dominant method of instruction. The primary reason for this is that it is the method that most teachers have been taught by and they continue to use the method despite its limitations in meeting some goals (Vaidya, 2003). It is very convenient for a teacher to prepare and deliver a lecture since no special equipment or resources are required, except perhaps a piece of chalk. This has resulted to the method being labelled "chalk and talk". The method also enables teachers to cover a wider content in a given time.

Nevertheless, the lecture method has come into disrepute because of its failure to foster the varied outcomes of science teaching. A method which is based strictly on verbal exchanges can be ineffective in developing higher order thinking; and possibly present a less than accurate view of the scientific enterprise. The method restricts students to passive listeners and they are therefore likely to be inattentive since they are not actively involved (Okere, 1996).

Admittedly, this method has some place at the higher secondary stage. It can be used on certain occasions, such as, introducing a new topic, for orienting, motivating, and interesting student's in the new work; summarising daily and weekly lessons at the end of the unit; reviewing; supplementing student's information; emphasizing those points which are generally overlooked by students; giving important incidental information; and finally giving illustrative and inspirational talks based upon modern scientific development and the history of science and technology (Vaidya, 2003; Zverev, 1967). Figure 1 shows the schematic diagram of the lecture method.

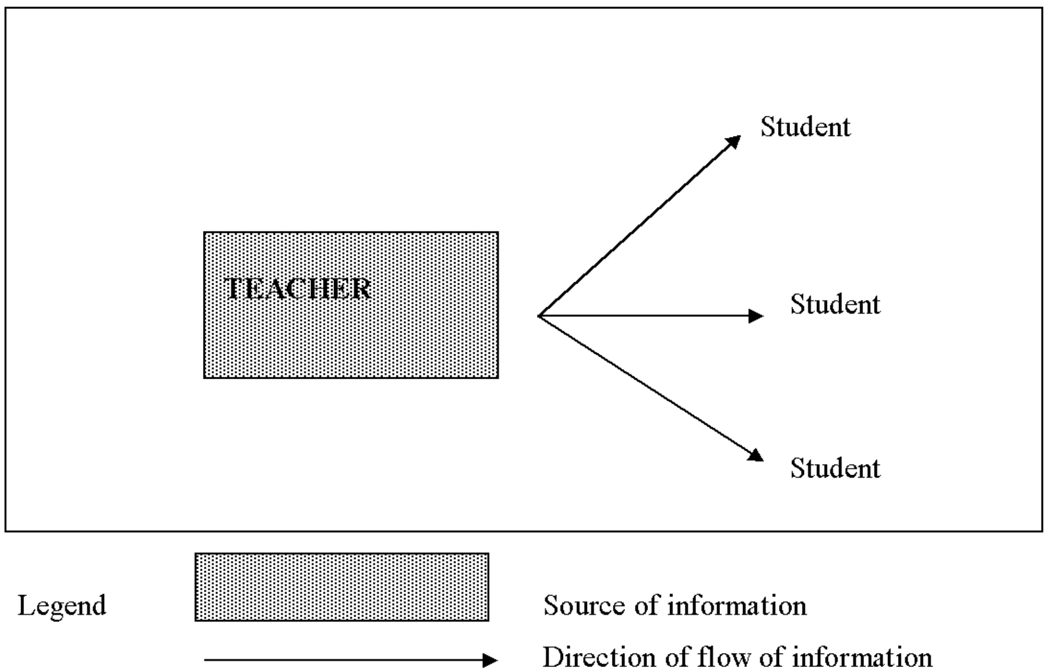

Figure 1: A Schematic Diagram of the Lecture Method (Vaidya, 2003)

As shown in the Figure 1, the dominant characteristic of the lecture method is that the information flows from the teacher to the students verbally and the student is expected to listen, understand and to transcribe the information into his notes. The information flow is in one direction. The role of a lecture in which the teacher is perceived as the sole authority is frequently criticized in many academic circles (Vaidya, 2003).

However, a teacher who uses the lecture method to clarify ideas and point out relationships between concepts and phenomena or concepts and concepts can certainly raise the level of instruction (Kubir, 1981; Vaidya, 2003). For example a class might be taught the essential postulates of the kinetic molecular theory, by having a set of five to ten concepts listed on the chalkboard.

For example: -

- All matter is made up of particles.
- All particles are in continuous random motion.
- Particles collide with each other and cause one another to increase or decrease their motion.

(Kubir, 1981, p43)

If in a lecture, the above list is presented with the teacher pointing how these properties of matter can be used to explain such things as why water evaporates when it is well below its boiling point or why water becomes cooler as it evaporates or any other phenomena that can be explained by applying the knowledge of kinetic molecular theory, then the teacher may raise the entire level of understanding to meaningful learning (Kubir, 1981; Vaidya, 2003).

To make the lecture lively, the teacher should involve the students, at least after the lecture. Students can question, clarify and challenge what the teacher has lectured (Zverev, 1967). The Lecture can also be interspersed with a discussion to make the students active. In using the lecture method, the teacher should therefore be prepared to allow questions during the lecture as appropriately as possible. He/she should also anticipate difficult questions and prepare appropriate responses in advance. In this study, the lecture method was used in clarifying and correcting learners' prior misconceptions about the concepts on charges.

2.5.1.1 Characteristics of a Good Lecture

It should be clear that a method is not itself a solution to teaching situation. Methods have various strengths and weaknesses, but there are also characteristics, which differentiate between good and poor utilization of a method.

The following are characteristics associated with good lecturing: -

i) An enthusiastic presenter who is well organized, challenging and clear in his presentation.

ii) The presentation includes an overview, logical organization and closure.

iii) The organization of the lecture is made explicit to the audience so that they understand the relationship between various components and parts.

iv) Verbal and visual clues are provided to give emphasis and smooth transitions between elements of the lecture.

v) Attention is maintained thorough appropriate anecdotes, physical activity, humour and especially enthusiasm for the topic.

vi) The audience is challenged to become intellectually involved with the topic being presented.

(Mc Leish, 1976, p20).

When lecturing is the chosen or necessary teaching method, one way to keep students engaged is to pause periodically to assess student understanding or to initiate short student discussions. Calling on individual students to answer questions or offer comments can also hold student attention. However, some students prefer a feedback method with more anonymity. If they have an opportunity to discuss a question in small groups, the group can offer an answer, which removes any one student from the spotlight.

For the lecture method to be successful there should be a clear indication and summary of the science topic or concept taught. The teacher should include varied examples and anecdotes. In some cases, a good lecture can raise the entire level of understanding to meaningful learning without using anything more than verbal instruction. The lecture method of teaching has invited harsh criticism from educators. Some improvements have however been made on it. For example, recitation sessions are often added to instructional programmes, which at one time were strictly lectures. Some science textbooks have been written in a conversational style with the teacher asking the questions and pupils' answers following it. Lastly, lecturers have made their presentations more interesting by judicious use of audiovisual materials.

2.5.2 The Demonstration Method

A popular alternative to the lecture method is one that is based on the idea that students learn more through observation than verbal communication (Vaidya, 2003). The objectives for the use of demonstrations in the science classroom are quite varied, and science teachers are encouraged to develop skills in the presentation of techniques so that the various outcomes are achieved. The single most valued outcome of a good demonstration is that it encourages students to be more aware of the actual phenomena being studied and subsequently directs them towards the study of science (SMASSE, 2004).

Demonstrations motivate students on the short-term to try to appreciate the physical reality upon which the theoretical laws of science are based, a reality that can be lost in a strictly verbal approach to teaching. In the long term, demonstrations can spark the reflective and creative aspects of science by challenging the pre-conception or partial knowledge (Vaidya, 2003; Kubir, 1981). Naturally, demonstration is an effective method of teaching as compared to the lecture method where the teacher simply talks.

In demonstration method, the teacher demonstrates and illustrates certain fundamental phenomena and the various applications of abstract principles through a series of experiments. However, no matter how good a demonstration is, it does not provide first hand experience to the students (Vaidya, 2003). The Figure 2 below shows a schematic diagram of the demonstration method.

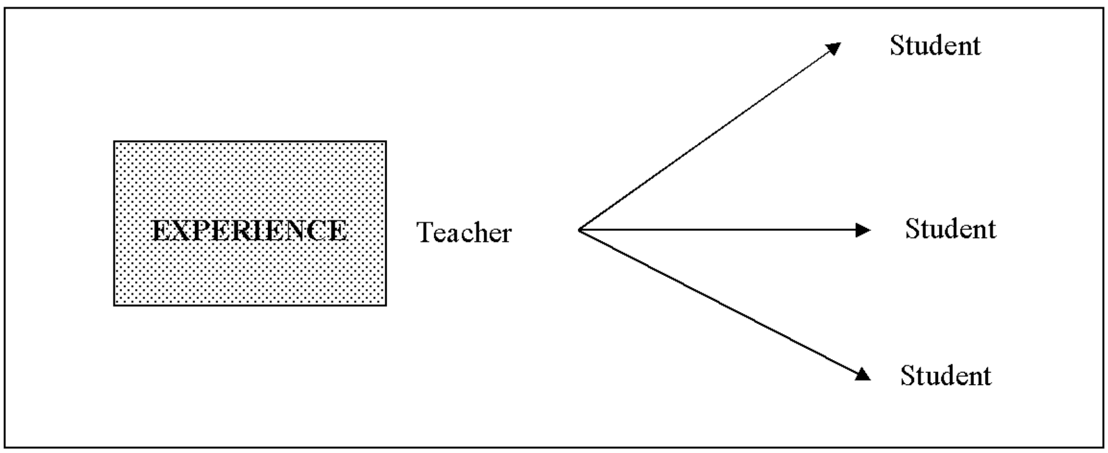

Figure 2: A Schematic Diagram of the Demonstration Method (Vaidya, 2003).

As shown in the figure, the model of demonstration is similar to the lecture method, except that the teacher giving a demonstration or phenomena to the student is himself between the demonstration and students. He can control the presentation by pointing out the significant features of the demonstration, and can weave into his presentation explanation about the phenomenon. Sometimes teachers use demonstration to serve as a focus for asking the students about their own understanding of the phenomenon being studied (Kochhar, 1992; Kubir, 1981).

Besides the desire to motivate students, the use of demonstrations can be a strategy for confirming or verifying information that the student might already know by presenting the information in a concrete mode (Vaidya, 2003). The use of the demonstrations is key to an instructional programme designed to develop process skills (Risk, 1968). Demonstration is particularly useful under the following situations: -

(i) When the teacher wants to demonstrate to his class the operation of an equipment.

(ii) When the teacher wants to illustrate a particular phenomenon like echo or interference.

(iii) Demonstration may be used as a motivating device when introducing a lesson.

(iv) Demonstration may be used in verification of observed phenomenon or trend of data.

(v) When the teacher wants to illustrate scientific procedures.

(vi) When the teacher wants to instil process skills to learners.

(vii) When the materials and equipments are inadequate.

(viii) When experimenting with dangerous chemicals.

(Bennaars *et al,* 1994, p217).

The demonstration should be selected both in terms of the needs of pupils as well as the ideas, materials, procedures or technique that can be observed profitably. The physical environment should be carefully arranged to ensure a smooth demonstration, clear vision and hearing by the pupils.

This method is appropriate for teaching specific facts and basic science skills. Students are told reasons why content is important and this helps to clarify the lesson objective (Zverev, 1967). However, the success of the method depends largely on the creativity of the teacher. It requires well-organized content preparation and good oral communication skills. The steps in a demonstration must be followed in prescribed order. The method may therefore be ineffective for higher-order thinking skills, depending on the knowledge base and skill of the teacher.

2.5.2.1 Characteristics of a Good Demonstration

Whether a demonstration is done for motivation, verification, knowledge transfer or as a focus event for teaching the scientific process, there are certain characteristics which differentiate between good and bad demonstrations. The following are characteristics of a good demonstration: -

(i) Demonstration should be simple and uncluttered. A demonstration should be visible in most of its significant details to all the members of the class. For this, consideration of the background against which experiments are shown is a must.

(ii) A demonstration should show only one major idea at a time. Too many ideas in one demonstration confuse students.

(iii) A demonstration should be timely and appropriate to the goals and objectives of the lesson. Demonstrations should not be carried out solely to entertain or because the materials are available.

(iv) A demonstration needs to be well prepared and rehearsed. An instructor should not be placed in the situation of explaining why the demonstration failed in order to illustrate the point that it was supposed to show. A demonstration should be striking, clear-cut and convincing. For this reason, it is essential that it be pre-tested before hand exactly under the same circumstances it is to be reproduced.

(v) Demonstration should be large-scaled and visible to the entire class. If students cannot see what is being demonstrated, there is no reason for carrying out the demonstration in the first place. If some students can see and others cannot, an issue of fairness will certainly arise.

(vi) Demonstrations should be direct and lively. Long pauses waiting for things to happen can lead to disruptive student behaviour. This can be particularly awkward for novice, teachers, who do not have the skill at filling in. Varied demonstrations should be well spaced throughout the class period.

(vii) Demonstrations should be dramatic and striking. Whenever possible, the phenomena should attract and focus the students attention.

(viii) A demonstration should call for some activities on the students' part. Observation guides may be used which should require the students not only to look but also to record, tabulate and analyse the observations.

(Vaidya, 2003, p199).

Demonstrations can be very effective for illustrating concepts in class, but can result in passive learning without careful attention to engaging students (Kochhar, 1992). They can provoke students to think for themselves and are especially helpful if the demonstration has a surprise, challenges an assumption, or illustrates an otherwise abstract concept or mechanism. Demonstrations that use everyday objects are especially effective and require little preparation.

For a demonstration to be successful, the pupils should be arranged such that they can all view the demonstration. If possible, they should be arranged with the short ones in front and the tall ones behind (Bennaars *et al*, 1994). Alternatively, they can be arranged in a semi circle. This is particularly suitable for a large class. The demonstration should be supplemented with illustrations and explanations. Questions should be asked during the demonstration to keep the pupils alert.

2.5.3. The Discussion Method

This is another useful method of teaching. A problem, an issue or a situation in which there is a difference of opinion is suitable for discussion method. In this method, ideas are initiated and there is an exchange of opinions accompanied by a search for its factual basis (Kochhar, 1992). Discussion is therefore an ordered process of collective decision-making. It seeks agreement, but if not reached, it has the value of clarifying and sharpening the nature of the agreement (Bennars *et al,* 1994). Students should be more actively involved in the discussion than the teacher who initiates it. In this case, the teacher guides the students. Figure 3 shows a schematic diagram of the discussion method.

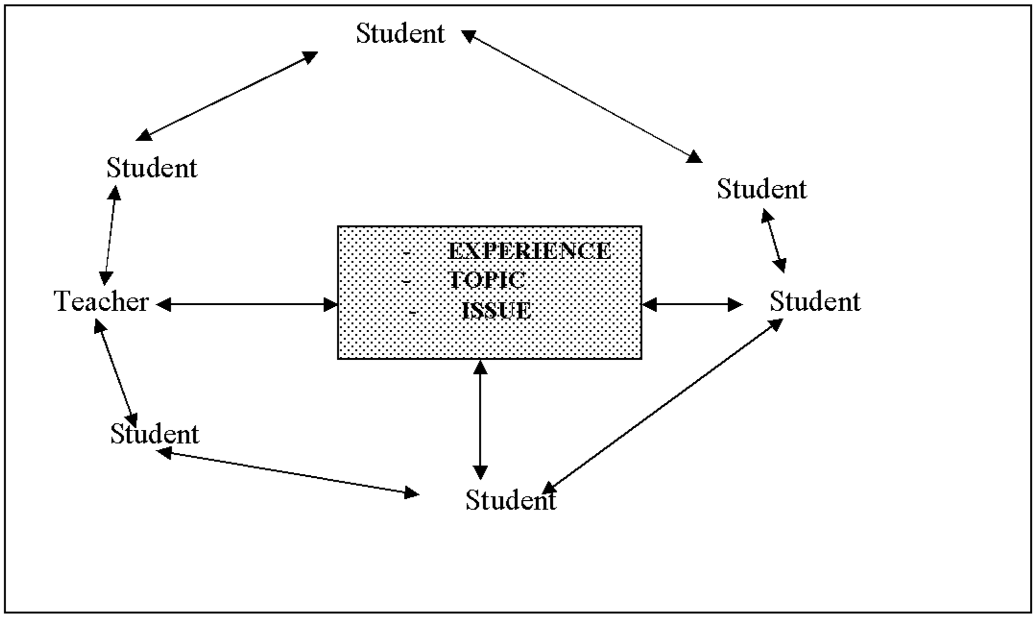

Figure 3: A Schematic Diagram of the Discussion Method (Vaidya, 2003).

As shown in the figure 3, learning occurs through active interactions between the students themselves and the teacher. Students or the teacher initiate ideas about a topic or a daily life experience. There is exchange of opinions accompanied by search for its factual basis. Conclusions are then drawn.

2.5.3.1 Preparation of a Discussion

Before a discussion starts, the teacher should examine the topic to be discussed to ascertain that students are familiar with the topic and have interest in it. Usually the topic of discussion should be relevant to the students' daily lives.Secondly, pre-planning is necessary for a discussion lesson. Students should be given an opportunity to seek information in advance. The sitting arrangement for the discussion should be thought of in advance. The teacher should direct the discussion by ensuring that students adhere to discussion rules. For example, talking should be done only when allowed, everyone must listen when someone else is talking and respect must be shown for other members' points of view (Bennaars *et al*, 1994).

Discussion may be a very effective means of teaching physics especially for small classes. For the Kenyan situation where secondary school classes have an average of 40 students, the teacher may divide the class into half if necessary. A discussion enables the learners to be active participants in the learning process and makes them to be broadminded in their reasoning (Okere, 1996).Focused discussion is an effective way for many students to develop their conceptual frameworks and to learn problem-solving skills as they try out their own ideas on other students and the instructor (Kubir, 1981). The give and take of technical discussion also sharpens critical and quantitative thinking skills. Classes in which students must participate in discussion force them to go beyond merely plugging numbers into formulas or memorizing terms. They must learn to explain in their own words what they are thinking and doing. Students are more motivated to prepare for a class in which they are expected to participate actively.

Student-centered discussions are less predictable than instructor-centered presentations. They are more time consuming, and they can require more skill from the teacher. To lead an effective discussion, the teacher must be a good facilitator, by ensuring that key points are covered and monitoring the group dynamics. Guidance is needed to keep the discussion from becoming disorganized or irrelevant. Some students do not like or may not function effectively in a class where much of the time is devoted to student discussion. Some may take the point of view that they have paid to hear the expert (the teacher). For them, and for all students, it is useful to review the benefits of discussion-based formats in contrast with lectures whose purpose is to transmit information.

Sensitivity to personality, cultural, linguistic, and gender differences that may affect students' participation in discussions is also important, especially if participation is graded. When students do not spontaneously engage in a discussion, they may be unprepared or they may be reluctant to speak or to be assertive. Some may be more comfortable making comparisons than absolute statements and others may be more comfortable with narrative descriptions than with quantitative analysis. You might try various strategies to engage your students in meaningful discussion by posing questions that measure different levels of understanding

2.5.4 The Class Experiment or Laboratory Method

Class experiment method is a hands-on and minds-on approach to science teachings in which the students have the opportunity to gain some experience with the phenomena associated with their course of study (Vaidya, 2003). The laboratory method of science instruction is characterized by the student actually producing and manipulating the various variables that are under exploration. The student controls and observes changes under investigation. Figure 4 shows a schematic diagram of the laboratory method.

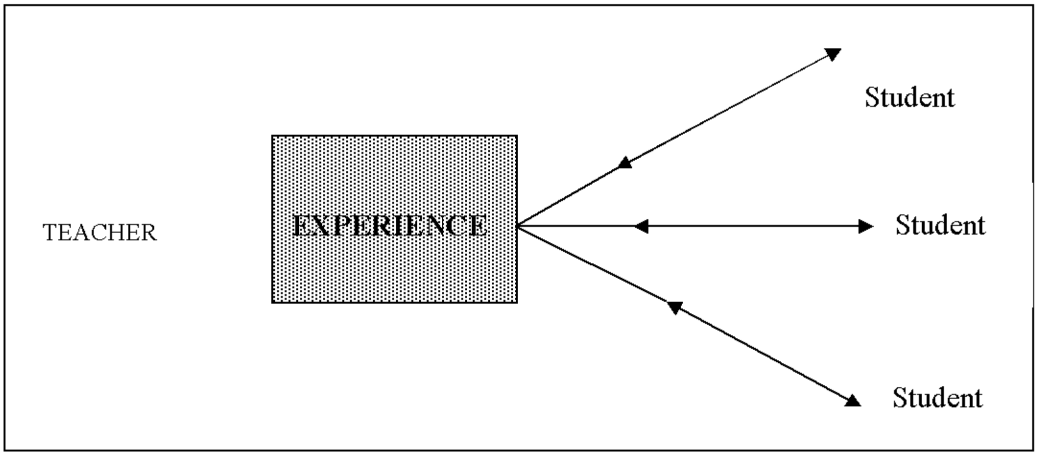

Figure 4: Schematic Diagram of the Laboratory Method (Vaidya, 2003)

As shown in figure 4, in the laboratory method, the teacher initiates the activity by determining the laboratory exercise, but it then becomes the responsibility of the student to gain the information by doing the experiment.

However, it should be noted that the aim of laboratory work is not to demonstrate what has been learned in lectures, but rather to enable the students to understand the origin of physical laws. In fact, the students' should derive physics laws from experimental investigations. It is improper for example to tell students to go to the laboratory to verify laws which have already been stated in class by the teacher as this may inhibit their curiosity and creativity (Okere, 1996).

2.5.4.1 Conducting a Laboratory Experiment

The process of conducting a laboratory experiment involves the following steps:-

i) Introducing pupils to the experiment and equipment to be used.

ii) Giving instructions: This step involves either giving pupils hand-out about the instructions to follow or writing the instructions on the board and explaining the sequence.

iii) Grouping of pupils: The size of the group will depend on the nature of the experiment and the apparatus available.

iv) Helping pupils in groups: The teacher is supposed to move around during the practical to assist pupils with difficulties and to ensure that the instructions are being followed.

v) Data collection: The teacher should check pupils' data during the practical to ensure that they are meaningful.

vi) At the end of a practical all groups should present their results for discussion. It is from discussions that conclusions are drawn.

vii) Writing laboratory reports: The pupils are expected to write a report of the work they have done in the laboratory. This exercise should be encouraged because it serves as a permanent record of what pupils have done and they can refer to it later.

viii) Cleaning up: Time should always be left at the end of the practical for cleaning up of the apparatus used.

(Okere, 1996, p83)

The value of the laboratory method may not rest in the cognitive domain, except for some information about the actual laboratory itself. Rather its value is in developing attitudes about the process of science and the nature of scientific investigations. When science courses are perceived as part of a career ladder leading to a profession with scientific or technical pre-requisites, then laboratory work is not only essential, but also it should be a major focus of the curriculum (Zverev, 1967).

It is hard to imagine learning to do science, or learning about science, without doing laboratory work. Experimentation underlies all scientific knowledge and understanding. Laboratories are wonderful settings for teaching and learning science. They provide students with opportunities to think about, discuss, and solve real problems. At the secondary school age the students may learn better if they are given the chance to experiment and see what will happen. According Martin (2000), hands-on activities are the best way to bring students into the realization that science is life and the two cannot be separated.

Despite the importance of experimentation in science, many science teachers fail to convey the excitement of discovery to the majority of our students. They generally give science laboratory work low marks, often describing them as boring or a waste of time (Kubir, 1981). It is clear that many laboratory work programs are suffering from neglect. Typically, students work their way through a list of step-by-step instructions, trying to reproduce expected results and wondering how to get the right answer. While this approach has little to do with science, it is common practice because it is efficient.

2.5.5 Project Method

The project method is an approach, which relies heavily on student interest, and socio-economic problems that might be addressed through science. The method is based on the students trying to understand and perhaps resolve some problem or conflict, which impacts them (Vaidya, 2003). Students work on real life problems through project work that brings them into contact with the environment. Project work also assists students in acquiring skills needed for scientific and technological development.

The evaluation of the project should be done both by the pupils and the teacher. The pupils should estimate the qualities of what they have done before the teacher gives her evaluation. This evaluation is to be done in the light of plans, difficulties in the execution and achieved results. This step is very useful because as a result of the project, the pupils can know the value of information, interest, skills and attitudes that have been modified by the project (Gredler, 1997).

Despite its great importance in the learning process, investigation has indicated that very little project work is taking place in Kenyan Secondary Schools. Fourteen Physics teachers in Kwale District, Coast Province were interviewed and from the results, it was evident that all the teachers interviewed had not done any project work (Okere, 1996).

The following are some of the suggestions which, if implemented could promote positive attitude towards project work. First, the project work should be evaluated at the end of the four years of secondary schooling. The assessment should be based on the number of quality of projects completed. Secondly, there should be zonal resource centres where schools with inadequate facilities can share the available resources. Thirdly, the teachers should promote physics clubs in their schools so that pupils can appreciate the application of physics in the society (Bennaars *et al*., 1994).

From the foregoing discussion, all the above teaching methods have their strengths and weaknesses. The variety of teaching and learning methods which is used within a course is an important ingredient in creating a course with interest to students. To effectively teach scientific concepts, various methods could be combined in the instruction. A constructivist teaching strategy that takes into account the students' prior knowledge and experiences about a phenomenon is likely to be more effective.

2.6 Constructivist Teaching Strategy

Basically defined, constructivism means that as we experience something new we internalize it through our past experiences or knowledge constructs we have previously established. Cobb (1994) states that "Meaning is constructed by the cognitive apparatus of the learner". Saunders (1992) explains and agrees with Watzawick (1984) that "Constructivism can be defined as that philosophical position which holds that any so-called reality is, in the most immediate and concrete sense, the mental construction of those who believe they have discovered and investigated it. In other words, what is supposedly found is an invention whose inventor is unaware of his act of invention and who considers it as something that exists independently of him; the invention then becomes the basis of his world view and actions". These past experiences are also referred to as our worldview.

During the years of childhood, children's ideas evolve as a result of experience and socialization into "common sense" views (Driver, 1989). Steffe (1990) explains that Constructivists view learning as the adaptation children make in their functioning schemes to neutralize perturbations that arise through interactions with our world. Fabricius (1983) asserts that reality becomes the phenomena we experience through construction.

Wheatly (1991) suggests two principles of learning through the constructivist strategy:
Principle one states that knowledge is not passively received, but is actively built up by the cognizing subject. Ideas and thoughts cannot be communicated in the sense that meaning is packaged into words and 'sent' to another who unpacks the meaning from the sentences. That is, as much as we would like to, we cannot put ideas in student's heads, they will and must construct their own meanings. Principle two states that the function of cognition is adaptative and serves the organization of the experiential world, not the ontological reality (Glasersfeld, 1987). Thus we do not find truth but construct viable explanations of our experiences.

Scott (1987) defines a constructivist teacher in science as one who perceives students as active learners who come to science lessons already holding ideas about natural phenomena, which they use to make sense of everyday experiences. Such a process is one in which learners actively make sense of the world by constructing meaning. Tobin and Tippins (1993) would add to the definition of the construction of knowledge in science education. They state that the constructed knowledge of science is viewed as a set of socially negotiated understandings of the events and phenomena that comprise the universe. They further explain that in order to have new knowledge, that "knowledge is accepted by the scientific community as viable because of its coherence with other understandings and its fit with experience". An interesting debate stems from this definition of how "new" knowledge then comes about. Tobin and Tippins (1993) continue to explain that "scientific knowledge continues to change over time because goals and problems of society change leading to new experiences; technology provides new ways of experiencing; what is known continues to increase at an exponential rate; and the individuals that comprise the scientific discipline continually change.

Understanding new information requires some relevant prior knowledge. Prior to instruction, students have acquired a fairly rich informal knowledge about a topic, which is not always scientifically correct but often plausible (Giyoo, 1993; Atwater, 1994; Driver & Bell, 1986). Good and Brophy (1995) explain the constructivist model of learning as the one that emphasizes students' development of knowledge through active discussion processes that link new knowledge to prior knowledge. Ausubel (1977) has clearly pointed out that the most important single factor influencing learning is what the learner already knows. The learner must therefore interpret tasks and try to construct solutions by using materials he already has (Glasersfield, 1989).

In constructivist teaching strategy, learners are seen as constructing meaning from input and processing it through existing cognitive structures (Bartlett 1932). In this regard, learners are assumed to be responsible for their own learning (Driver & Bell 1986). Driver and Bell further argue that if learners are not responsible for their learning, it may lead to them separating knowledge they learn in science lessons from their everyday world and consequently they may view school science as knowledge acceptable only within contrived situations in classrooms and laboratories but which has no use in out-of school experiences. This is in agreement with Wittrock's (1974) and Kelly's (1969) view which hold that learners must themselves actively construct or generate meaning from sensory input. The same view is shared by Osborne and Freyberg (1990) who term it as generative learning model of teaching. Constructivist perspective also view learning as an activity, which involves constructing meanings through a social process where pupil interact with each other as well as their teacher (Okere 1996). According to Hermain (1989), society and social interaction are important factors in the constructivist view of knowledge.

The social environment of the classroom is good at throwing up constraints which challenge individual perceptions. People often have different views of a situation. If these views seem incompatible, there is a need for reconciliation which can lead to the social mediation of individual knowledge. Through discussion or argument, the participants negotiate new positions which lead to shared meanings developing. Such negotiation is not bargaining, but a genuine offering of individual perspectives and meanings for consideration by others. It involves making an effort to listen to and understand other perspectives. As a result common, or 'taken-as-shared' (Confrey, 1990) meanings develop in a classroom.

Therefore, an important part of a constructivist oriented curriculum should be the negotiation of meaning. Students need to be given opportunities to make sense of what is learned by negotiating meaning; comparing what is known to new experiences, and resolving discrepancies between what is known and what seems to be implied by new experience (Tobin, 1990). The resolution of discrepancies enables an individual to reach an equilibrium in the sense that there should be no remaining curiosity regarding an experience in relation to what is known. Negotiation also can occur between individuals in a classroom. The process involves discussion and attentive listening, making sense of the points of views of others, and comparing personal meanings to those embedded within the theories of peers. When a person understands how a peer is making sense of a point of view, it is then possible to discuss similarities and differences between the theories of peers within a group. Justifying one position over another and selecting those theories that are viable can lead to consensuses that are understood by those within a peer group (Driver, 1989).

The process of learning should not stop at what has been learned in the negotiation of a class consensus. It is important that students learn to compare knowledge constructed in class with knowledge constructed by the community of scientists (Glasersfeld, 1989). This process can involve accessing other learning resources such as books, videotapes, and practicing scientists. The consensuses negotiated within a class can be adapted by students as they make sense of the theories negotiated in other communities. By engaging in such a process students can realize that what is regarded as a viable theory depends on what is known at the time and the context in which the theory is to be applied. Also they can begin to understand how to select the best theoretical formulation for use in a particular set of circumstances.

In a constructivist setting, knowledge is not objective; mathematics and science are viewed as systems with models that describe how the world might be rather than how it is. These models derive their validity not from their accuracy in describing the real world, but from the accuracy of any predictions that might be based on them (Postlewaite, 1993). The role of the teacher is to organize information around conceptual clusters of problems, questions and discrepant situations in order to engage the student's interest. Teachers assist the students in developing new insights and connecting them with their previous learning. Ideas are presented holistically as broad concepts and then broken down into parts. The activities are student centered and students are encouraged to ask their own questions, carry out their own experiments, make their own analogies and come to their own conclusions (cheek, 1992).

According to constructivist teaching strategy the teacher guides learners in construction, organization and restructuring of the conceptions or frameworks which learners already have (Driver & Bell, 1986). This is because some of the prior knowledge they bring to class may not be in line with scientific knowledge (Kiboss, 1997; Driver, 1984). The construction of meanings is therefore an active process of hypothesizing and hypothesis testing (Driver, 1984). In constructivist view, a classroom is therefore often pictured as an arena in which youngsters are asked to consider the ideas and theories they hold for a particular topic, to explore these to some extent, to examine some of their consequences, to listen to and consider the ideas of others and to begin to reshape their own ideas in order to take account of new factors (Watts & Bentley, 1989).

Furthermore, according to constructivist view, learners actively take knowledge, connect it to previously assimilated knowledge and make it theirs by constructing their own interpretation (Cheek, 1992). Students come into a classroom with their own experiences and a cognitive structure based on those experiences. These preconceived structures are valid, invalid or incomplete. The learner will reformulate his or her existing structures only if new information or experiences are connected to knowledge already in memory. Inferences, elaborations and relationships between old perceptions and new ideas must be personally drawn by the student in order for the new idea to become an integrated, useful part of his memory. Memorized facts or information that has not been connected with the learner's prior experiences will be quickly forgotten. In short, the learner must actively construct new information onto his existing framework for meaningful learning to occur (Yager, 1991).

In teaching using constructivist strategy, Okere (1996) has highlighted the following teaching sequence: Orientation, Elicitation, Restructuring, Application and Review. This sequence has been discussed in the conceptual framework in line with Driver (1989) sequence and are in agreement with Osborne and Freyberg (1990) phases of constructivist teaching process namely:

i. Preliminary phase: Where the teacher prepares students for learning by eliciting their ideas.

ii. Focus phase: In this phase the teacher guide the learners to focus attention on a particular concept to be taught.

iii. Challenge phase: This involves testing of the validity of views given by the learners and comparing them with scientific views.

iv. Application phase: This involves giving a problem whose solution requires the use of the scientific view constructed by the learners (Osborne & Freyberg, 1990, p110).

Constructivist teaching strategy is based on the belief that learning occurs as learners are actively involved in a process of meaning and knowledge construction rather than passively receiving information. Learners are the makers of meaning and knowledge. Constructivist teaching strategy thus fosters critical thinking and creates motivated and independent learners.

Learning of science involves being initiated into the culture of science. If learners are to be given access to the knowledge systems of science, the process of knowledge construction must go beyond personal empirical enquiry. Learners need to be given access not only to physical experience but also to concepts and models of conventional science (Driver *et al*., 1994). If teaching is to lead students towards conventional science ideas, then the teacher's intervention is essential, both through providing appropriate experiential evidence and making the theoretical ideas and conventions available to students.

To teach effectively using the constructivist teaching strategy, the teacher should follow the constructivist teaching guidelines. This may prove a difficult transformation since most teachers were prepared for teaching in the traditional, objective manner. It requires a paradigm shift and requires the willing abandonment of familiar perspectives and practices and the adoption of new ones (Brooks & Brooks, 1993). The following represent a summary of some suggested characteristics of a constructivist teacher: -

i) Become one of many resources that the student may learn from, not the primary source of information.

ii) Engage students in experiences that challenge previous conceptions of their existing knowledge.

iii) Allow students responses to drive lessons and seek elaboration of students' initial responses. Allow students some thinking time after posing questions.

iv) Encourage the spirit of questioning by asking thoughtful, open-ended questions. Encourage thoughtful discussion among students.

v) Use cognitive terminology such as "classify", "analyse" and "create" when framing tasks.

vi) Encourage and accept student autonomy and initiative. Be willing to let go of classroom control.

vii) Use raw data and primary sources, along with manipulation, interactive physical materials.

viii) Do not separate knowing from the process of finding out.

ix) Insist on clear expression from students. When students can communicate their understanding, then they have truly learned.

x) Allow significant wait time after posing questions.

xi) Provide time for students to construct relationships and create metaphors.

xii) Nurture students' natural curiosity

(Brooks & Brooks, 1993, p68)

Constructivism therefore leads to new beliefs about excellence in teaching and learning and about the roles of both teachers and students in the process. In constructivist classrooms, students are active rather then passive; teachers are facilitators of learning rather than transmitters of knowledge (Stein *et al.*, 1994). Constructivist teaching emphasizes thinking, understanding, reasoning and applying knowledge while it does not neglect basic skills. It is based on the idea that learners construct their own knowledge, rather than reproduce someone else's knowledge. Chaille and Britain (1991) point out that in a constructivist classroom the teacher is no longer the transmitter of knowledge but the facilitator of learning. The teacher as controller of students is a myth (Tobin & Dawson, 1992). The facilitator of learning needs to keep in mind that instruction will vary depending on the learners' prior knowledge, current interest, and level of involvement (Chaille & Britain, 1991). A skilful teacher will understand that students have existing knowledge, which may be incomplete or wrong, but will guide perceptions and initiate understandings (Tobin & Dawson, 1992).

Yager (1991) concurred with Brooks and Brooks (1993) and suggested the following procedures for teachers to use in line with the constructivist teaching strategy. According to him, the teacher should: -

i) Seek out and use students' questions and ideas to guide lessons and whole instructional units.

ii) Accept and encourage students' initiation of ideas.

iii) Promote student leadership, collaboration, location of information and taking actions as a result of the learning process.

iv) Use student thinking, experiences and interests to drive lessons.

v) Encourage the use of alternative sources for information both from written materials and experts.

vi) Encourage students to suggest causes for events and situations and encourage them to predict consequences.

vii) Seek out students' ideas before presenting teacher ideas or before studying ideas from textbooks or other sources.

viii) Encourage students to challenge each other's conceptualisation and ideas.

ix) Encourage adequate time for reflection and analysis; respect and use all ideas that students generate.

x) Encourage self-analysis, collection of real evidence to support ideas and reformulation of ideas in light of new knowledge.

xi) Use student identification of problems with local interest and impact as organiser for the course.

xii) Use local resources (human and material) as original sources of information that can be used in problem resolution.

xiii) Involve students in seeking information that can be applied in solving real-life problems.

xiv) Extend learning beyond the class period, classroom and the school.

xv) Focus on the impact of science on each individual student.

xvi) Refrain from viewing science content as something that merely exists for students to master for tests.

xvii) Emphasise career awareness especially as related to science and technology.

(Yager, 1991, p35)

The role of the teacher in the constructivists view should therefore be: to help students learn how to learn; being a learner too; ensuring equity for all students; creating a friendly, supportive learning environment; providing learning opportunities; listening to students; using the students' ideas, experiences and interests; challenging sensitively the ideas of students; providing the resources to help the students learn; ensuring the students communicate in a variety of modes; identifying and nurturing the scientific talents and interests of all students – provided the teachers are aware of the effectiveness of an open science programme which allows students to realise their own potential at their own pace (Tobin & Tippins, 1993).

Constructivist activities in any subject area can range from very simple to sophisticated and complex depending on the teacher's learning objectives. If a teacher were to devise a constructivist activity, the first thing that she or he would have to do is establish an educational objective. The teacher would then need to think of a meaningful activity that would, at the same time, help students to reach the objective and to explore and construct knowledge based on what they are reading and what they already bring to the activity. The possibilities for constructivist activities are limitless. It is important, however, regardless of subject area, to provide enough activities for student choice and to encourage student-generated activities. Constructivist teaching strategy is an exceptionally interesting and exciting way to teach because students are involved in learning activities they appear to enjoy, and much more student-teacher contact is possible. It extends one's impact as a teacher (Cook, 1992).

A teacher may structure a lesson in the following format. The first objective in a constructivist lesson is to engage students' interest on a topic that has a broad concept. This may be accomplished by doing a demonstration, presenting data or showing a short film. Ask them open-ended questions that probe the students' preconceptions on the topic.Next, present some information or data that does not fit with their existing understanding. Let the students break into small groups to formulate their own hypotheses and experiments that will reconcile their previous understanding with their discrepant information. The role of the teacher during the small group interactive time is to circulate around the classroom to be a resource or to ask probing questions that aid the students in coming to an understanding of the principle being studied. After sufficient time for experimentation, the small groups share their ideas and conclusions with the rest of the class, which will try to come to a consensus about what they learned (Lord, 1994).

In a constructivist classroom, teachers create situations in which the students will question their own and each other's assumptions. In a similar way, a constructivist teacher creates situations in which he or she is able to challenge the assumptions upon which traditional teaching and learning are based. Belenky, Clinchy, Goldberger, and Tarule (1986) report that at the constructivist level of knowing and thinking, we continually re-evaluate our assumptions about knowledge; our attitude towards "the expert" is transformed; we are not troubled by ambiguity but are enticed by complexity; and we take on a never-ending quest for truth and learning where truth is seen as a process of construction in which the knower participates. A constructivist teacher's perception of expertise in the classroom is based on the experience of his or her students in interaction with each other and with their teacher, and his or her ability to tolerate ambiguity is high as evidenced in the tendency to create complexity.

Holding a constructivist view of knowledge, Lester and Onore (1990) point out, enables a teacher to explore and form new ideas about teaching and learning. But the job of translating this belief into daily classroom practice is still present. This job is often made difficult with all that impinges on it, for example, the existing school system and its policies, and the school culture.

Teachers are individuals who are often drawn into teaching by a love of kids. Constructivist teachers develop skills and abilities to empower students and to make them feel competent and significant. Perhaps some of what a constructivist teacher does is intuitive. Constructivist teaching also requires intelligence, creativity, patience, responsiveness, and the ability to live with ambiguity permitting one to spontaneously abandon a plan in order to accommodate specific individual or classroom situations. And while the job of being a constructivist teacher is demanding, its value is evident in the impact on students' learning and personal development (Lester & Onore, 1990).

Constructivist teacher and a constructivist classroom exhibit a number of discernible qualities markedly different from a traditional or direct instruction classroom. A constructivist teacher is able to flexibly and creatively incorporate ongoing experiences in the classroom into the negotiation and construction of lessons with small groups and individuals. The environment is democratic, the activities are interactive and student centered, and the students are empowered by a teacher who operates as a facilitator or a consultant (Lord, 1994).

Constructivist classrooms are structured so that learners are immersed in experiences within which they may engage in meaning-making inquiry, action, imagination, invention, interaction, hypothesizing and personal reflection. Teachers need to recognize how people use their own experiences, prior knowledge and perceptions, as well as their physical and interpersonal environments to construct knowledge and meaning. The goal is to produce a democratic classroom environment that provides meaningful learning experiences for autonomous learners (Lester & Onore, 1990).

Constructivist theory holds that "learning means constructing, creating, inventing and developing one's own knowledge (Steffe & Gale, 1995). From this principle flows the belief that the mind actively constructs knowledge and invents concepts using existing understandings. Constructivism suggests that students remember more and process information better when it is clustered around existing and related ideas. The teacher's task is to facilitate the building of intellectual scaffolding upon which increasingly sophisticated understandings can be erected (Fosnot, 1996).

In a constructivist classroom, the focus is on how individual students accommodate information into their existing mental schemata. They are challenged to reorganize their cognitive world to account for new experiences. They embrace problems as their own, use prior knowledge as a starting point, accommodate new information and construct tentative solutions by integrating old and new knowledge together (Confrey, 1990). Learning is anchored around "big ideas" that can be generalized across experiences. Instead of focusing on discrete pieces of data and collections of facts, students conceptualize in a more global sense.

Facts and information are not merely memorized and reproduced; rather they are used as tools to form generalizations and understandings with greater meaning. Students pursue open-ended investigations and generate several possible solutions or explanations to a problem, which may be expressed as concepts or generalizations (Chaille & Britain, 1991). They actively question and interpret materials to develop conceptual understandings. In such a setting, student "learning is deeper, more comprehensive and longer lasting." In such an environment the classroom teacher is both a facilitator of inquiry and a transmitter of knowledge. As Steffe and Gale (1995) have pointed out, "From a didactic perspective, a teacher is a presenter of knowledge. From a discovery perspective, he or she is simply a provider of experiences. In a constructivist approach, both these functions are combined."

This perspective of learning presents an alternative view of what is regarded as knowledge, suggesting that there may be many ways of interpreting or understanding the world. No longer is the teacher seen as an expert, who knows the answers to the questions she or he has constructed, while the students are asked to identify their teacher's constructions rather than to construct their own meanings. In a constructivist classroom, students are encouraged to use prior experiences to help them form and reform interpretations. This may be illustrated by reference to a personal response approach to literature, a constructivist strategy first articulated by Rosenblatt (1938). Rosenblatt (1978) argues for a personal and constructive response to literature whereby students' own experiences and perceptions are brought to the reading task so that in transacting with that text, the realities and interpretations which the students construct are their own. A reader response approach to literature rejects the idea that all students should necessarily come to the same interpretation of a selection of literature, that single interpretation being the teacher's or someone else's. A reader response approach allows students to explore variant interpretations, the teacher's own interpretation being only one possible interpretation in the classroom.

In a traditional classroom, an invisible and imposing, at times, impenetrable, barrier between student and teacher exists through power and practice. In a constructivist classroom, by contrast, the teacher and the student share responsibility and decision making and demonstrate mutual respect. The democratic and interactive process of a constructivist classroom allows students to be active and autonomous learners. Using constructivist teaching strategy, teachers are more effective. They are able to promote communication and create flexibility so that the needs of all students can be met. The learning relationship in a constructivist classroom is mutually beneficial to both students and teachers (Rosenblatt, 1978).

Yager (1991) offers the following format for structuring a constructivist lesson:-

(i)	Starting the lesson	- Observe surroundings for points to question. - Ask questions - Consider possible responses to questions - Note unexpected phenomena - Identify situations where students' perceptions vary.
(ii)	Continuing the lesson	- Engage in focussed play - Brainstorm possible alternatives - Look for information - Experiment with materials - Observe a specific phenomena - Design a model - Collect and organise data - Employ problem solving strategies - Select appropriate resources - Students discuss solutions with others

- Student design and conduct experiments
- Students evaluate and debate choices
- Students identify risks and consequences
- Define parameters of an investigation

(iii)	Proposing Explanation and Solutions	- communicate information and ideas - Construct and explain a model - Review and critique solutions - Utilize peer evaluation - Assemble appropriate closure - Integrate a solution with existing knowledge and experiences
(iv)	Taking action	- Make decisions - Apply knowledge and skills - Transfer knowledge and skills - Share information and ideas - Ask new questions - Develop product and promote ideas - Use models and ideas to illicit discussions and acceptance by other.

(Yager, 1991, p46)

The Yager (1991) format of constructing a lesson is in agreement with the stages of the Driver's (1989) constructivist model of teaching and learning namely: orientation, elicitation, restructuring of ideas, application of ideas and the review of change of ideas. The format is also supported by Osborne and Freyberg (1990) phases of constructivist teaching process. These phases include: the preliminary phase where the teacher prepares students for learning by eliciting their ideas; the focus phase in which the teacher guide the learners to focus attention on a particular concept to be taught; Challenge phase which involves testing of the validity of views given by the learners and comparing them with scientific views; Application phase which involves giving a problem whose solution requires the use of the scientific view constructed by the learners. Activating learners' prior knowledge is very important since what is learned is always learned in relation to what one already knows. When teachers are familiar with a students' prior knowledge they can provide learning experiences to build on these existing understandings (Steffe & D'Ambrosio, 1995). Prior knowledge can be activated in many ways for example, by asking students what they know, by brainstorming, by doing semantic mapping, by predicting outcomes or by performing some skill or process. Lord (1994) and Yager (1991) have given the following checklist that a teacher can utilize to determine the degree of constructivist teaching strategy in their classrooms versus more conventional teaching methods that are objective in nature.

More conventional (Objectivist) teaching methods		**More constructivist teaching strategy**
Teacher…………………	Identifies the issue/ topic……………………	Student
No………………………	Issue is seen as relevant…………………	Yes
Teacher…………………	Ask question……………………………	Student
Teacher………………….	Identifies written and human resources………….	Student
Teacher………………….	Locates written resources……………….	Student
Teacher………………….	Plan investigations and activities……….	Student
No……………………….	Varied evaluation techniques used…………..	Yes
No………………………	Students practice self-evaluation………	Yes
No………………………	Concepts and skills applied to new situations…….	Yes
No………………………	Students take action……………………	Yes
No……………………..	Science concepts and principles emerge because they are needed………	Yes
No……………………..	Extension of learning outside the school is evident………	Yes

Constructivist teacher talk of students' construction of concepts, while the traditionist or the objectivist teacher talks of transmission. When there is failure of match between the students' ideas and the scientific ideas, constructivists talk of imperfect construction while traditionist talks of failure of the attention or imperfect comprehension. Certainly translations can be made from constructivist discourse to traditional discourse. For instance: 'perturbation' = 'anomaly', 'viability' = 'confirmation', 'construction of knowledge' = 'learning', 'facilitation' = 'teaching', 'accommodation' = 'theory change'.

Negotiation is an important aspect of a constructivist classroom. It unites teachers and students in a common purpose. Smith (1993) confirms that negotiating curriculum means "custom-building classes every day to fit the individuals who attend". Boomer (1992) explains that it is important when negotiating for teachers to talk openly about how new information may be learned and about constraints such as obligatory curriculum. He comments on the meaning of negotiating the curriculum and asserts that negotiating the curriculum means deliberately planning to invite students to contribute, and to modify, the educational program, so that they will have a real investment both in the learning journey and the outcomes. Negotiation also means making explicit, and then confronting, the constraints of the learning context and the non-negotiable requirements that apply.

Cook (1992) explains why negotiating the curriculum with students is important and argues that learners will work harder and better, and what they learn will mean more to them if they are discovering their own ideas, asking their own questions, and fighting hard to answer them for themselves. They must be educational decision makers. Out of negotiation comes a sense of ownership in learners for the work they are to do, and therefore a commitment to it.

A constructivist teacher offers his or her students options and choices in their work. Rejecting the common practice of telling students what to do, he or she engages their trust and invites them to participate in a constructivist process that allows them to be involved in decisions about their learning. Students actively involved in their own learning is a vital reality in a constructivist classroom. Students may participate in the construction of the curriculum by negotiating the themes that will be the focus of their work along with the selection of literature from a predetermined range of literature. Students may also participate in the design of their assignments, although the parameters for these may be established by their teacher.

Finally, students may have some involvement in the way their assignments are evaluated (Boomer, 1992).

The main tenet of constructivist learning is that people construct their own understanding of the world, and in turn their own knowledge. According to Ernest (1996), constructivist teaching strategy could lead to the following pedagogical implications: -

(i) Sensitivity toward and attentiveness to the learner's previous constructions. This includes using students' previous conceptions, informal knowledge and previous knowledge to build upon new knowledge.

(ii) Using cognitive conflict techniques to remedy misconceptions. Engaging in practices like these allows students to trouble their own thinking, and it is through this conflict that they will develop their own meanings, or at least seek to rectify the conflict.

(iii) Attention to metacognition and strategic self-regulation. This follows from the previous suggestion when students think about their thinking, and become responsible for their learning.

(iv) Use of multiple representations. In science and mathematics, multiple representations offer more avenues with which to connect to students' previous conceptions.

(v) Awareness of the importance of goals for the learner. This awareness of goals refers to the difference between teacher and learner goals, and the need for learners to understand and value the intended goals.

(vi) Awareness of the importance of social contexts. Various types of knowledge occur in various social settings. For instance informal knowledge versus formal knowledge.

(Ernest, 1996, p346)

Constructivism increasingly presents itself as an ethical as well as learning, teaching and an epistemological theory. As a recent paper says "There is also a sense in which constructivism implies caring, -caring for ideas, personal theories, self image, human development, professional esteem, people – it is not a take-or-leave-it epistemology" (Watts & Bentley, 1989). This ethical dimension is manifest in the frequency in which notions of emancipation and empowerment occur in constructivist writing. Constructivism is thought to be a morally superior position to its rivals in the learning theory and pedagogy. It offers teachers “a moral imperative for deconstructing traditional objectivists conceptions of the nature of science, mathematics and knowledge, and for reconstructing their personal epistemologies, teaching practices and educative relationship with students (Wheatley, 1991).

From the foregoing discussion, it is quite evident that the constructivist teaching strategy is more learner centered as compared to the conventional teaching methods. The present study used the constructivist teaching strategy in teaching the topic Electrostatics to form One students. The study incorporated the constructivist lesson formats discussed above. The formats are in agreement with the teaching sequence suggested by Driver (1989) discussed at length in the theoretical framework.

2.7 Constructivist Teaching Strategy and Achievement in Science

Educationists all over the world have been struggling to develop strategies that can optimise the attainment of teaching and learning objectives. They are continuously faced with the challenges of responding to the changes in strategies that enhance teaching and learning of science (SMASSE, 2004). In order to enhance learning and achievement in sciences, effective teaching strategies need to be employed (Odalo, 2000).

Constructivist teaching strategy could enhance teaching and learning of scientific concepts, which sometimes prove too difficult for the learners (Okere, 1996). By considering the learner’s prior knowledge and experience about scientific phenomenon, constructivist teaching strategy enables the learner to fully comprehend the phenomenon. This could in turn be reflected in learners’ achievement in science. In a study conducted in America by Caprio (1994), the constructivist teaching strategies was employed and compared to the traditional lecture method in teaching anatomy and physiology in a community college. The result showed that students taught using constructivist teaching strategy obtained better exam grades.

Brooks and Brooks (1993) offer five guiding principles of constructivism that can be applied to the classroom: -

(i) The first principle is posing problems of emerging relevance to students. A focus on students' interest using their previous knowledge as a departure point helps students engage and become motivated to learn. The relevant questions posed to the students will force them to ponder and question their thoughts and conceptions.

(ii) Another guiding principle is structuring learning around primary concepts. This refers to building lessons around main ideas or concepts instead of exposing students to segmented and disjoint topics that may or may not relate to each other. The use of broad concepts invites each student to participate irrespective of individual styles, temperaments and dispositions.

(iii) The third principles is seeking and valuing students' points of view. This principle allows for access to students' reasoning and thinking processes, which in turn allows teachers to further challenge students in order to make learning meaningful. To accomplish this, however, the teacher must be willing to listen to students, and provide opportunities for this to occur.

(iv) Adapting curriculum to address students' suppositions is the fourth principle. The adaptation of curricular tasks to address students' suppositions in a function of the cognitive demands implicit in specific tasks and the nature of questions posed by the students engaged in these tasks.

(v) The final principle is assessing student learning in the context of teaching. This refers to the traditional disconnect between contexts of learning versus that of assessment. Authentic assessment is best achieved through teaching; interactions between both teachers and students, and students and students, and observing students in meaningful tasks. (Brooks & Brooks,1993, p84)

Constructivism in education emerged after the behaviourists' movement as a welcome and refreshing view of learning that centers on the active learner within the teaching-learning process. This emphasis on the individual (within the greater social context) during instruction has drawn attention to the prior beliefs, knowledge, and skills that individuals bring with them. Prior knowledge has been shown to significantly influence the ways individuals make meaning out of instruction. The constructivists focus on the social context and larger community of learners has resulted in a major shift away from individually-based instruction to instruction that incorporates and embeds teaching within the larger community of peers, younger students, as well as those who are older. Finally, constructivist's greatest contribution to education may be through the shift in emphasis from knowledge as a product to knowing as a process. This legacy of constructivism will likely prove to be a lasting and meaningful shift in the structure of schooling.

The constructivist teaching strategy emphasizes the following six important elements: Situation, Groupings, Bridge, Questions, Exhibit, and Reflections. These elements are designed to provoke teacher planning and reflection about the process of student learning. Teachers develop the situation for students to explain, select a process for groupings of materials and students, build a bridge between what students already know and what they want them to learn, anticipate questions to ask and answer without giving away an explanation, encourage students to exhibit a record of their thinking by sharing it with others, and solicit students' reflections about their learning (Ernest, 1996). The present study applied the constructivist teaching strategy in teaching the topic Electrostatics and determined its effects on conceptualisation using a Physics Achievement Test set from the same topic.

2.8 Gender and Performance in Sciences

Tsuma (1998) notes that there is a school of thought in the field of sociology, which holds the view that science has in-built features which inhibit girls from studying it. He further notes that boys bring with them to science conception of masculinity while girls bring with them feminist conception. As several studies, and particularly that of Häußler (1987) show, interest in physics is progressively decreasing for girls with increasing age. Girls' diminishing interest in physics correlates closely to the growing acceptance of their gender role. These effects are not necessarily intentional; parents are often unaware of things they are doing which discourage their daughters from studying math, physics and science. Consequently, their gender-role stereotyped behaviours and expectations are often immune to modification based on their children's actual talents and performance. Such socializing effects of parents' behaviours and beliefs are, for example, to give technical toys to boys, dolls to girls. Girls are asked to help mother doing the housework, boys are asked to assist father doing craftwork and other technical tasks in house and garden. Boys are encouraged using tools such as hammer, saw, file or electric drill; girls are warned not to hurt themselves.

Early interests and talents for math, physics and science are noticed more likely by parents of boys than by parents of girls. Parents think it is more important for sons than for daughters to take advanced courses in math and science, especially in physics. Parents think that math is more difficult for daughters than for sons and that girls have to work harder than boys to get the same learning results in school. Parents are less likely to encourage girls to take advanced math courses (Hanna & Kuendiger, 1986). This means when children are entering school, and also in the following years, girls have less opportunity to practice in technical and scientific fields than boys, and their science knowledge acquired in school has a much smaller basis of experience. So, when teachers rely on equal processing for boys and girls, boys have the better chance.

This has led to more boys than girls studying science subjects in schools. Agreeing with this view, Aduda (2003) contends that when girls are given an option in science subject, fewer opted for physics. The Kenya National Examination Council examination report, of year 2002, further attests to this. In that year K.C.S.E results, for example, out of the 91,647 girls who sat for K.C.S.E, only 15,312 opted for physics. The mean score for physics was 26.61 % for girls while boys' means score was 30.89 %.

According to Fennema and Sherman (1978) girls experience a drop in their self-confidence in mathematics and sciences before they experience any academic decline. This is attributed to differential treatment boys and girls receive in schools. Classroom activities are chosen more often to appeal to boys than girls. This can contribute to faulty perceptions that science is a male domain (Wachanga, 2002). However, Mwangi, Chiuri and Mungai (2001) suggest that it is easier to shape girls' interest, behaviour, attitude and curiosity towards science at an early age and sustain the same to adult hood. In this study the constructivist teaching strategy was applied. All activities carried out were balanced in terms of gender. The learners were guided in the construction of meaning of the concept of charge based on their prior everyday life experiences, regardless of their gender.

2.9 Driver's Constructivist Model of Teaching and Learning

The theoretical framework of the study is based on Driver's 1989 constructivist model of teaching and learning. According to this model, learning involves construction of meaning by the learners of what they hear or see, by generating links between their existing knowledge and the new phenomena attended to (Driver & Bell, 1986). According to Good and Brophy (1995), this construction process is important because unless the students build their own representation of new learning, it will be retained as relatively meaningless and inert rote memory. The teaching sequence used in this study is one coined by Driver in 1989. The effects of using this teaching sequence were determined in comparison with the conventional methods of teaching. The physics topic covered was Electrostatics in Form One physics syllabus. Figure 5 illustrates the teaching sequence based on constructivist view of teaching and learning.

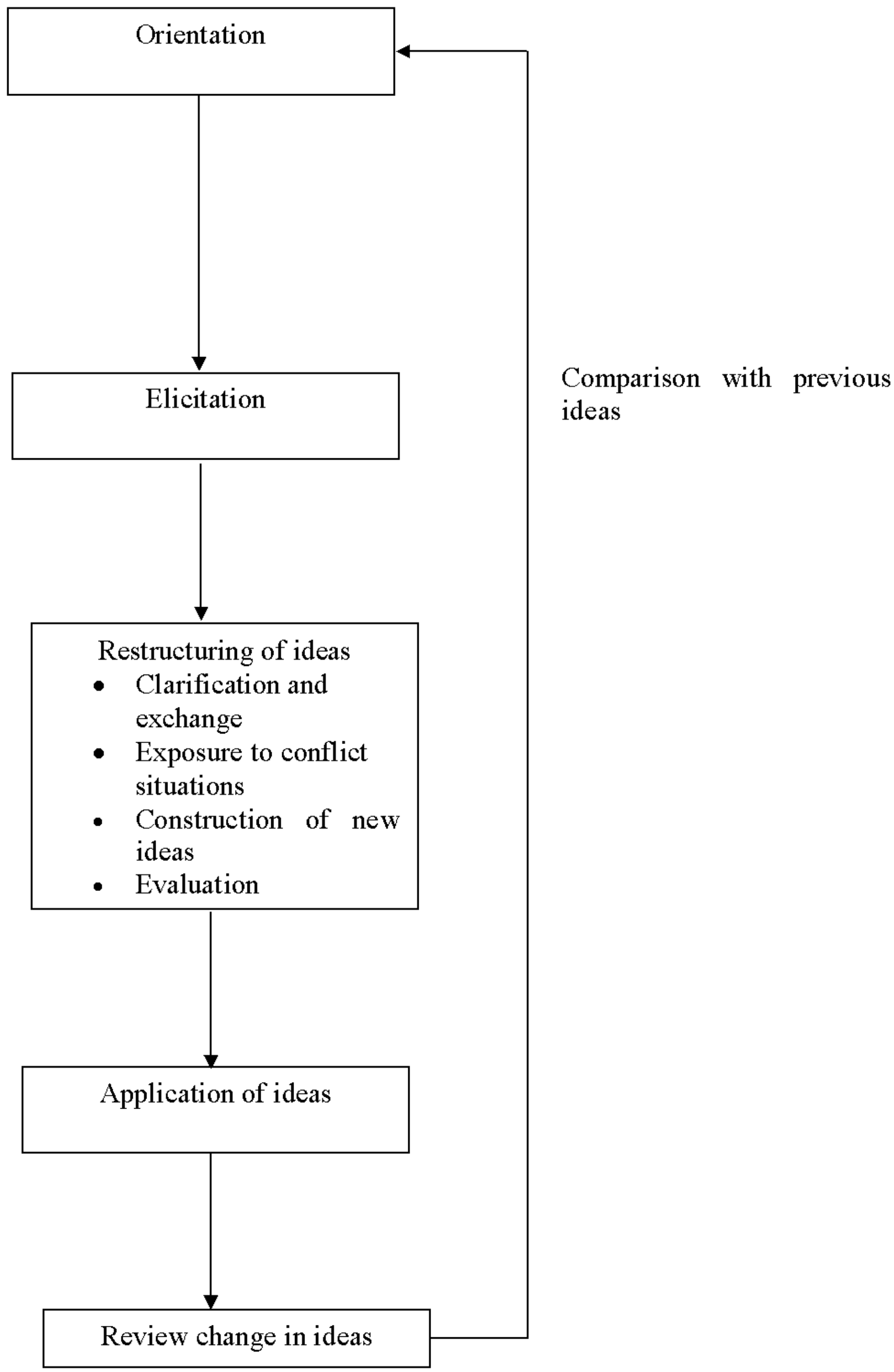

Figure 5: Teaching Sequences Based on Constructivist View of Teaching and Learning (Driver, 1989, p40)

Stages in the teaching sequence

i. **Orientation**

This is the introductory stage. The teacher is expected to introduce the topic using relevant set inductions. In the present study, the teacher may begin by giving examples of applications of the concept of Electrostatics or give a story with relevance to the concept of charges.

ii. **Elicitation of ideas**

At this stage, pupils' prior conceptions are elicited through use of probing questions. The teacher may guide students in performing several experiments, which may lead to a discussion about the concept of charges.

iii. **Restructuring of ideas**

Pupils in this stage get involved in activities aimed at enabling them to change their prior conceptions through discussions. The teacher clarifies and restructures the observations made by the students from the experiments conducted. He/she guides the students in constructing meanings about the concept of Electrostatics.

iv. **Application of ideas**

Pupils are given the opportunity to apply new ideas in new situations. The students could be asked to explain on some applications of the concept of Electrostatics in every day–to-day life.

v. **Review of change in ideas**

The pupils existing ideas about the concept of charges are elicited and compared to their prior conceptions. This is used to assess to which extent conceptual change has taken place. If no change has taken place, the teacher could once again help them restructure their prior conception and scientifically conceptualize on the concept of Electrostatics.

(Driver, 1989, p42)

The Driver's (1989) teaching sequence encourages the use of interactive approach that actively involves pupils in the learning process. Keraro (2002) points out that if effectively used, this teaching sequence would enhance meaningful learning of science. Using the constructivist teaching strategy, a teacher may structure a lesson in the following format (Twomey, 1989). The first objective of a constructivist lesson is to engage students' interest on a topic that has a broader concept. This may be accomplished by doing a demonstration, presenting data, or showing a short film. Ask open-ended questions that probe the students' preconception on the topic. Next, present some information or data that does not fit with their existing understanding. Have students break into small groups to formulate their own hypotheses and experiments that will reconcile their previous understanding with the discrepant information.

The role of the teacher during the small group interactions is to circulate around the classroom to be a resource or to ask probing questions that aid students in coming to understanding of the principle being studied. After sufficient time for experimentation, the small groups share their ideas and conclusions with the rest of the class, which will try to come to a consensus about what they learned. Appendix A gives the constructivist teaching strategy module on the topic Electrostatics in Form One physics syllabus. It gives a guide on the sequence and the activities to be carried out in the teaching of the Electrostatics topic using the constructivist teaching strategy.

2.10 Conceptual Framework

Learning outcomes depend on the teaching strategies the teachers use. In this study conventional teaching methods, constructivist teaching strategy and Student Gender were the independent variables on which the learning outcomes depended on. The learning outcomes were the students' conceptualisation of the concept of Electrostatics and formed the dependent variable. The conceptualisation of the Electrostatics concept was measured using a Physics Achievement Test (P.A.T). The learning outcomes are also found to be influenced by other factors forming the extraneous variables. These include students' entry behaviour, age, teachers' training and the school environment. The age of the students also determine the prior experience the learners have about charges. The teachers' training and experience determine their effectiveness in teaching the science concepts. The school environment and facilities determine the practical skills and experiences acquired by learners. Figure 6 gives the conceptual representation of relationship between the variables of the study.

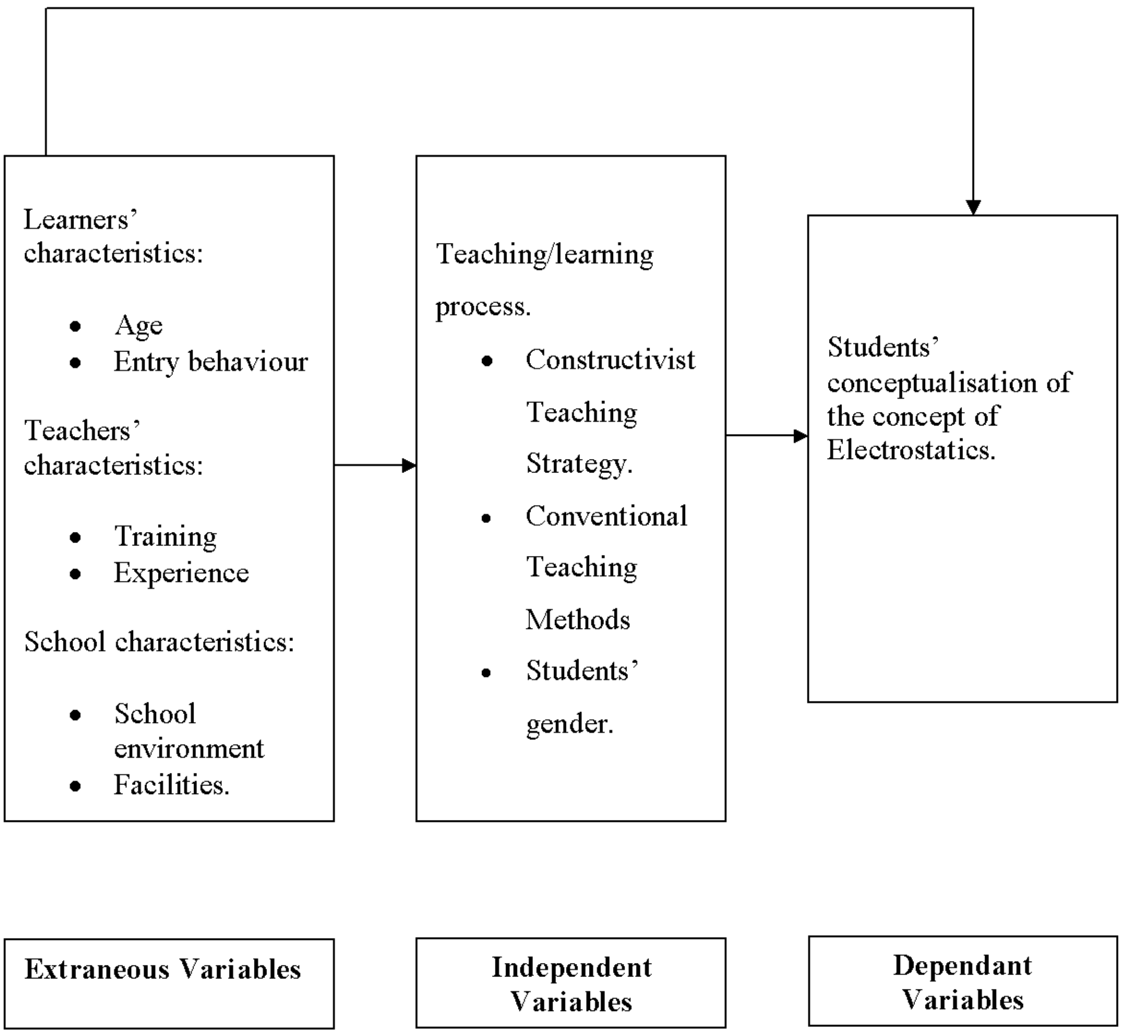

Figure 6: Conceptual Representation of Relationship of the Variables of the Study

To take care of the extraneous variables the researcher selected schools with almost the same facilities and involved teachers with a minimum qualification of a diploma in education and with more than 3 years teaching experience. By taking Form One students, the study ensured that the subjects were in the same age bracket and had similar entry behaviour. Participation of learners in all activities was balanced in terms of gender.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter discusses the research design used; the population under study, sampling procedure and sample size, the instruments used in data collection, data collection and analysis procedures.

3.2 Research Design

The study involved a quasi-experimental research. Solomon four non-equivalent control group design was used. The reason for this is that secondary school classes once constituted exist as intact groups and school authorities do not normally allow such classes to be broken up and reconstituted for research purposes. The Solomon four-group design is also considered rigorous for quasi-experimental studies (Borg & Gall, 1989; Ary *et al.*, 1982; Cook & Campbell 1979). This design makes it possible to evaluate the main effects as well as the reactive effects of testing, history and maturation (Fraenkel & Wallen, 2000). The research design may be represented as follows:

Table 3:
The Solomon Four Non-equivalent Control Group Design

Group I	O_1	X	O_2
Group II	O_3		O_4
Group III		X	O_5
Group IV			O_6

Where O_1, O_3, are pre-test observations while O_2, O_4, O_5 and O_6 are post-test observations

X is the treatment where students were taught using constructivist teaching strategy.

Group I – is the experimental group that received the pre-test, treatment X and the post-test.

Group II – is the true control group, which received a pre-test, followed by a control condition and finally a post-test.

Group III – this is the experimental group that received treatment X and a post-test. It was not be pre-tested.

Group IV – it is the control group that received the post-test only.

3.3 Population

The population of the study comprised all Form One students in Nakuru district. To take care of the gender factor, schools considered in the study were co-educational schools. Nakuru district was chosen because it has the highest number of co-educational secondary schools in the Rift-valley province. The district has 148 co-educational secondary schools. This provided a wider frame in selecting schools that took part in the study and bearing similar characteristics. The Form One physics students were targeted because at their level, physics is a compulsory subject.

3.4 Sampling Procedures and Sample Size

Four schools were purposively sampled from a sampling frame consisting of all 148 co-educational secondary schools in Nakuru district. This was done to ensure homogeneity in characteristics of the selected schools. It was also done to minimize accessibility to the schools by the researcher from the operating office. The form One students from each of the four selected schools formed the four groups of study. For those schools with more than one Form One stream, random sampling was done to select one stream to take part in the study.

The assignment of the four groups to either experimental or control groups was done through simple random sampling. The sample size of the study comprised 140 students. This agrees with Mugenda and Mugenda (1999) who suggested that for experimental studies at least 30 subjects are recommended. Table 4 gives a summary of the sample size stratification.

Table 4:
The Sample Size Stratification

Group	Experimental/control	Number of students
I	Experimental	34
II	Control	31
III	Experimental	41
IV	Control	34
	Sample size of the study	140

3.5 Instrumentation

A Physics pre-test Physics Achievement Test (PAT) based on physics concepts previously learned was developed. This helped to measure the entry level of the learners. A post-test PAT was then constructed based on the concept of Electrostatics.The test comprised 20 items and tested the first three levels of cognitive domain namely: knowledge, comprehension and application. Three experts from the Department of Curriculum and Instruction in the Faculty of Education and Human Resources, Egerton University assessed the content validity of the instruments.

3.5.1 Development of the Instruments

Constructivist teaching strategy module on Electrostatics topic was developed based on Form One physics syllabus (see appendix A). Electrostatics is the study of stationary electrical charges. Recent developments have made the study of Electrostatics important as it has many industrial applications such as in electronics, electrostatic generators, electrostatic loud speakers and microphones, copying machines and aeroplane instrumentations among others. The teaching module was developed in line with the constructivist teaching sequences coined by Driver in 1989. Appendix A gives a detailed guide on the sequences to be followed and the activities to be carried out in each stage. The teachers in the experimental groups were inducted for one week on the usage of the module in the teaching of the Electrostatics topic. A Physics Achievement Test (PAT) on previously taught Physics concepts was developed and used as a pre-test. A post-test PAT on the topic of Electrostatics in the Form One physics syllabus was then developed. All teachers involved in the study were trained in the scoring of the PAT and were taken through the PAT marking scheme (see appendix C).

3.5.2 Reliability and Validity of the Instruments

The Post-test (PAT) was pilot tested in a co-educational secondary school in Nakuru district with similar characteristics to the research schools and in a class, which had covered the topic on Electrostatics. The item analysis of the PAT was done to ascertain the validity, difficulty level and discriminative power of each item. The reliability coefficient of the instrument was computed using Cronbach's coefficient alpha. An alpha value of 0.8889 was obtained. This is above the threshold value of 0.70 that is considered suitable to show reliability of instruments (Fraenkel & Wallen, 2000; Popham, 1990; Kathuri & Pals, 1993).

3.6 Data Collection Procedures

The researcher sought for a research permit from the Ministry of Education Science and Technology to conduct the study. The sampled schools were consulted in advance to seek the consent of the principals and the teachers in carrying out the study and informing them of the role they would play. The teachers who took part in the study were inducted for one week on the use of constructivist teaching strategy and scoring of PAT.

A pre-test (PAT) was administrated to the two-pre-test groups i.e. group I and II, to measure the entry level of the students before the use of constructivist teaching strategy. The constructivist teaching strategy was then used in teaching the Electrostatics topic to groups I and III while groups II and IV were taught the same topic using conventional teaching methods. The treatment lasted five weeks of the normal lessons allocation in the school timetable. The post-test PAT was then administered to all the four groups at the end of the teaching on the Electrostatics concept. Students' scores in the PAT were recorded and used for data analysis.

3.7 Data Analysis

Both quantitative and qualitative methods of data analysis were used. This involved the use of inferential statistics and descriptive statistics inform of means and standard deviations. The Analysis of Variance (ANOVA) was used to test statistical significant difference within and between the means in the post-test PAT scores for the groups exposed to constructivist teaching strategy and those exposed to conventional teaching methods. A t-test was used to test for any statistical significant difference between boys and girls on the conceptualisation of the concept Electrostatics and also between the pre-tested groups to ascertain homogeneity in characteristics between experimental and control groups. A computer program, Statistical Package for Social Science (SPSS) was used for the data analysis. The hypotheses were tested at the significance level of 0.05. Table 5 gives a summary of the methods used to test the hypotheses.

Table 5:

Summary of Methods used to Test Hypotheses

Hypotheses	**Independent variable**	**Dependent variable**	**Statistical tests used**
Ho1: There is no statistically significant difference in conceptualisation of Electrostatics topic between students taught using Constructivist Teaching Strategy and those taught using Conventional Teaching Methods	• Constructivist Teaching Strategy (CTS) • Conventional Teaching Methods (CTM)	Students' score in Physics Achievement Test (PAT)	ANOVA t-test
Ho2: There is no statistically significant gender difference in conceptualisation of Electrostatics topic when taught using Constructivist Teaching Strategy	• Constructivist Teaching Strategy (CTM) • Students' gender	Students' scores in Physics Achievement Test (PAT)	t-test

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1. Introduction

This chapter presents the research findings of the study on the effects of constructivist teaching strategy on students' conceptualisation of Electrostatics topic in Physics. Both descriptive and inferential statistics have been used. The findings are presented in form of tables and their interpretations given.

The two hypotheses of the study are re-stated and tested using ANOVA and t-test and the results presented in tabular form. Conclusions are finally made to either accept or reject the hypothesis at a significance level of 0.05.

4.2 Results of the Pre-tests

A physics pre-test Physics achievement Test (PAT) was administered to Group I (Experimental) and Group II (Control). This sought to ensure that the groups used in the study had similar characteristics and same entry level before administration of the treatment (Borg & Gall, 1989). The PAT was marked out of a maximum score of 50 and the scores then converted to percentages. To test for the homogeneity of the groups, a t-test was used. Table 6 shows the t-test results of the pre-test scores on PAT for the two groups.

Table 6:

t-test Results of the Pre-test Score on PAT

Group	N	Mean	Std Deviation	Std Error mean	df	t-value	p-value
Group I	34	25.18	8.88	1.52	63	0.230	0.819*
Group II	31	24.58	11.90	2.14			

* – not significant at $\alpha = 0.05$ significance level ($p>0.05$).

From Table 6, the pre-test mean score for group I was 25.18 while mean score for group II was 24.58. The t-test value was t (63) = 0.230 and p- value was 0.819 ($p>0.05$). The result showed that the two groups had no significant difference and therefore had similar conceptualisation level before the treatment was administered. Table 7 shows the results of pre-test scores on PAT in regard to gender.

Table 7:

t-test Results of the Pre-test Scores on PAT by Gender.

Gender	N	Mean	Std Deviation	Std Error mean	df	t-value	p-value
Male	31	26.94	12.25	2.20	63	1.535	0.130*
Female	34	23.03	7.99	1.37			

* – not significant at $\alpha = 0.05$ significance level ($p>0.05$).

From Table 7, the pre-test mean score for male and female students was 26.94 and 23.03 respectively. The t-test value was 1.535 and p-value was 0.130 ($p>0.05$). This showed there was no significant difference, t (63) = 1.535, $p>0.05$. The results indicate that both male and female students who took part in the study had similar level of conceptualisation in physics before the administration of the treatment.

The findings indicate that both boys and girls have the same mental potential to perform in a physics achievement test. The findings prove untrue the commonly held belief that girls perform poorly than boys in sciences. The continued differential gender performance could be attributed to the use of conventional teaching methods which apparently motivates boys then girls.

4.3. Effects of Constructivist Teaching Strategy on Students' Conceptualisation of Electrostatics Topic in Secondary Schools Physics

In order to find out the effects of constructivist teaching strategy on students' conceptualisation of Electrostatic topic in secondary school Physics, the post-test mean scores on PAT were analysed. The tests carried out sought to compare and establish whether post-tests mean scores on PAT for students taught using constructivist teaching strategy were significantly different from the post-test PAT mean scores of those students taught using conventional teaching methods. Hypothesis Ho1 sought to establish that there was no statistically significant difference in conceptualisation of Electrostatics topic in Physics between the students taught using constructivist teaching strategy and those taught using conventional teaching methods. Table 8 shows the PAT post-test mean score obtained by the four groups.

Table 8:

PAT Post-test Score by the Four Groups

Group	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Group I	34	38.24	13.73	2.35	18	64
Group II	31	22.45	15.12	2.72	2	68
Group III	41	24.29	11.62	1.81	4	54
Group IV	34	18.94	11.60	1.99	4	44
Total	140	25.97	14.74	1.25	2	68

From table 8, the experimental groups I and III were found to have a PAT post test score mean of 38.24 and 24.29 respectively. The control group II and IV were found to have a PAT post test mean score of 22.45 and 18.94 respectively. This shows that the experimental groups had higher mean scores than the control groups. The experimental group I and II were taught using the constructivist teaching strategy while the control groups II and IV were taught using the conventional teaching methods. It can be deduced from the results that the administration of the treatment had a positive impact on the students' conceptualisation level of the electrostatics topic in Form 1 physics. This showed that the constructivist teaching strategy is better than the conventional teaching method in teaching of physics concepts.

Figure 7 gives a clear graphical comparison of the four groups performance in the post-test PAT.

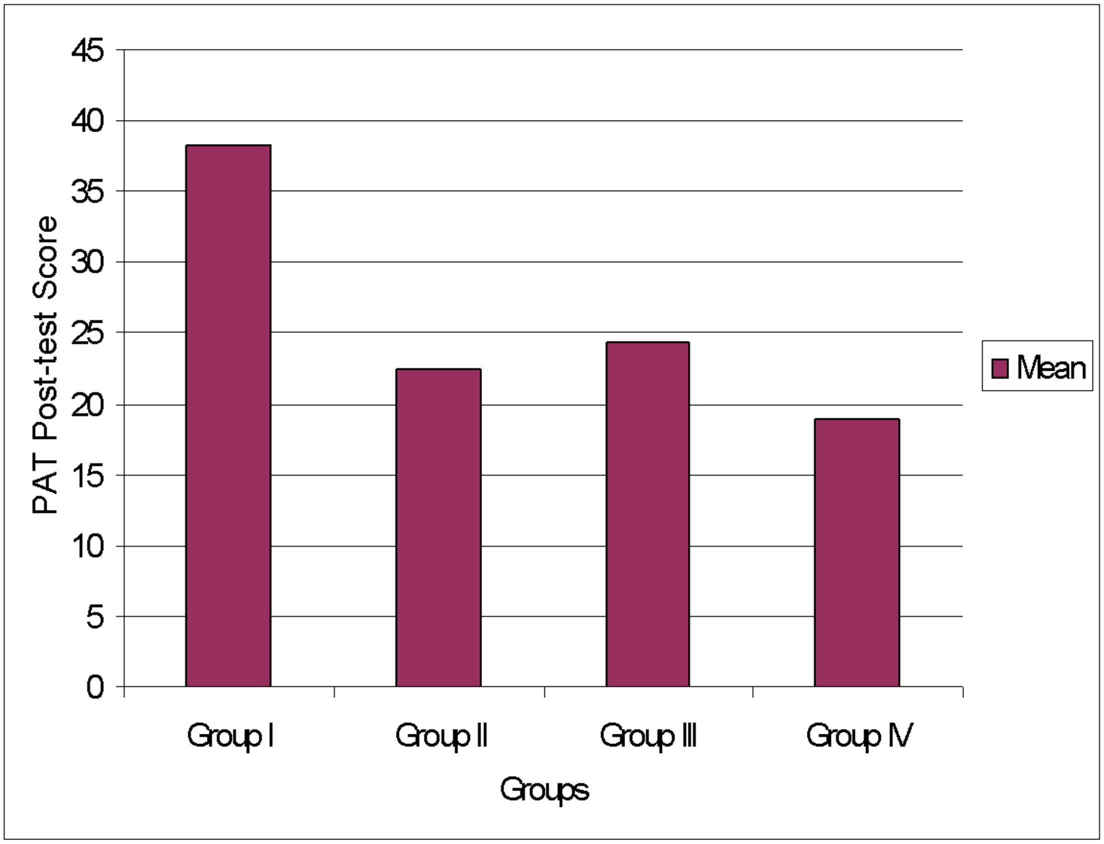

Figure 7: A Bar Graph Showing the Performance of the Four Groups

From Figure 7, the PAT post-test mean scores were found to be higher for the experimental groups I and III as compared to the control groups II and IV. This vividly showed that the use of constructivist teaching strategies enhanced conceptualisation of the electrostatics topic better than the use of conventional teaching methods.

To find out whether there was any significant difference in the means among the groups, a one-way ANOVA test was carried out. The results are shown in Table 9 below.

Table 9:

Analysis of Variance (ANOVA) of the Post Test Scores on PAT

	Sum of squares	**df**	**Mean square**	**F**	**sig**
Between groups	7293.720	3	2431.240	14.425	.000*
Within groups	22922.165	136	168.545		
Total	30215.886	139			

* - significant at α = 0.05 significance level (p<0.05)

From table 9, the difference in post test PAT mean scores among the four groups was found to be significant F (3,136) = 14.425, p-value = 0.000 (p<0.05). The result of ANOVA test therefore indicate that there is a statistically significant difference in conceptualisation of Electrostatics topic in physics between students taught using constructivist teaching strategy and those taught using conventional teaching methods. In order to establish the specific groups where this significant difference occurred, a Post Hoc multiple comparison using Scheffe and Turkey tests were used. Scheffe and Turkey test are used to compare the posttest mean scores for every possible pair of sample groups in order to find out whether there is any significant difference between the groups. The tests were preferred since the number of cases per group was different. The results of the tests are shown in tables 10 and 11. The dependent variable in the tests is the posttest mean scores in PAT.

Table 10:

Scheffe Pair Wise Comparison of the Post–test Score on PAT for the Four Groups

(I) Sample groups	(J) Sample groups	Mean difference (I-J)	Std error	Sig
Group I	Group II	15.78	3.22	.000*
	Group III	13.94	3.01	.000*
	Group IV	19.29	3.15	.000*
Group II	Group I	-15.78	3.22	.000*
	Group III	-1.84	3.09	.949
	Group IV	3.51	3.22	.757
Group III	Group I	-13.94	3.01	.000*
	Group II	1.84	3.09	.949
	Group IV	5.35	3.01	.371
Group IV	Group I	- 19.29	3.15	.000*
	Group II	- 3.51	3.22	.757
	Group III	-5.35	3.01	.371

* - The mean difference is significant at $\alpha = 0.05$ significance level

From Table 10, the Scheffe post hoc multiple comparison test showed a significant difference of the post-test on PAT between the experimental and the control groups at the significance level of alpha value of 0.05. When group I (experimental group) was compared to group II (control), group III (experimental) and group IV (control), the difference was found to be significant. The unexpected significant difference between group I and group III could be attributed to the failure of the teacher who taught group III to adhere to the constructivist teaching strategy guidelines given. Nevertheless, generally the test indicated statistical significant difference between the experimental and the control groups. This shows that the constructivist teaching strategy can enhance the conceptualisation of the physics concepts better than the conventional teaching methods. Table 11 gives further post hoc pairwise multiple comparison of the post-test score on PAT for the four groups.

Table 11:

Turkey Pair Wise Comparison of the Post-test Score on PAT for the Four Groups

(I) Sample groups	(J) Sample groups	Mean difference (I-J)	Std error	Sig
Group I	Group II	15.78	3.22	.000*
	Group III	13.94	3.01	.000*
	Group IV	19.29	3.15	.000*
Group II	Group I	-15.78	3.22	.000*
	Group III	-1.84	3.09	.933
	Group IV	3.51	3.22	.696
Group III	Group I	- 13.94	3.01	.000*
	Group II	-1.84	3.09	.933
	Group IV	-5.35	3.01	.284
Group IV	Group I	- 19.29	3.15	.000*
	Group II	- 3.51	3.22	. 696
	Group III	-5.35	3.01	.284

*-The mean difference is significant at $\alpha = 0.05$ significance level

From the results of Scheffe and Turkey tests, it can be observed that the pairs of the PAT mean scores between groups I and II, groups I and III and groups I and IV were significantly different at α= 0.05 significance level. The mean scores between groups II and III, group II and IV, and III and IV were not significantly different. The unexpected significant difference between group I and III could be attributed to unstable instrumentation whereby the teacher in group III might have changed his standards of teaching using constructivist teaching strategy due to fatigue, lack of insight or skill or changes in criterion of judgement in scoring of PAT. This is likely to have introduced some errors in the results. From table 8, the mean scores of the experimental groups (I and III) were higher then those of the control groups (II and IV) indicating that student taught using the constructivist teaching strategy conceptualised Electrostatics topic better than those taught using the conventional teaching methods. Since the ANOVA tests result showed that the difference between the means of the post-tests scores for the four groups were significant, we reject the null hypothesis one (Ho_1) which stated that "there is no statistically significant difference in conceptualisation of Electrostatics topic in physics between students taught using constructivist teaching strategy and those taught using conventional teaching methods". This suggests that the constructivist teaching strategy enhanced conceptualisation of Electrostatics concept in physics.

4.4 Effects of Constructivist Teaching Strategy on Conceptualisation of Electrostatics Topic in Secondary School Physics by Gender

In order to find out the effects of constructivist teaching strategy on conceptualisation of Electrostatics topic in secondary school physics by gender, post-test scores for boys and girls in groups I and III were analysed. Hypothesis Ho_2 sought to establish that there was no statistically significant gender difference in conceptualisation of Electrostatics topics in physics when taught using constructivist teaching strategy. A t-test was used to test this hypothesis. Table 12 shows the results.

Table 12:

t-test Results of the Post-test Score on PAT by Gender

Gender	N	Mean	Std dev	Std error mean	df	t-value	p-value
Boys	38	33.16	13.66	2.22	73	1.572	0.120*
Girls	37	28.00	14.74	2.42			

*–not significant at α =0.05 significance level, ($p>0.05$)

The results from table 12 indicate that there was no statistically significant difference between the PAT post-test scores for boys and girls exposed to constructivist teaching strategy, t (73)= 1.572, p-value was 0.120 ($p>0.05$). We therefore retain the null hypothesis two (Ho_2) which stated "there is no statistically significant gender difference in conceptualisation of Electrostatics topic in physics when taught using constructivist teaching strategy". This suggests that the constructivist teaching strategy is not gender bias and it enhanced conceptualisation of Electrostatics concepts equally in both boys and girls.

4.5 Discussion of the Results.

4.5.1 Results of Pre-test.

The t-test results of pre-test PAT means scores for group I and II in table 6 showed a non-significant difference between the groups, t(63) = 0.230, p-value = 0.819 ($p >0.05$). A comparison by gender between the pre-test PAT scores for the two groups also indicated a non-significant difference, t(63)= 1.535, p-value = 0.130 ($p >0.05$).

Since the four groups were assigned to either experimental and control groups randomly, the results showed that the groups were similar in their conceptualisation level in physics before the administration of the treatment. The groups used were therefore similar in characteristics and suitable for the study (Cook & Campbell, 1979).

4.5.2 Effects of Constructivist Teaching Strategy on Students Conceptualisation of Electrostatics in Secondary School Physics

The findings from table 8 showed higher mean scores in post-test PAT for experimental groups I and III as compared to control groups II and IV. The researcher then used one-way ANOVA to test whether the difference in means scores between experimental and control groups were significant. The results in table 9 showed a statistically significant difference, $F(3,136) = 14.425$, p-value = 0.000 ($P<0.05$). Multiple comparison using Scheffe and Turkey tests in table 10 and11 also showed a significant difference in the means between experimental and control groups.

The findings therefore imply that the use of constructivists teaching strategy enhanced the conceptualisation of the Electrostatics topic in physics compared to conventional teaching methods. Ausubel (1977) clearly pointed out that the most important single factor influencing learning is what the learner already knows. The learner must therefore interpret tasks and try to construct solutions by using methods he already has (Glasersfield, 1989). Learning in physics, should therefore be built on the learners prior practical experiences while at the same time correcting any misconceptions or learners' alternative framework (SMASE, 2004).

Other researchers have also evaluated the effectiveness of the constructivist teaching strategy. In one evaluation (Caprio, 1994) the constructivist strategy was employed and compared to the traditional lecture-lab format for the second semester of a two-semester anatomy and physiology sequence in a community college in America. The two students' groups were matched for academic ability and pre-requisites. The same exam was then administered to both groups of students. The results showed that students taught using constructivist teaching strategy obtained better exam grades. The average exam score for the constructivist group was 69.7% (N=44) while for that taught by the traditional lecture-lab method was 60.8% (N=40). A t-test showed that the grade difference was significant at 0.01 level. Caprio's (1994) study also offered many personal insights on the perception of student learning. The students in the constructivist group seemed more confident of their learning. The students in the constructivist class also seemed to like the subject better, had more learning energy and took more responsibility for their learning.

Another American constructivist study by Carey (1989), probed the nature of students' views on scientific inquiry. Despite instruction in the scientific method in the traditional mode, many students did not understand the nature or purpose of scientific inquiry. To them, science was seen as a random activity that has little meaning in real life. Grade 7 students were rated by interviews on a scale of 1 to 3 about their conception of how science is investigated before and after constructivist teaching strategy was applied.

Prior to the teaching-using constructivist teaching strategy, most students fell in level 1 category. Level one-category students viewed science as a way of understanding facts about the world. After the learning unit, most of the students moved to a level 2 understanding; they saw scientific inquiry as being guided by questions and ideas. They also understood the difference between an idea and an experiment. Level 3 understanding was achieved only by few students. At this level, the students understand the cyclic, cumulative nature of science and recognises the goal of science as the construction of deeper explanations of the universe. According to Carey (1989), the use of constructivist teaching strategy raised the students' level of understanding.

Constructivist teaching strategy is guided by five basic elements; activating prior knowledge, acquiring knowledge, understanding knowledge, using knowledge, and reflecting on knowledge (Tolman & Hardy, 1995). Activating prior knowledge is very important since what is learned is always learned in relation to what one already knows. When teachers are familiar with a students' prior knowledge they can provide learning experiences to build on these existing understandings (Steffe & D'Ambrosio, 1995). Prior knowledge can be activated in many ways for example, by asking students what they know, by brainstorming, by doing semantic mapping, by predicting outcomes or by performing some skill or process. As Simon (1995) points out in his article, "Elaborating Models of Mathematics Teaching", teacher's knowledge is constantly being constructed as he or she interacts with students. Gurney (1995) states that articulation of prior knowledge acquaints teachers with students' thinking, affording insights from which to plan instruction.

Research has shown that students must acquire their own knowledge in a way that helps them determine the extent to which it fits their existing knowledge. Shapiro (1994), describe a lesson, ("Muscle Building"), where students' build their own model of a muscle. In each step, students have to interpret new knowledge in the context of what they already know.Once students have been exposed to new knowledge, the process of understanding knowledge begins. Teachers can assist in this development by providing many experiences that motivate students to explore this new knowledge and have them communicate their interpretations of it. Research indicates that communicating knowledge is essential for understanding (Fensham & Gunstone, 1994). There are many ways in which knowledge can be shared for example, conferencing between teacher and student, small group activities in which students voice their interpretations, oral reports, projects, role playing and demonstrations.

Constructivist teaching strategy emphasizes thinking, understanding, reasoning and applying knowledge while it does not neglect basic skills. It is based on the idea that learners construct their own knowledge, rather than reproduce someone else's knowledge. Chaille and Britain (1991) point out that in a constructivist classroom the teacher is no longer the transmitter of knowledge but the facilitator of learning. The facilitator of learning needs to keep in mind that instruction will vary depending on the learners' prior knowledge, current interest, and level of involvement (Chaille & Britain, 1991). A skillful teacher will understand that students have existing knowledge, which may be incomplete or wrong, but will guide perceptions and initiate understandings (Tobin & Dawson, 1992).

Students must activate prior knowledge in order to extend and refine this knowledge. The most effective activities for knowledge use are problem-solving activities (Steffe & Gale, 1995). This encourages students to continue to examine and build on their knowledge. When students work in groups to solve problems, it is more useful than when they work alone because they have the opportunity to constantly voice ideas and receive feedback (Chaille & Britain, 1991). The findings of the present study are therefore supported by the literature since the use of constructivist teaching strategy enhanced the conceptualisation of Electrostatics concept in physics. This is reflected in the better performance in the Physics Achievement Test (PAT) for groups taught using constructivist teaching strategy.

4.5.3 Effects of Constructivists Teaching Strategy on Conceptualisation of Electrostatics Topic in Secondary School Physics by Gender

The t-test results on table 12 indicated that there was no statistically significant difference in conceptualisation of the Electrostatics topic in physics between boys and girls when constructivists teaching strategy was used.

The findings indicate that when male and female students are taught using constructivist teaching strategy, they perform equally well. The strategy is therefore not gender biased. This is quite in contrast with a commonly held belief that girls perform poor in physics (KNEC, 2002). The girls' poor performance could be attributed to use of conventional teaching methods, which gives more attention to boys. The use of constructivist teaching strategy therefore helped girls to build in their self-confidence in physics and consequently performed equally better like boys.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, IMPLICATIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter enumerates summary, conclusions and recommendations made from the findings of the study whose purpose was to investigate the effects of using constructivist teaching strategy on students' conceptualisation of Electrostatics topic in Form One physics syllabus. The implications of the findings of the study are discussed and possible further areas for research recommended.

5.2 Summary

Following the continued low performance and enrolment in physics subject at the secondary school level, the researcher carried out this study to determine the effects of using Constructivist Teaching Strategy (CTS) on the students' conceptualisation of the Electrostatics topic in the secondary school physics. This was done in the view of finding out whether the use of CTS would enhance the performance in the subject and consequently attract high enrolment for the subject at the KCSE. A Physics Achievement Test (PAT) on the Electrostatics topic in Form One physics syllabus was set and administered to the students in the four groups of the study. The PAT scores provided data for analysis .The researcher used both the ANOVA and the t-test.

The one way ANOVA test was carried out to determine whether there was any statistical significant difference in conceptualisation of Electrostatics topic between student taught using CTS and those taught using conventional teaching methods (CTM). The results indicated a statistically significant difference.

The t-test was carried to test for any statistical significant gender difference in conceptualisation of the Electrostatics topic when CTM was used. The results indicated that the difference was not statistically significant.

5.3 Conclusions

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

(i) The use of constructivist teaching strategy enhances conceptualisation of physics concepts better then the conventional teaching methods.

(ii) The use of constructivist teaching strategy does not result to significant difference in conceptualisation of physics concepts between boys and girls. The strategy is therefore not gender biased.

In summary, constructivist teaching strategy offers a bold departure from the conventional objectivist teaching strategies. The goal is for the learner to play an active role in assimilating knowledge onto his existing mental framework. The ability of students to apply their school-learned knowledge to the real world is valued over memorizing bits and pieces of knowledge that may seem unrelated to them. The constructivist teaching strategy requires the teacher to relinquish his role as sole information-dispenser and instead to continually analyse his curriculum planning and instructional methodologies. A curriculum built upon constructivist beliefs is concerned with the aspects of learning in which students make sense of experiences in terms of existing knowledge.

Research has shown that much can be gained by the infusion of constructivism into instructional design. It can provide environments in which learning is achieved through discovery and inquiry. It offers promise in the development of successful learning experiences by producing students who think, apply knowledge and solve problems. Perhaps the best quality for a constructivist teacher to have is the instantaneous and intuitive vision of the pupils' mind as it gropes and fumbles to grasp a new idea (Brooks & Brooks, 1993). Clearly, the constructivist teaching strategy opens new avenues for learning as well as challenges for the teacher trying to implement it.

5.4 Implications

Focusing on a more educational description of constructivism, meaning is intimately connected with experience. Students come into a classroom with their own experiences and a cognitive structure based on those experiences. These preconceived structures are valid, invalid or incomplete. The learner will reformulate his/her existing structures only if new information or experiences are connected to knowledge already in memory. Inferences, elaborations and relationships between old perceptions and new ideas must be personally drawn by the student in order for the new idea to become an integrated, useful part of his/her memory. Memorized facts or information that has not been connected with the learner's prior experiences will be quickly forgotten. In short, the learner must actively construct new information onto his/her existing mental framework for meaningful learning to occur.

Constructivism has important implications for teaching. First, teaching cannot be viewed as the transmission of knowledge from enlightened to unenlightened; constructivist teachers do not take the role of the "sage on the stage". Rather, teachers act as "guides on the side" who provide students with opportunities to test the adequacy of their current understandings.

Second, if learning is based on prior knowledge, then teachers must note that knowledge and provide learning environments that exploit inconsistencies between learners' current understandings and the new experiences before them. This challenges teachers, for they cannot assume that all children understand something in the same way. Further, children may need different experiences to advance to different levels of understanding.

Third, if students must apply their current understandings in new situations in order to build new knowledge, then teachers must engage students in learning, bringing students' current understandings to the forefront. Teachers can ensure that learning experiences incorporate problems that are important to students, not those that are primarily important to teachers. Teachers can also encourage group interaction, where the interplay among participants helps individual students become explicit about their own understanding by comparing it to that of their peers.

Fourth, if new knowledge is actively built, then time is needed to build it. Ample time facilitates student reflection about new experiences, how those experiences line up against current understandings, and how a different understanding might provide students with an improved view of the world.

Constructivist teaching strategy is associated with many benefits. Children are likely to learn more, and enjoy learning more when they are actively involved, rather than passive listeners. Education works best when it concentrates on thinking and understanding, rather than on rote memorization. Constructivism concentrates on learning how to think and understand.

Secondly, Constructivist learning is transferable. In constructivist classrooms, students create organizing principles that they can take with them to other learning settings.

Constructivism gives students ownership of what they learn, since learning is based on students' questions and explorations, and often the students have a hand in designing the assessments as well. Constructivist assessment engages the students' initiatives and personal investments in their journals, research reports, physical models, and artistic representations. Engaging the creative instincts develops students' abilities to express knowledge through a variety of ways. The students are also more likely to retain and transfer the new knowledge to real life.

By grounding learning activities in an authentic, real-world context, constructivism stimulates and engages students. Students in constructivist classrooms learn to question things and to apply their natural curiosity to the world. Consequently, Constructivism promotes social and communication skills by creating a classroom environment that emphasizes collaboration and exchange of ideas. Students must learn how to articulate their ideas clearly as well as to collaborate on tasks effectively by sharing in group projects. Students must therefore exchange ideas and so must learn to "negotiate" with others and to evaluate their contributions in a socially acceptable manner. This is essential to success in the real world, since they will always be exposed to a variety of experiences in which they will have to cooperate and navigate among the ideas of others.

Constructivism represents one of the big ideas in education. Its implications for how teachers teach and learn to teach are enormous. If our efforts in reforming education for all students are to succeed, then we must focus on students. To date, a focus on student-centered learning may well be the most important contribution of constructivism. Learning should involve activities to process the new material, linking it to what the student already knows. Tasks should be authentic, set in a meaningful context, and related to the real world. They should not just involve repeating back facts as this causes ‘surface’ learning.

The findings of the present study imply that the use of constructivist teaching strategy enhances conceptualisation of physics concepts. Physics teachers could use the strategy to improve the poor performance in the subject at school and national level. The findings also showed that both girls and boys perform equally well when the constructivist teaching strategy is used. The physics teachers could use this strategy to remove the common held belief that physics subject is tough and can only be done by boys. This will ensure a balanced gender enrolment and performance for the subject in K.C.S.E examination. The use of the strategy is likely to assist more females to venture in many careers hitherto viewed as a preserve for males such as Engineering.

5.5 Recommendations

The findings of the study showed that the constructivist teaching strategy enhanced conceptualisation of physics concepts. It encourages active and meaningful learning and promotes responsibility and autonomy. Because constructivist teaching strategy is beneficial in achieving desirable educational goals for students, it is important for teachers to grow professionally towards a constructivist practice.

If the strategy is incorporated in the teaching of physics, it could translate to better performance in physics both at school and national level. The girls' enrolment in the subject may also increase since the strategy is not gender biased. Based on the findings of this study, the researcher makes the following recommendations.

(i) Teachers training colleges and universities to incorporate the constructivist teaching strategy in their physics education curriculum. This will help in equipping the teacher trainees with a better strategy to use when they come out into the field of teaching.

(ii) The quality assurance and standards officers in the Ministry of Education, Science and Technology should help in advising teachers on the importance of using the constructivist teaching strategy in the teaching of physics and other sciences. This is likely to improve the performance in these subjects.

(iii) The curriculum developers should come up with a physics curriculum and instructional materials that incorporate the use of constructivist teaching strategy. This will guide the teacher on what he is expected to do in using constructivist teaching strategy to enhance conceptualisation of the concepts.

(iv) The Ministry of Education Science and Technology should organize regular in-service training for practising teachers to train them on the importance of using constructivist teaching strategy.

5.5.1 Recommendations for Further Research

The findings of the study have shown that the use of constructivist teaching strategy enhanced conceptualisation of physics concepts. The scope of the study was however limited. The researcher makes recommendations for further research in the following areas:-

(i) A study on the effects of constructivist teaching strategy on students' motivation to learn physics.

(ii) A study to determine the effects of using constructivist teaching strategy on students' creativity in physics.

(iii) A study to determine the effects of using constructivist teaching strategy on conceptualisation in other subjects.

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APPENDICES

Appendix A: Constructivist Teaching Strategy Module on Electrostatics Topic in Form One Physics

For the experimental groups, the teachers will be required to use the constructivist teaching strategy, as coined by Driver in 1989. The following sequence shall be followed by the teachers in the experimental groups and in line with the Form One physics syllabus. The topic shall be taught in ten lessons of 40 minutes each. However, the module will just act as a guide and teachers are expected to creatively come up with activities that need to be carried out at each stage

LESSON 1, 2, 3 & 4

Orientation stage

- The teacher is expected to introduce the topic using a relevant set induction. Students may be asked whether they have ever observed sparks when they take off their silk clothes at night.
- The teacher may also ask them whether they know what causes lightning.
- This will in turn lead to some discussion in the class. Students are expected to come up with ideas about what charges are, based on their everyday life experiences.

Elicitation stage

The teacher is expected to guide the students in performing several experiments, which may lead to conceptualisation of the term charge.

For example

i). **The balloon stay put** - The students could be asked to blow a toy balloon and rub it briskly with a piece of fur, then place it against the wall and make the observation. The students will be asked the reason as to why the balloon stays against the wall.

ii). **Attracting water to a comb** – Adjust a tap so that a very thin stream of water flows from it. Now give a comb a charge by rubbing it through your hair several times. Hold the comb 2 or 3cm from the stream of water. The water is strongly attracted by the charge on the comb.

iii). **Attraction of pieces of papers by a plastic objects** - Students will be asked to rub their plastic pens on the hair and place the pens near some pieces of papers. They should then make observations and record them.

iv). **Repulsion with balloons**: - Blow up two balloons and tie them with strings 1 meter long. Rub their surfaces with fur and hold the strings together and observe how they repel. Put your hand between them and observe what happens. Record your observations.

LESSON 5, 6, 7 & 8

Restructuring stage

The teacher clarifies and restructures the observations made from the experiments conducted. He/she guides the students to construct the meaning of the terms positive and negative charge, conductors and insulators, basic law of charges, the unit of charge etc.

The teacher also introduces the gold leaf electroscope. Guides the students on how it can be constructed, charged using induction and contact methods and on its uses.

Several experiments are then conducted using the electroscope.

The teacher will then evaluate whether the students have conceptualised the taught concepts by asking them questions.

The teacher concludes the lesson by making the following generalization:

- There are two types of charges: positive and negative charges.
- When two substances are rubbed together, charging occurs and they acquire opposite charges.
- Uncharged materials contain the same number of opposite charges that neutralize each other.
- The basic law of charges states that “like charges repel and unlike charges attract each other”.
- The S I units of charge is Coulombs
- The instrument used to detect charges in a body is called an electroscope
- An electroscope can be charged either negatively or positively using induction or contact methods.
- Conductors allow flow of charge in them while insulators do not.
- When two appositely charged bodies come near or in contact with each other, discharging occurs accompanied sometimes by a crackling sound and a spark.

LESSON 9 & 10

Application stage

The students are asked to suggest situations in everyday life where the concept of Electrostatics applies. The teacher may lead by giving them some few examples of application. E.g.

- Vehicles having an earthing chain
- Lightning arrestors

Review stage

The teacher reviews the students existing ideas and compares them with the previous conception. Any misconception is clarified and corrected.

A physics achievement test will then be administered to test whether the students have fully understood the concept of Electrostatics.

Appendix B: Physics Achievement Test (PAT)

Admission No…………………………

Gender: Male ☐ Female ☐ (tick appropriately). Time: 1 hour

INSTRUCTIONS

This paper consists of 20 questions. ANSWER ALL questions in the spaces provided. Read the questions carefully before writing your answer.

1. Name two types of electric charge (2 marks)

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2. State the basic law of charges (1 mark)

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3. List three methods by which an object can be charged (3 marks).

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4 State the S.I unit of charge (1 mark)

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5. A plastic pen held in the hand can be charged by rubbing it on the hair but a metallic one cannot. Explain (2 marks)

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6 Draw a diagram of the gold-leaf electroscope and label its parts (5 marks)

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7. State the functions of any four parts of a gold leaf electroscope (4 marks)

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8. Describe briefly how you would use an ebonite rod and a duster only to charge an electroscope positively (4 marks)

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9. Explain why during the charging of a metal sphere, it should be supported on an insulating stand (2 marks)

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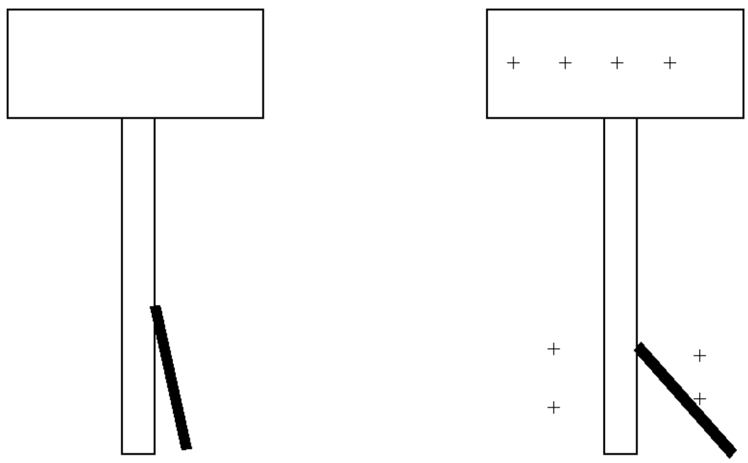
10. The two electroscopes in the figure below are identical



The one on the right is charged but the other one on the left is not. Copy the diagrams and show the divergence of the leaves after the two electroscopes are connected with a thin conducting wire (2 marks)

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11. Explain the term earthing as used in Electrostatics? (2 marks)

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12. State two uses of an electroscope (2 marks)

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13. A hand brought close to the cap of a charged electroscope causes the leaf to fall permanently but a plastic pen does not have similar effect. Explain (2 marks)

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14 Differentiate between a conductor and an insulator as used in Electrostatics (2 marks)

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15. A positively charged glass rod is gradually brought closer to a negatively charged electroscope. The leaf first collapse then diverges. Explain. (3 marks)

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16. Explain the following observations

a. A nylon dress sticks on to the body and crackles when removed (2 marks)

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b. A glass window when wiped with a dry cloth on a dry day soon becomes dusty (2 marks)

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17. It is dangerous to carry an umbrella with a pointed top during a rainstorm when walking in an open field. Explain (2 marks)

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18. Explain why the casing of an electroscope may need to be earthed during charging (2 marks)

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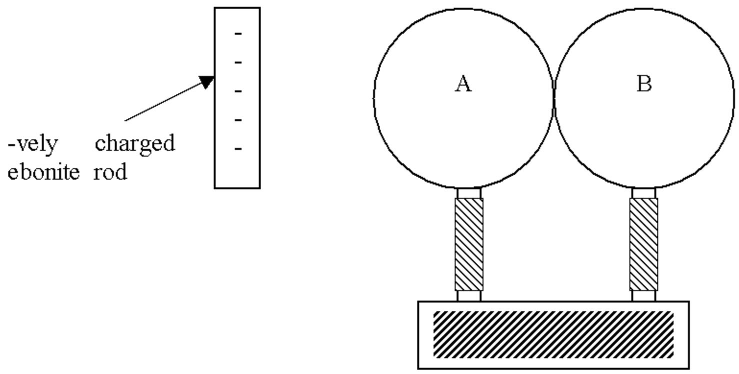
19. Show the charge distribution on metal spheres A and B in the figure below when a charged ebonite rod is brought close but not in contact with A. (2 marks)



20. State three ways by which a charged object can be discharged (3 marks)

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Appendix C: PAT Marking Scheme

1. – Positive charge
   - Negative charge (1 mark for each)

2. Like charges repel and unlike charges attract (1 mark)

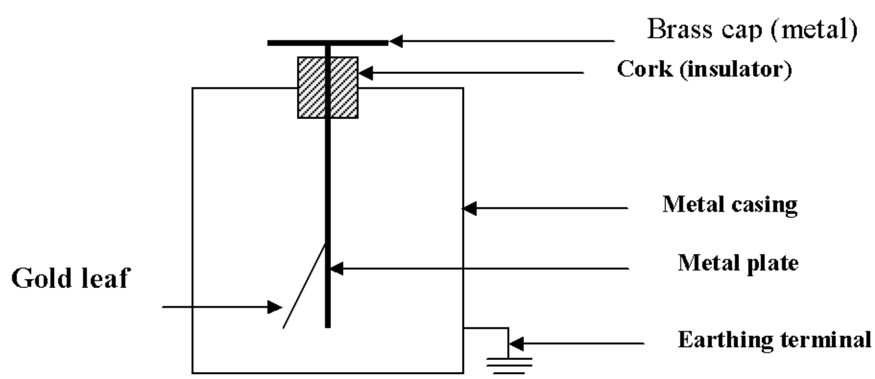
3. - Charging by friction
   - Charging by contact
   - Charging by induction (1 mark for each)

4. Coulomb (c) (1 mark)

5. The metallic pen is a conductor and cannot be charged directly when held by the hand since it rapidly pass on charges to the body from where they are lost to the earth.

   (2 marks for correct explanation)

6.



(2 marks for correct diagram; 3 marks for correct labelling)

7. Gold leaf – This indicate the presence of charge

   Metal casing – It shields the leave from the air outside which might disturb the leave or cause rapid loss of charge.

   Metal plate – It supports the gold leaf

   Insulator – It prevents unwanted flow of charge between the earth and the cap

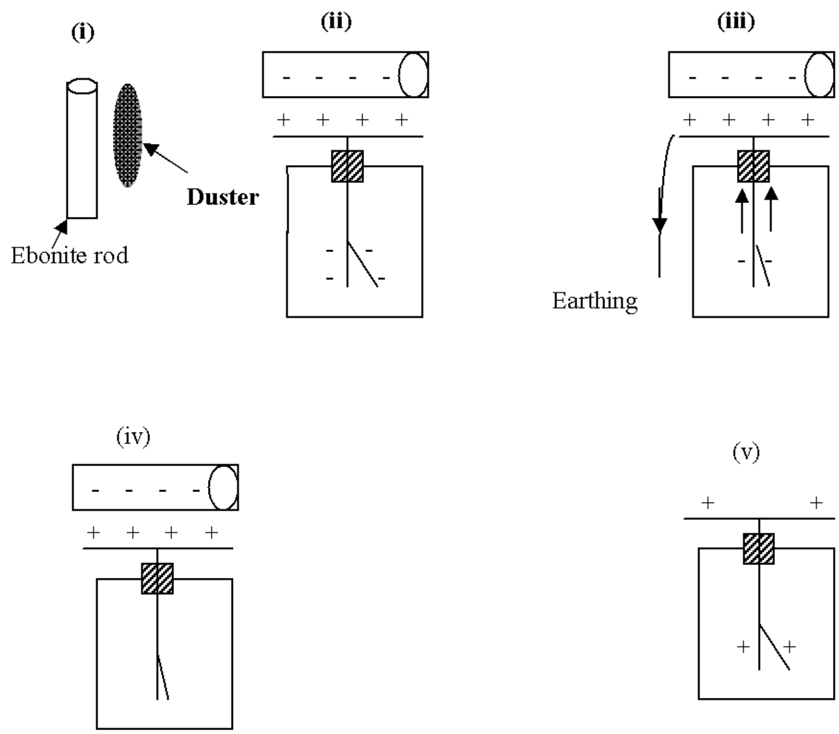
   Brass cap – This has free and free electrons (negative charges), which can be repelled or attracted to one end.

   (1 mark each for any correct four parts and functions)

8. - Charge the electronic rod by rubbing it with the duster.

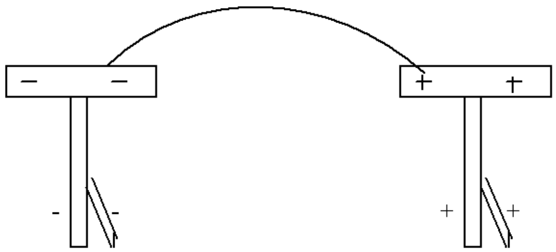
- Hold the rod parallel and close to the cap
- Without removing the rod, connect the cap to the earth by touching it
- Remove the hand from the cap **first**
- Then remove the rod
- The electroscope becomes positively charged

This can be explained diagrammatically as shown below



(4 marks for correct description)

9. This is to prevent the flow of charges from the sphere to the earth.(2marks)

10. 

(2marks for correct diagram)

11. This refers to the flow of electrons from a charged body to the earth to neutralize the charge on the body
(2marks for correct explanation)

12. -to detect the presence of charge on a body
-to test for the sign of charge on a body
-to test for the quantity of charge on a body
-to test for insulation properties of a material
(2marks for any two)

13. -The hand conducts charges to the earth making the electroscope to be uncharged
-Plastic pen is an insulator and does not allow flow of charge through it (2marks)

14. - Conductors are materials through which electric current (electrons) move freely.
- Insulators are materials that do not allow free flow of charges through them
(2 marks)

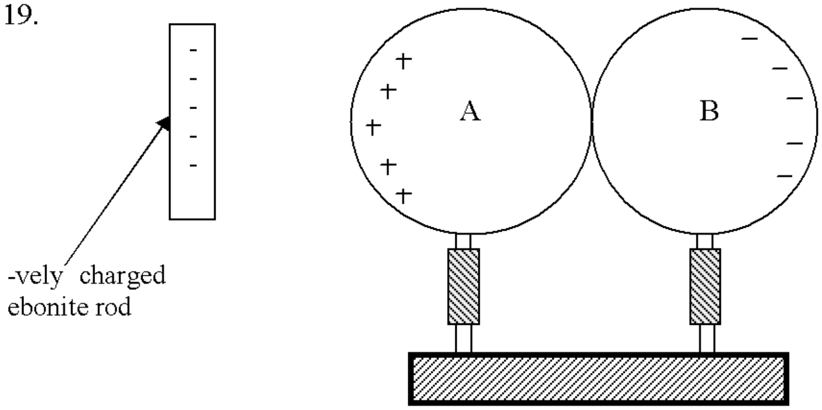
15. - The leaf divergence reduces slightly first because the positive charges of the rod attract negative charges on the leaf and the plate, making the electroscope neutral.
- On moving the rod much lower, the leaf divergence increases again to higher position. This is because the strong positive rod attracts more electrons from the plate and the leaf, making them more positive. Hence they repel further. (3 marks)

16. a) When removed, the nylon dress acquires charges due to rubbing against the body. This makes it stick to the body. The crackling sound is produced when the charges on the dress try to neutralise one another. (2 marks)
b) The glass window gets charged when wiped using the dry cloth. Dust gets attracted to the charged surface of the glass window hence becoming dustier. (2 marks)

17. Point action may take place whereby the charges on the clouds may be discharged by earthing through the tip of the umbrella, your body and then to the ground. This may be cause electrocution. (2 marks)

18. This is done to neutralise any charge in the casing that could have an effect in the leaf divergence. (2 marks)

19.



(2marks for correct diagram)

20. - By earthing
    - By passing frame near the charged object
    - By subjecting the charged object to radiation such as ultraviolet rays
    - Loss of charge can occur as air molecules knock over the surface of the charged object.
    - Rubbing the objects with a moist cloth discharges the object.

(1 mark each for any correct three)

Appendix D: Letter of Research Authorization

MINISTRY OF EDUCATION, SCIENCE & TECHNOLOGY

Telegrams: EDUCATION", Nairobi

Fax No.
Telephone: 318581
When replying please quote

REPUBLIC OF KENYA

JOGOO HOUSE
HARAMBEE AVENUE
P. O. Box 30040
NAIROBI
KENYA

MOEST 13/001/35C 425/2

18th August 2005

David Gahiu Ngatia
Egerton University
P.O. Box 536
NJORO

Dear Sir

RE: RESEARCH AUTHORISATION

Please refer to your application for authority to carry out research on "Effects of Constructivist teaching strategy on students Conceptualization of Electrostatics topic in secondary school Physics in Nakuru District".

I am pleased to inform you that you have been authorized to carry out research in Nakuru District for a period ending 28th February 2006.

You are advised to report to the District Commissioner, The District Education Officer, Nakuru District and The Principals of the secondary schools you will visit before embarking on your research project.

Upon completion of your research, you are expected to submit two copies of your research findings to this office.

Yours faithfully

B.O. ADEWA
FOR: PERMANENT SECRETARY

Cc
The District Commissioner