IMPLICATIONS OF VIRTUAL LABORATORY-BASED INSTRUCTION ON STUDENTS' LEARNING OF PHYSICS IN SECONDARY SCHOOLS IN KENYA

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A Thesis Submitted to the School of Education in Partial Fulfilment of the Requirements for the Award of the Degree of Doctor of Philosophy in Curriculum and Instruction of Masinde Muliro University of Science and Technology

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DECLARATION

DECLARATION BY CANDIDATE

I declare that this thesis is my original work and that it has not been presented in any other university/institution for consideration for any certification.

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CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance by Masinde Muliro University of Science and Technology a thesis titled: ''***Implications of Virtual Laboratory Based-Instruction on Students' Learning of Physics in Secondary Schools in Kenya.''***

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DEDICATION

To my mother, Peres Apondi Okono, who conveyed the aspirations of my father, the late Joseph Okono Wahu, on the need and value for higher education for his children.

LIST OF ABBREVIATIONS AND ACRONYMS

CEMASTEA	Centre for Mathematics, Science and Technology in Education in Africa
CBC	Competency Based Curriculum
B.Ed	Bachelor of Education
KCSE	Kenya Certificate of Secondary Education
ETS	Experimental Teaching Strategy
ICT	Information Communication Technology
JICA	Japanese International Cooperation Agency
KICD	Kenya Institute of Curriculum Development
KNEC	Kenya National Examinations Council
LABS	Laboratories
MOEST	Ministry of Education, Science and Technology
LOS	Lesson Observation Schedule
PTQ	Physics Teachers Questionnaire
SDG	Sustainable Development Goals
PSQ	Physics Students' Questionnaire
TSC	Teachers Service Commission
SPSS	Statistical Package for Social Sciences
UNICEF	United Nations Children's Fund
VE	Virtual experiments
VL	Virtual Laboratory
VLBI	Virtual Laboratory-based Instruction

ABSTRACT

Physics plays a key role in the industrial and technological development of a country. However, in the recent years, low candidature has been witnessed at the Kenya Certificate of Secondary Education (KCSE) level in Physics, which can be attributed to low student motivation and consistent poor performance in the subject. For instance, in the years 2016, 2017, 2018 and 2019 Kisumu County registered low mean scores of 4.23, 4.98, 4.67 and 4.10 respectively in Physics in KCSE. Therefore there is need for incorporation of more effective teaching strategies for performance in Physics to improve, and for students' interest and attitude in learning the subject to change.The implementation of relevant teaching strategies is critical in driving students' active classroom participation in achieving learning outcomes in Physics. To this end, it is impossible to ignore the importance of Information Communication and Technology (ICT) integration in the teaching of Physics in Kenyan secondary schools. Particularly, virtual reality devices are becoming increasingly common and useful in the teaching and learning processes. Enhanced with virtual reality technology, Virtual Laboratory-Based Instruction (VLBI) has the potential to make unobservable phenomena accessible in any school, leading to significant progress in the acquisition of science process skills. Technology-based or technology enhanced learning leverages all learners, irrespective of their traits or socio-economic situation. This study aimed at establishing implications of integration of VLBI on students' learning of Physics in Secondary Schools in Kenya. This study was guided by the following objectives: to establish the effect of VLBI on students' level of interaction in classroom; to establish the effect of VLBI on students' achievement; to compare the frequency of use of experimental teaching approach between VLBI classroom and physical laboratory classroom and; to determine the relationship between teachers' knowledge on selected ICT frameworks and the use of VLBI. The study was supported by behaviourism and connectivism learning theories and adopted Solomon-Four Group- quasi experimental research designs. The study's target population consisted of 3,500 Physics form three students and 88 Physics teachers from 230 Kisumu County public secondary schools. Physics teachers were purposively sampled from each of the schools selected. There were 358 students and 72 teachers as the sample. Data collection was done using Physics Teachers Questionnaire, Physics Achievement Test for students, Physics Students' Questionnaire and Lesson Observation Schedule. Data presentation was made using frequency tables, figures and analysed using inferential statistics. The inferential statistics involved the use of ANOVA, t-test, multiple regression analysis and Duncan post-hoc tests. Qualitative data was analysed thematically. Results of the study indicated significant differences between experimental groups and control groups on level of classroom interaction ($F=123.3$, $p< 0.05$), achievement in physics ($F=115.7$, $p< 0.05$), and number of experiments conducted (119.97, $p< 0.05$). However, the study established that there was no significant difference ($F=1.174$, $p> 0.05$) between teachers' knowledge and use of VLBI. The study concluded that 64.5% of variance in the VLBI was explained by learners' interaction in the classroom, learners' achievement, number of virtual experiments conducted and the teachers' knowledge on the selected ICT frameworks. The findings generated from this study may give educational researchers, planners and secondary school teachers an opportunity to design and put into practice various classroom based innovations that would enable seamless integration of ICT in classroom instruction.

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CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Physics is among the core pillars that support development worldwide, because of its central role in setting the standard for technological advancement. Physics promotes national-wealth, improves health and accelerates industrialization (Argaw, 2016). Teaching and learning of Physics is more important than ever in fulfilling the Sustainable Development Goals (SDGs) and Kenya's Vision 2030. According to Mulhall et al (2019), Physics is perceived as a difficult subject both in its teaching and learning. Majority of learners in secondary schools generally view Physics as irrelevant, boring and difficult (Owen et al, 2018). The mathematical facet of Physics makes most learners shy away from the subject. This leads to minimal student - teacher communication making the student and the teacher to live in different worlds and speak different languages (Carter, 2018). Attempts have been made at making Physics more interesting to learners, and to cater for their needs to no avail.

To subdue the problems experienced in the learning of Physics, determination of the students' perception about Physics as a subject is evidently essential (Yagbasan, 2012). In addition, Angell (2004) discovered that students find physics to be more challenging because they must simultaneously deal with experiments, calculations and formulas, conceptual explanations and graphs at the same time. This concurs with the findings of Redish (1994) who demonstrated that, the nature of Physics requires the learner to be equipped with skills such as: interpretation of tables of numbers, graphs, equations and diagrams.

To learn Physics requires requisite knowledge and skills from different areas such as algebra and geometry, posing a challenge to most learners, particularly those with lower levels of mathematical proficiency (Linder et al, 2014). It has been noted in Northern Europe that the scales are tipping against careers that are related to Physics, despite its significance in technology and science. Mergan et al (2006) note that many trained Physics teachers in developing countries tend to seek employment in more developed countries as opposed to theirs. In order to improve the learning outcomes in Physics, more developed countries have formulated strategies whereby instructional objectives are guided by the learner's interests, goals and motivation (Sukarmin et al, 2017). Furthermore, Aykutlu et al (2015) established that developed countries have managed to scale down the negative attitude towards Physics and courses related to it.

Students' conceptualization and attention span have been observed to increase when creative experiments are incorporated into the teaching process for physics (Shishigu et al., 2017). According to Bogusevschi et al. (2020), student-cenered approaches promote effective teaching and learning of Physics in Turkey. In addition, interactive teaching methods have been recommended in Slovakia's higher education as an effective approach in teaching Physics since it represents a form of elementary tool for understanding most of the technical subjects (Kristak and Nemec, 2011). Edward (2010) notes that poor performance in Physics in South Africa has been a major challenge for the Department of Education as performance in Physics has been low compared to other countries. In Rwanda, the traditional teacher-centred teaching approach was identified as the major barrier towards the instruction of Physics (Uwizeyimana, 2018).

The traditional approach is widely used in most secondary schools especially in Physics classrooms (Kindie, 2019). Kipyator (2017) established that educators continue to employ the conventional teaching method in developing countries like Kenya. This approach has failed to improve Physics performance and student motivation (Kipyator, 2017). As a result, these nations must urgently adopt student-centered teaching strategies for physics. In a study that was carried out in Siaya County in Kenya, similar outcomes were reported where it was found that the majority of teachers employ teacher-centered approaches when teaching physics (Okono et al, 2015).

Problem-based learning, class experiments, cooperative learning, project work, inquiry-based learning, question-and-answer sessions, and collaborative learning, are examples of learner-centered pedagogies that employ interactive strategies to encourage students to actively participate in the classroom and, as a result, develop students' technical abilities (Zafar, 2017). Such pedagogical approaches equip students with decision making, teamwork, and problem-solving and presentation skills which are essential and relevant to the solving of the labour market demands. By focusing on how to apply new knowledge to solve problems or value addition, a learner-centered curriculum enables students to take ownership of what they learn (Rieckmann, 2018). The teacher guides students to derive solutions to real issues and challenges, instead of passively waiting on the teacher as a unitary source of information. Students thus discover new information and come up with solutions.

On the other hand, traditional instruction is primarily lecture-based and teacher-oriented, with the teacher directing the learning of the students and speaking most of the time (Assen et al.2018).

The traditional teaching method is essentially one-sided, with the students passively receiving instruction. Peer activities and discussions are rarely used. Students are unable to follow and comprehend Physics concepts when cooperative skills are not utilized in the instruction process because there is insufficient effective communication and engagement with students (Hoogerheide et al., 2016). Due to a lack of creativity, interaction, and critical thinking, the teaching process can easily be perceived as dull and boring by students because it involves pouring information over their minds (Cohen, 2018).The use of traditional lecture methods as a teaching methodology during the entire lesson limit cooperation among the learners result in a boring class where learners are inattentive and absent minded (Gemechu, 2019) This encourages memorization by rote. Newly invented technologies can change the quality of education when integrated in the education across Sub Saharan Africa (SSA) (Madichie, 2019).

According to the Kenya Ministry of Education (2012), the government advance the incorporation of Information and Communication Technology (ICT) to enable the learners master appropriate competencies, which include knowledge, skills, values, and attitude. Teachers have a major role in this set up since they are expected to ensure that the classroom environment is conducive for all learners, and to enhance cooperation among learners. Wagner et al, (2017) established that student's participation could easily be affected by pedagogical factors such as: the teacher, the teaching approach, the course and even the topic at hand.

Despite all emphasis being on student participation, Kindie (2019) posits that learning should be an incorporation of different activities since a classroom has different learners who have different learning abilities and learning styles. As a result, students should participate in a variety of activities in class. Michalec et al. (2015) underscore the value of explicit discussion groups and respect among learners as a determinant of the level of participation in the classroom by the learners. The major concern of this study was the poor performance in KCSE in Physics by students and the low enrolment it has as a science compared to Chemistry and Biology. All these concerns point at pedagogical approaches on the secondary schools Physics curriculum implementation in Kenya. This study investigated implications of ICT integration, and specifically the adoption of VLBI on the study of physics by secondary school students within Kisumu County. Tables 1.1 and 1.2 show the overall candidature, enrolment in Physics and students' average scores in Physics in KCSE examinations nationally and in Kisumu County respectively (KNEC, 2019).

Table 1.1: Students' Enrolment and KCSE Average Scores in Physics Nationally From 2016 to 2019

Year	KCSE Candidates	Physics Candidates	KCSE Average Scores (%)	Standard Deviation
2016	574,125	146,229(25.47)	37.20	37.08
2017	611,952	159,229(26.02)	38.10	38.07
2018	660,204	162,146(24.56)	37.87	34.58
2019	697,222	165,450(23.73)	36.64	36.72
Average	**635,875**	**158,263 (24.94)**	**37.45**	**36.61**

(Source: Kenya National Examinations Council KNEC -2019)

Table 1.2: Students' Enrolment and KCSE Average Scores in Physics in Kisumu From 2016 to 2019

Year	KCSE Candidates	Physics Candidates	KCSE Average Score (%)	Standard Deviation
2016	15,721	3,093 (19.68)	34.80	35.73
2017	16,640	3,511(21.10)	35.50	36.92
2018	18,131	3,999 (22.06)	35.14	36.01
2019	20,776	4,547 (21.89)	35.43	37.72
Average	**17,817**	**3,790 (21.18)**	**35.22**	**36.60**

Source: (Kenya National Examinations Council-2019)

Table 1.3: Students' Enrolment and Average Score in KCSE in Chemistry and Biology in Kisumu from 2016 to 2019

Year	KCSE Candidates	Chemistry Candidates	KCSE Average Score (%)	Biology Candidates	KCSE Average Score (%)
2016	15,721	14,687(93.42)	38.76	13,842(88.05)	41.05
2017	16,640	15,192(91.30)	40.12	14,919(89.66)	38.07
2018	18,131	17,720(97.73)	41.12	18,010(99.33)	43.58
2019	20,776	19,850(95.54)	39.02	19,321(93.00)	42.72
Average	**17,817**	**16,862(94.63)**	**39.76**	**16,862(92.51)**	**41.35**

Source: (Kenya National Examination Council-2019)

Table 1.1 shows that national average scores in Physics in Kenya has been low, registering an average of 37.45% in KCSE examinations. The standard deviation recorded in 2016 was 37.08, compared to 34.58 in 2018. This reflects a disparity between the high and low achievers. The national average mean score of 37.45% was low in absolute terms (Karanja, 2016). The overall enrolment as seen from Table 1.1 increased from 146,229 in 2016 to 165,450 in 2019. This could be attributed to government policy of 100% transition from primary to secondary schools. However, enrolment rates in Physics are not directly proportional to the overall candidature increase. Instead, it declined from 26.02% to 23.73% between 2016 and 2019. The subject enrolled averagely at 24.94% of the total candidature at KCSE as compared to the other sciences. Chemistry and Biology enrolled 94.63% and 92.51% respectively (KNEC, 2019)

Table 1.2 indicates that performance and enrolment in Physics in Kisumu County was similarly low at 35.22% and 21.18% respectively. The poor performance and low enrolment mirrored the national performance. This shows that the county was far from attaining an average mean score of 50% and enrolment in Physics against total KCSE candidature. The low outputs in physics performance is as a result of inappropriate teaching methods, low student motivation in learning Physics, poor distribution and utilization of Physics learning materials, minimal learning activities in Physics classroom and failure to complete the syllabus, among other factors (SMASSE, 1998).

The dismal average scores in Physics is worrying and has made stakeholders to come up with different initiatives and programs to boost the performance. For instance, Strengthening of Mathematics and Science in Secondary Education (SMASSE) programme, which is an agreement between Japan and Kenya via Japanese International Cooperation Agency (JICA) has been at the forefront in changing pedagogical approaches in improving the teaching and learning situation. Teaching methods advocated for by various researchers and different scholars such as Njoroge, Changeiywo and Ndirangu (2014), Uside, Barchok and Abure (2013), Kapting'ei and Rutto (2014), Muriithi, Odundo, Origa and Gatumu (2013) and Changeiywo, Wambugu and Wachanga (2010) as being capable of enhancing implementation of the Physics curriculum in order to improve learners' motivation and achievement in Physics in the 21st Century include: Inquiry-Based Teaching (IBT), project method, laboratory practical, discovery experiment, Mastery Learning Approach (MLA) and ICT integration. Pedagogical reforms are therefore urgent in order for the country to achieve vision 2030 and SDGs by the year 2030.

The declining learner's motivation to study Physics and the low enrolment rates in Physics have been an international problem (Amunga, Amadalo & Musere, 2011; Andrews, 2006; Semela, 2010). Most countries, including the USA, UK, Germany and the Netherlands have recorded low enrolment and graduation rates (Institute of Physics [IOP], 2012; Suleiman, 2013 & Thomas, 2012). Existing research literature shows that low interest in the subject emerged as early as lower high school. As a result, college enrolment has been affected (Adeyemo, 2010; Aina, Olanipeku and Garubu, 2015; Semela, 2010).

In this regard, some factors were identified and perceived to be the cause of low motivation in Physics. Cognizant of these challenges, attempts were made by the Kenyan education sector to improve students' motivation in Physics. These, among others, included introduction of SMASSE project which encouraged the use of learner-centered teaching strategies like: ICT integration and introducing "innovative" Physics curricula (SMASSE, 1998). Despite the fact that the SMASSE program had been on for about 24 years, low motivation to study Physics among students still persisted in Kisumu County, as is the case nationally. Odhong (2014) established various strategies adopted by Physics teachers in Kisumu County to enhance performance in Physics. The strategies that the teachers employed included exposing students to practical lessons, students developing positive attitudes towards Physics and teacher learner discussions. However, with all these strategies in place the average score in Physics in Kisumu County between 2016 to 2017 at KCSE remain dismal. It is against this background that the study sought to establish the implications of VLBI on students' learning of Physics.

1.2 Statement of the problem

Physics is one of the science subjects taught in secondary schools in Kenya. It is one of the key cornerstones for the country's industrialization and economic growth as envisaged in Kenyan vision 2030 (Republic of Kenya, 2010). Despite the fact that knowledge obtained from the study of Physics is quite substantial and critical in a country's development, there has been perpetual low average scores in Physics at KCSE level in Kenya (KNEC, 2015). Kenya National Examination Councils report (KNEC, 2019) between 2016 and 2019 Physics recorded an average score and enrolment of 37.45% and 24.94% respectively.

Ngari (2017) established that Physics registered a lower candidature in KCSE compared to other sciences. Many schools have decided not to offer Physics beyond form two level as a result of the widespread perception that it is a difficult subject. If unchecked, the continued declining performance and low rates of enrolment in Physics will be among the factors that jeopardize Kenya's bid to achieve vision 2030, which was purposed to accelerate Kenya into an industrialised middle income nation.

The SMASSE in-service programme is one of the government initiatives that was designed to equip Science and Mathematics teachers with current pedagogical practices in secondary schools. Despite these interventions, Physics average scores in KCSE remains dismal. The concern of this study was that for over a decade, students' average scores in Physics in secondary schools in Kenyan has been below average, making the subject less popular among the learners. The persistent low marks in Physics have been associated with the use of teacher centred teaching and learning approaches that culminate into demotivated learners. This study was, therefore, interested in exploring the urgent need to improve and better the learning and teaching of Physics in the secondary schools by using a new approach of student-centred teaching strategies through integration of ICT and discarding the traditional teacher centred methods. In the learning and teaching of science, innovative methods for teaching, especially integrating virtual reality (VR) technology in the Physics laboratory has the potential to make unobservable phenomena accessible (Maharaj-Sharma et al, 2017). This approach will bridge the gap of abstract concepts in Physics, as well as improve the learners' scores.

1.3 Purpose of the Study

The purpose of the study was to establish the significance of VLBI on students' learning of Physics in Secondary Schools in Kenya.

1.4 Objectives of the Study

i. To establish the effect of VLBI on students' level of interaction in classroom in learning of Physics in secondary schools.
ii. To establish the effect of VLBI on students' achievement in learning of Physics in secondary schools.
iii. To compare the frequency of use of experimental teaching approach between VLBI classroom and Physical laboratory classroom in the learning of Physics in secondary schools.
iv. To determine the relationship between teachers' knowledge on selected ICT frameworks and the use of VLBI in the learning of Physics in secondary schools.

1.5 Research Hypotheses

The study tested four null hypotheses at 0.05 alpha levels of significance to accomplish these objectives. The hypotheses tested in the study were that:

H_{01}: There is no statistically significant difference on students' level of interaction in class room interaction between students exposed to VLBI and those not exposed.

H_{02}: There is no statistically significant difference in student's achievement in Physics between students exposed to VLBI and those not exposed.

H_{03}: There is no statistically significant difference on the frequency of use of various experiments during teaching between students exposed to VLBI and those not exposed.

H_{04}: There is no statistically significant difference between the teachers' knowledge on selected ICT frameworks and the use of VLBI.

1.6 Justification of the Study

The 2006 National ICT policy has been put into action by the Kenyan government. Additionally, it has developed a plan that is in accordance with the Economic Recovery Strategy Paper for the Creation of Wealth and Jobs (ERSWEC) and the 2004 E-Government Strategy. These have aided in the realization of Kenya's vibrant digital society. The policy is built on UNESCO'S ICT Competency Framework whose aim is to develop skills and competencies of teachers for them to be able to integrate ICT in education and in other key sectors and processes. This strategy is supported by the Kenya Education Sector Support Programme (KESSP), a sector investment program with the goals of achieving universal education and the Sustainable Development Goals (SDGs).

The policy focuses primarily on supporting and encouraging ICT training for civil society leaders, decision-makers, community, as well as the creation of e-educational networks to encourage e-learning at all educational levels and make it easier to share educational resources. The policy further emphasizes on assisting the disadvantaged, women and youth by creating opportunities for them to gain ICT competencies, enhancing capacity and skills for research and development in ICT sector.

Physics is a core and fundamental science and as such there is no doubt that it occupies a very important position in various careers and is a pillar in driving the Big Four Agenda of the Government of Kenya. This necessitates efforts to study physics at the higher secondary level, including the application of technology-enhanced active learning to enhance learning outcomes, considering that it is one of the science subjects required to qualify for admission at tertiary level of education for science-based courses. However, despite the fact that physics plays a significant role and is heavily stressed in secondary education, students' scores remain below average. Stakeholders in education are increasingly concerned about this. In order to attain the SDG's, Kenya needs to embrace and promote ICT enhanced teaching and learning.

1.7 Significance of the Study

There have been various innovations in ICT that are geared towards improving and enhancing quality of education. Despite all these, the effects have not really been significant in educational institutions. The majority of institutions are unable to take advantage of the rapid advancement of technology because they still rely on systems that are nearly out of date. This study intended to create awareness that would encourage educational establishments to use and adapt to new technologies in order to improve teaching, learning, and skill acquisition in line with today's world. To improve the effectiveness and quality of the delivery of physics by promoting the establishment of a framework for a learning process that embraces technology, it was necessary to develop a prototype to guide educational institutions on how to deal with emerging technologies.

Moreover, the outcomes from the research will benefit the education stakeholders in understanding the significance of ICT integration in a learning environment. The results will be used to create a new avenue in learning and build on the salient place of technology in the classroom.

1.8 Delimitations of the Study

The study was based in public secondary schools in Kisumu County and covered the 7 sub-counties namely, Nyando, Kisumu East, Kisumu Central, Seme, Nyakach, Kisumu West and, Muhoroni. The independent variables were determinants such as, students' level of interaction in Physics classroom, students' achievement in Physics, frequency of use of experimental teaching strategy and the agreement between teachers' knowledge on the selected ICT frameworks and the use of VLBI in learning of Physics, while the dependent variable was effects of the use of VLBI in learning of physics, which is inextricably linked to improve learning outcomes and learner satisfaction. The respondents were Physics students and teachers who were given questionnaires to complete.

1.9 Limitation of the Study

This study focused on Physics, which is a science subject offered at the secondary school level in the Kenyan curriculum. The study was limited to factors such as students' existing knowledge of computer usage and teachers' level of competence in using computers. The research was limited by the accuracy, dependability and reliability of Physics Achievement Test. The study purposely targeted public schools in Kisumu County.

Public schools have basic features that are generally present in rural and urban schools and therefore the outcomes of this research study can be generalized to the entire study population.

1.10 Assumptions of the Study

The following assumptions served as the basis for this study:

i. That the adoption and use of VLBI promoted the teaching and learning of Physics by providing equal opportunities to all the learners irrespective of their individual traits.

ii. That the students were willing to learn Physics using the ICT tools developed for schools.

iii. That the teachers were able to develop and provide learners with VLBI learning resources such as animations to support digital learning of Physics.

1.11 Theoretical Framework

A learning theory is characterized as a thoughtful methodology of arriving at an understanding (Begg, 2015). Most notably, this research identified behaviourism and connective learning theories as the foundations of the study environment that focuses on and accommodates different learners' needs and abilities to achieve educational objectives. Firstly, the theories of learning are important since they are global frameworks which explain and familiarize us on how learning occurs regardless of the individual differences that exist among students in a classroom learning environments. Second, the unique nature of these theories may serve as an argument in favour of using ICT as a teaching and learning tool in the classroom. Moreso, the research relied on learning theories that provide teachers with instructional strategies that encourage active learning and teaching of physics in secondary schools and primarily describe the learning process.

Teachers or instructors should be enlightened of the significance of learning theories and that when choosing a pedagogy to use, they must take into account the type of students, available technologies, and the curriculum. The specific learning theories should be used to inform and direct the process of incorporating technological tools into the teaching and learning environment. Skinners' (1968) stimulus and response theory serves as the foundation for behaviourism theory. The student is thought to be conditioned to respond in a certain way to a stimulus that the teacher put forward. In this theory, according to Ertmer et al. (2013), learning is not entirely the responsibility of the learner; rather, the teacher directs the learning process, provides the content, evaluates students, and reinforces their responses. A change in the learner's behaviour is a sign that learning has occurred.

According to Altuna et al. (2015), the majority of that is reinforced through a system of positive or negative rewards. When ICT is used as a stimulus to enable students to repeat and practice the material they have learned, behaviourism theory can be applied to the integration of ICT technologies into pedagogy. This will help students realize the behaviourism principles. Stimuli can be a variety of technological tools that a student uses during the learning process to acquire knowledge in an environment with ICT resources. Based on behaviourist principles, Computer-Aided Instruction (CAI) is used to teach subject-related facts, skills and information (Dede, 2008). These applications can engage the learner in accordance with behaviourist methods by giving them activities with which they have to interact until they get the result they want. ICT tools applications are a good way to teach material through practice and repetition because they boost the students' development of creative and critical thinking skills.

To put it another way, technology is at the center of students' knowledge (Siemens, 2004). The tools that the students use take the tutoring role: They include the content of the subject, the goals that need to be accomplished, and the reinforcements that will be used during the assessment. In terms of enthusiasm and content mastery, the immediate feedback and reinforcement are crucial because they provide evidence that the process of learning has taken place successfully and that the set objectives have been met. Learning happens at the learner's own pace. Since behaviourist practices and principles are still applicable in the classroom, adopting ICT based on behaviourism theory is crucial to this study. ICT has been thought of as a tool that gives out instructional materials and acts as a tutor so that the learner can interact with the material.

By providing the learner with step-by-step instructions, the machine directs the learner's interaction with it. Dede's (2008) finding that the behaviourist instructional approach makes students passive and inhibits mental actions, which contribute to learning, is supported by the learning process. Even though secondary school teachers attempt to incorporate ICT into a variety of subjects, their instruction continues to be a fusion of various learning theory principles. Behaviourism theory is criticized for its failure to focus on the thinking process, whereas it tends to explain how people learn through reaction to stimuli and other external forces (Glasersfeld et al., 2014). These concerns, in addition to shifting trends, emerging innovations, and the proliferating availability of brand-new ICT capabilities, the study opted for a shift from behaviourism learning theory to connectivism learning theory to address the weaknesses of behaviourism learning theory.

Connectivism is regarded as the relevant learning theory for the digital age because it can accommodate both knowledge development and learning objectives (Downes, 2008; Siemens, 2004). According to this theory of learning, Students establish connections through the data flow that occurs between members of their network and them. Garcia et al. (2013) maintain that learning occurs when students interact with one another, which is accomplished through peer collaboration, expressing opinions, and dialogic criticism. Siemens (2004) says that connectivism focuses on how students use the knowledge they get from their own personal networks. The shortcomings of behaviourism theory are addressed by connectivism, which explains the recent developments in learning. According to Bell (2011), the principles of connectivism include understanding information as facts passed on, the requirement of special cognitive abilities to successfully work together to process and distribute information. Still, connectivism emphasizes the creation of networks for connecting people and giving them access to current processed information. According to Kop and Hill (2008), the socio-technological nature of the theory makes it significant and relevant because it enables teachers and students to connect, create learning communities, and access platforms, interacting with, thinking about, and disseminating relevant knowledge. In order to empower themselves and their peers, connectivism encourages the creation nodes and networks for students and teachers to share and acquire knowledge in real time. The learning process, according to Bartolomé and Steffens (2015), involves connecting specialized nodes or information sources like individuals, libraries, organizations, websites, and data bases. When in-service teacher training is inadequate due to a variety of obstacles, these nodes are important entities that can help teachers grow by giving them current information for enrichment and professional development. Students can participate in self-directed learning by adjusting their learning actions and achieving their goals through network interaction. The learning process that results from these interactions is heavily influenced by cognitive, affective, and emotional factors.

Isling et al (2013) show that with regards to connectivism, an ICT educating and learning achievement is directed by educators' ICT capabilities and their mentalities in the homeroom. This assertion demonstrates that teachers are, in fact, in charge and central figures in the process of integrating ICT into the classroom. Teachers play an important role in directing students toward the content they require in the connectivism setting. The variety of networks and transfers that occur during the connecting process have an impact on the learning process. In addition, the learning process is cyclical in the sense that students connect to a network in order to share and discover new information, alter their beliefs, and then reconnect to a network in order to share these realizations and discoveries (Newby et al., 2013). According to McLoughlin and Lee (2008), connectivism's learning process is characterized by helping students connect events and ideas and connecting information sets. Siemens (2008) argued that, knowledge is dynamic and is based on multiple opinions, which can be thought of as the process of connecting specialized nodes or information sources based on the learners' attitude. The ability to filter secondary and extraneous information, as well as the capacity to strive and pursue for current information, are the two essential skills that contribute to learning, according to the connectivism theory. Because it is difficult for a teacher to coach a student, the cultural diversity and online learning environment do not provide learners with the guidance they need to successfully implement these skills.

Connectivism, according to Bell (2011), aims to motivate educators and students to modify their activities. A good learning theory has three main components, as stated by Kerr (2006). As a result, a successful theory for learning should: offer a significant new perspective on the nature of learning, contribute to theory and accurately represent alternative historical perspectives. Because it fails to adequately explain how learning actually takes place, connectivism fails to meet these requirements. Consequently, it misrepresents the state of well-established alternative learning theories like behaviourism at the moment. Connectivism, on the other hand, adheres to the Vygotskyan theory because it makes use of the zone of proximal development (ZPD) and allows for informal learning in a digitally mediated environment.

One of the central tenets of connectivism as a theory is that knowledge is distributed across networks. It assumes that every educational establishment provides every student with the necessary technology to facilitate connectivism's learning environment of forming diverse networks based on connections, sharing, collaboration and communication. ICT has the potential to enhance the quality of education.

Since connectivism theory establishes the necessary connections for the learning process, which is the acquisition, sharing, and dissemination of knowledge, this can be accomplished most effectively.Even though connectivism has some flaws, it is currently the best learning theory for explaining how ICT is used in education in a networked society with a lot of, new technologies, information, and changes in human behaviour. Because connectivism is based on changes in society and the development of networks for the dissemination of knowledge, adopting connectivism does not imply abandoning previous learning theories. It also draws its principles and methods from established learning theories and disciplines.

According to Kandiri (2014), research employs a conceptual framework to elucidate a preferred method for approaching a thought or idea or to outline potential actions. The study seeks to establish implications of VLBI integration in learning of Physics. The conceptual framework that informed this study was based on system approach which posits that pedagogy has outputs and inputs, and that in order to have positive results, the inputs must be suitable and appropriate (Zohar, 2004). The study put into consideration the following variables: independent variables, dependent variables and moderating variables. This is illustrated in Figure 1.1

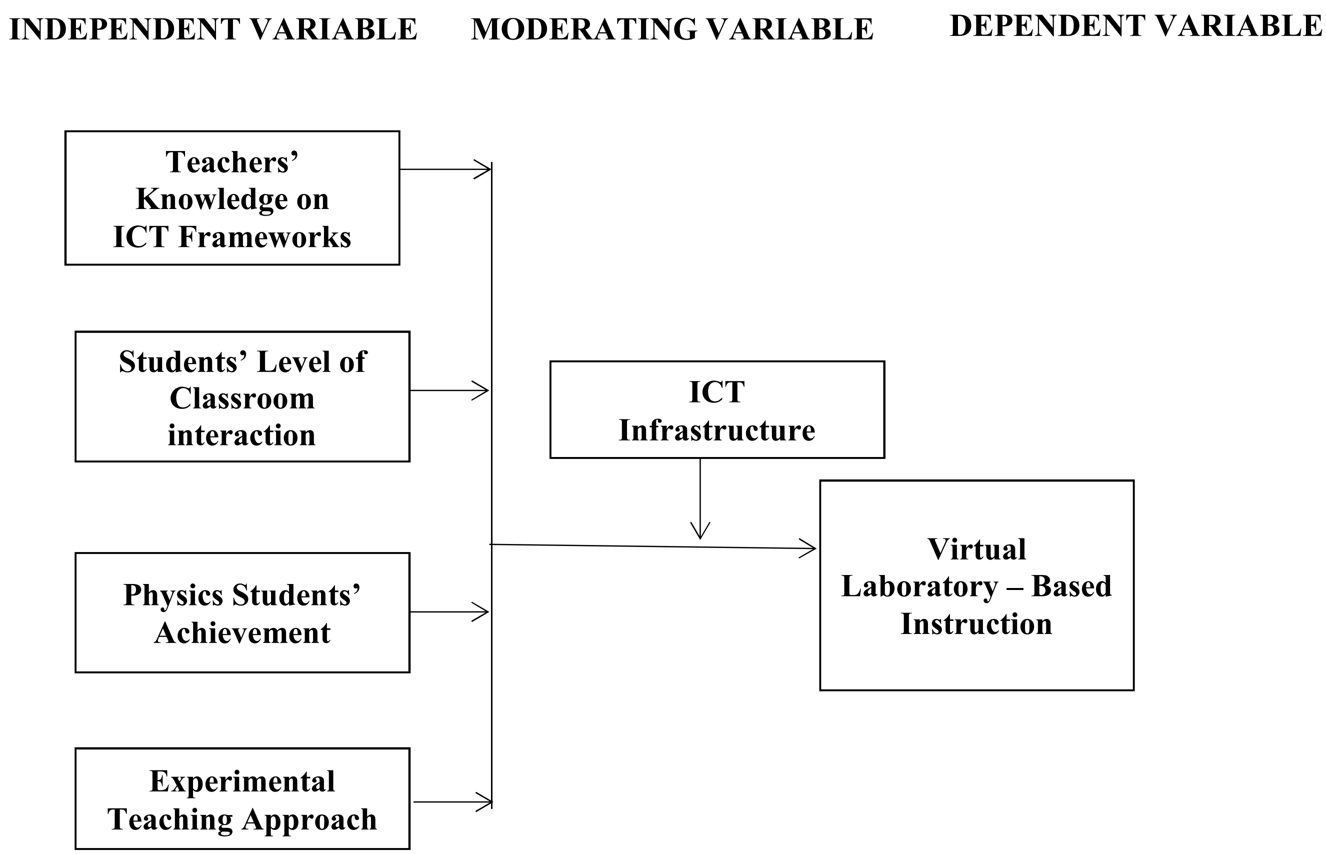

Figure: 1.1: Conceptual Framework

The independent variables in this situation are the factors that influence successful learner centred teaching and learning of Physics. These factors include selected ICT frameworks, Physics students' level of classroom interaction, Physics students' scores and frequency of use of experimental teaching strategy in the teaching of Physics.

The dependent variable in this study was the utilization of VLBI in learning Physics. The presence of ICT infrastructures was the study's moderating variable. The conceptual framework, therefore provided the concepts that served as the study's compass for analysing the use of ICT-integrated teaching and learning.

The framework showed some of the most important ideas that go into making ICT-integrated learning and teaching work. Through the conceptual framework, the researcher received an overview of the various issues and their connections in the study.

1.12 Operational definition of key Terms

Information and Communication Technology (ICT): basically, means various sets of technological tools and resources that are used to communicate, disseminate, create manage and store.

ICT integration: Refers to learning and teaching approaches (Pedagogies) in which the teacher uses virtual laboratory-based instruction to facilitate learning and where students use virtual apparatus to learn the content in Physics.

Virtual laboratory-based instruction (VLBI): Computer based activity where students interact via a computer interface.

Virtual experiments: Applications for multimedia that permit real-time video and digital simulations of laboratory activities.

Active learning: refers to learners centred teaching strategies.

Blended learning: A combination of ICT and different methods of content delivery which include electronic and online media as well as traditional face to face teaching strategy.

Achievement: This is used to refer to students' average scores in a test.

Teachers' beliefs: These can be regarded as teachers' opinion concerning educational issues and processes such as learning, teaching and curriculum.

E-learning: Is a term that refers to 'electronic learning,' meaning that an electronic device, in most cases a computer, is used to deliver part, or all of a course whether it is within or outside the school environment".

Instructional design: refers to the art and science of creating an instructional environment and materials that will bring the learner from the state of not being able to accomplish certain task to the state of being able to accomplish those tasks.

Pedagogy: that which relates to the research of various instruction approaches, creating the goals, objectives and aims of education and the manner in which those objectives and goals can be achieved. The field of education is greatly influenced by theories and educational psychology.

Physics teachers: These refer to teachers who have undergone CEMASTEA in-service courses on ICT integration in learning and teaching.

Learning of Physics: This process that leads to change, which occurs as a result of experience and increases the potential for improved in average scores and future learning in physics .

1.13 Organization of the Thesis

The next chapters of this thesis are organized as follows:

Chapter two presents a review of literature related to learning, learning theories, learning principles and ICT integration in learning and teaching. It seeks to identify key theories and framework related to promoting effective use of ICT in the classroom learning in higher education institutions. The chapter presents an analysis of factors identified from the relevant literature. It furthermore provides the knowledge gap that the thesis is predestine to resolve.

Chapter three discusses the research methods appropriate for this kind of study, that is, investigation undertaken, presentation and justification for the study. The chapter also describes the process and methods adopted in the study.

Chapter four presents the outcomes of the research from the analysis of collected data in light of the research objectives and goals. These include, the factors that characterize ICT integration and the suitability of employing VLBI.

Chapter five presents the research findings, summary of the findings and provide recommendations and conclusions research of the research findings

CHAPTER TWO

LITERATURE REVIEW

2.1 General Pedagogical Trends in Education

Nwaogu (2019) asserts that contemporary issues influencing education status include; government funding for education, poor teaching strategies, disciplinary policies, technology in education, bloated class sizes and learners' completion rates, among others. An international student assessment surveys carried out in Europe under agreed conceptual frameworks in Europe pointed out a decline in standings regarding science subjects' performance in member states (Science Education in Europe, 2011). According to Costin (2019), the primary explanation for the ongoing learning crisis is that many education systems in developing nations lack sufficient data on who is learning and who is not. The result has been poor performance, particularly in science subjects. Dhurumraj (2013) argues that some factors that lead to poor performance in sciences include inadequate resources, language of instruction, learners' background, parental involvement, large classroom capacity, learners' levels of development and the curriculum. An example of a country facing such challenges is South Africa.

There is a similar case for Uganda (Kiyaga, 2013) where learning of science subjects has remained a challenge, despite the promotional effort by the government. Poor performance in science subjects is increasing and has become a major concern among secondary school students in Tanzania (Jidamwa, 2012). The foregoing has been advanced by a number of factors among them, lack of teacher motivation and incentives which plays an important role in that they boost the teachers' effectiveness and efficiency, which positively affects students' performance.

For instance, in the past three years, Kisumu County in Kenya has registered a percentage pass rate of 30% in Physics in KCSE (KNEC, 2019 Report). This is an indication that the aforementioned challenges are common to most low- and middle-income countries. This means that it is imperative for developing countries such as Kenya to adopt robust teaching strategies and education frameworks that have yielded improved performance in science subjects across the globe, as evidenced in Finland (Amponsah et al, 2019), Singapore (Popova et al, 2018), Japan (Jordan et al, 2015) and South Korea (Dichev, 2017) among others.

The education system in Finland advocates for equality in education where all student despite their socio-economic background and place of residence have access to education (Sulkunen, 2016). The Finnish system has the highest outcome as compared to any other country in terms of the correlation between students' cognitive outcome and their self-efficacy, engagement and reading habits. The Finnish teaching framework is flexible and allows teachers to take part in the pedagogical and administrative procedures for making decisions within their schools and other educational levels within the Finnish school system (Green et al, 2020). The teachers are, thus, encouraged to engage in research that contributes to and enhances effective teaching practices during their career. The framework provides the teachers with broad pedagogical freedom and responsibilities with which they are able to influence their work. According to Halinen (2015) teachers and educators in Finland are able to manage their work mainly through negotiation and dialogue, which is a pedagogical way of thinking and acting in tough situations.

The ethos that underpins these working practices is primarily characterized by teachers, principals, and administrators' trust and hope.

According to Hancock (2011), education is highly valued in Finland such that with a masters degree, teachers, doctors and lawyers are accredited the same amount of respect and admiration. They have an attitude of going above and beyond to ensure the success of each and every student. They focus on preparing and showing students how to learn, instead of focusing on tests. The system does not believe in organizing learners into ability groups. The Finnish system does not have national examinations. Instead, it has an exit exam which students take in order to determine their next step. The Finnish education system puts more emphasis on learning rather than being exam oriented (Darling-Hammond, 2015). Teachers ardently embrace new innovations as long as they are regarded as appropriate for promoting student learning.

The key pillars that drive the Finnish learning outcomes include integration of digital literacy in the pedagogical approaches employed, emphasis on collaborative learning and emphasis on topics that reflect students' interest (Freeman et al., 2017). Long et al. (2017) suggested that the interaction in a technology-supported environment for learning between the teachers and the learners have resulted in various teaching methods that are mostly practised throughout the school system in Finland. Bloomberg (2017) reported that Finland has one of the best education systems in the world that is actuated by inculcating suitable professional development and in-service training. These have been realized by the government through adaption of instruction. Furthermore, the Finish government has succeeded in making the education system better by supporting use of ICT in education, thus making Finland the world's leader among information societies (Lehto, 2018). The merit of Finish education system is that it is driven by the theory of inventing problem-solving approaches where imparting skills and competencies demanded by the 21st century society is of greater importance than passing a sit-in examination (Ghavifekr, 2015). According to Amemado (2014) most developing countries are adopting the new learning strategies and methods that have long been employed in the developed world. More studies are being conducted on these learning methods so as to improve the learning outcomes (Ali et al., 2017). Thus, the benefits of integrating ICT in the education environment cannot be ignored (Aydin, 2013). Japan is one of the countries which has developed and embraced successfully active learning as a fundamental teaching methodology (Aki and Reiko, 2018). This has been achieved by accommodating the concept of "Jugyokenkyu" in teaching and learning process. According to Akiko (2015), "kenkyu" means research or learning and " jugyo" means lessons. This indicates that lessons involve systematic investigation in addition to learning (Ato & Obayashi, 2014). Instead of forcing students to respond in a predetermined manner, Japan places a greater emphasis on the capacity of students to solve problems on their own (Lestari et al.,2019).

This demonstrates that Japan encourages students to use their imaginations to learn (Funamori, 2017). Mari Kawamoto et al (2015) reports that students easily get bored and lazy if they are forced to think and learn in a specific way. ICT integration in Japanese schools has been lauded for increasing learners' motivation and learning outcomes (Waniek and Niculina, 2017). One of the key components of learning activities is learning media. since they are flexible and can be used for all levels of students, bearing the fact that they prompt learners to be accountable for their own learning and having more control over it too (Chotimah et al., 2018). It has been observed that students readily accept ICT integration because they easily absorb the lessons (Aki and Reiko, 2018).

Japanese teachers take into consideration the fact that it is necessary to adapt learning media to the subject matter, to enhance the process of comprehension, and to increase the students' achievement (Abdurrahman et al., 2018). In Singapore, the government has adopted ''Teach Less, Learn More'' pedagogical framework where more stress is laid on mastery of specific procedures and the abilities to clearly solve challenges (Robinson, 2017). In this framework, modes of teaching and evaluation are continuously modified and reviewed in order to articulate the creativity and thinking skills in the learners, and to encourage the production and use of knowledge. Numerous initiatives have been executed over time using this program including: *Thinking Program, Project Work, Integrated Program, promoting a Spirit of Enterprise and Innovation in Schools.*

For instance, since 2000, in order to give students a chance to experience integrated learning and investigate the interrelationships and connections between various disciplines, project work has been implemented in a number of schools. In all these interventions, ICT has been the bridging tool. Firstly, the ICT master plan in Education (MP1) was implemented followed by the vision in the "Thinking Schools, Learning Nation" (Poon et al., 2017). This enabled the Ministry charged with Education affairs in Singapore to shift away from efficiency-driven to ability-driven education whose aim was to develop and make use of the abilities and potential of every learner to acquire skills and competencies demanded by the country's labour market (Hui, 2017). Through both formal and informal curricula, this also made it possible to create an environment for learning that was focused on the needs of the student (Freeman et al., 2017).

The framework urged teachers to focus more on the quality and high level learning, which is achieved by the integration of technology into the education environment, and not just the amount of studying and studying for the exam (Robinson, 2017). As per to Berry (2011), this has led to lifelong learning, so called learning-to-learn and whole-person development in Singapore. The process of incorporation of ICT in schools in Singapore got to a level of maturity and stability when the second Master Plan was enforced that promoted students' ability to think critically, for example in application of acquired knowledge and skills (Tan et al, 2017). In Taiwan's science classrooms, it has become common practice to incorporate online technologies and databases into instructional designs (Hung, 2015). These technology-enhanced instructions have a major aim of improving learners' conceptual comprehension and basic process skills (Popova, 2018).

According to Darling-Hammond (2010) Korea's success in education was mainly achieved by replacing the existent overcrowded curriculum with the new integrated curriculum and emphasizing on several features to be included such as concentrating on a deeper comprehension of concepts, developing of core competencies (high order thinking skills, responsibility, self-control, self-directed learning, independence, social capital development creativity and problem-solving), addressing the requirements of a global economy based on knowledge and incorporating technology. As per the assertion of Darling-Hammond (2010), by 2002 every school in Korea had high-speed internet connection in classrooms and incorporated ICT in at least 10% of every subject. Thus, the learners are abreast with the use of both virtual and augmented reality in teaching and learning, which enhance learning by providing an immersed multimodal environment enriched by multiple sensory features. Enhancing technology in education is so significant that most schools countrywide are adopting it.

Ultimately, students of the current generation have been familiarised with digital technology and it is part of their learning experience. In the past two decades, there have been ambitious curriculum reform efforts by African countries in Sub-Saharan such as Rwanda, South Africa, and Kenya (Tigabu et al, 2015). Fleisch et al (2019) indicates that central point of focus of these reforms is acquisition of skills and digital literacy through competence-based pedagogy and learner-centred education, so as to present to the labour market graduates who are equipped with the relevant skills. According to Baeten et al (2016), ICT has the potential to transform education from lecture-based instruction centered on teachers to interactive learning environments centered on students. Developing countries such as Kenya, therefore, need to consider significant integration of ICT into curriculum designs, especially in the teaching of science subjects where critical thinking and learners' participation significantly promote learning. To this end, it is arguable that the competency-based curriculum in Kenya is guaranteed to realize much desired outcomes if the country joins the rest of the globe by embracing ICT-integrated pedagogical framework into it so as to support active learning.

2.2 Current Status of ICT integration in Education in Kenya

The use of computers in school has been determined to be an effective way of making pedagogy more efficient and enriched (Lumpkin et al, 2015). However, its implementation is quite varied across countries worldwide (Hennesy, 2019). In as much as one sees a proliferation of computer access in a classroom in developed countries, the introduction of computers, even at professional education levels, is a non-existent in other countries. Manufacturers have introduced programmes in some parts of the world to encourage schools to acquire microcomputers. In other countries government have offered subsidies to schools (Rabah, 2015).In order to realize more from what ICT offers and to bridge the digital divide in our economy, in the fiscal year 2010/2011, Ksh 1.3 billion was given by the Kenyan government towards the acquisition of 300 PCs for every supporter and to make ICT a reality in both metropolitan schools and rustic schools. These computers were intended to provide a platform for expanding ICT integration in education and ensuring equal access to high-quality instruction. Currently there is a partnership between various banks, TSC and KICD for teacher to acquire laptops at subsidized prices to use in instruction. While some recently introduced microcomputers have invariably hard disk-drives and the option of colour monitors, early machines had only black and white monitors and cassette tapes for secondary storage. There are significant differences between earlier ICT integration applications and more recent multimedia, multisensory-based innovations.

Due to the hardware and software constraints that instruction developers had to contend with, ICT integration that had been developed within the previous two decades was typically of lower quality. Recently, advanced hardware and software tools have been used by ICT developers to create and use high-quality 3-Dimensions simulations/animations, video segments and audio elements. Compared to earlier ICT technologies, these have made it easier to instructional materials that are of quality and encourages more learning. The making of route joins through easy-to-understand intelligent instruments (like hypertext and hypermedia) is one more critical progression (Stout et al., 2017). The effectiveness of ICT integration in education when implemented correctly is demonstrated by a large body of research in the literature.

According to Buthelezi (2018), this body of research also suggests that VLBI may actually be more efficient than conventional instructions. Freeman et al., (2017) support the effectiveness of virtual laboratory-based instruction when used as an interactive model for individualized and collaborative group learning. There is also a wide variations levels at which ICT integration is introduced in the curriculum. For instance, even in the first year of school, computers are being introduced due to the wider availability of quality software packages. According to the National ICT master plan, 2006, the utilization of information, communication, and technology (ICT) is becoming increasingly essential to the Kenya's socioeconomic development. The nation's goals, principles, and strategies for transforming Kenya into a digital society are outlined in the National ICT policy and also in e-Government strategy.

A nation only possesses an economy that is knowledge-based if its workforce is ICT-literate. This is recognized by the government. This has been advanced by the introduction of the new competency-based curriculum (CBC). The CBC has recognized computerized education as one of the centre - capability, enabling students to be useful laborers with cutting edge 21st-century abilities. KICD launched the e-content for schools in March 2010 and provided ICT materials to schools through partnerships with a number of organizations and the private sector (Laaria, 2013). The seriousness with which the government views the integration of ICT in schools make these efforts visible. With the CBC curriculum now in place, teachers are being trained to adopt and use ICT in the classroom. The majority of teachers in the country are not effectively using ICT to support management, teaching, and learning despite the importance of the government's strategies for implementing ICT in schools (Maduku et al., 2012).

While over 41% of public secondary schools in many nations use ICT in the classroom, the percentage in Kenya is still very low. This may be because the government's strategy did not take teachers' skills, attitudes, or reactions to these new tools into account.

2.3 Dynamics in Kenya Education System in Teaching and learning Physics

Liu et al. (2017) consider Physics as the foundation of technology and science in view of the fact that most tools that are necessary for scientific and technological advancement are products of Physics, for instance, robotics and artificial intelligence. With regard to science and technology, Physics is considered an essential subject due to the fact that it covers the essence of natural occurences and aids in understanding the rapid changes in technological trends (Wu, 2017). According to the Kenya Institute of Education, 2002, physics provides learners with the comprehension, skills and necessary knowledge for scientific research. It also encourages economic and technological growth in the society in which they live, which raises living standards (Kenya Institute of Education, 2002; Minishi et al. (2004). That being the case, Physics education should not only be a course taught in secondary school stages but should be a lifelong and reiterative area of knowledge.

The declining learners’ motivation to study Physics and the lack of interest in the subject in secondary schools or rather avoiding Physics, has been a problem across several nations (Semela, 2010). The decline in enrolment and graduation rate as a result of erosion of interest in Physics across various levels has been an issue in several countries like the USA, UK, Germany and the Netherlands (Institute of Physics [IOP], 2012). The perception that physics involves a lot of mathematics influences the implementation of the physics curriculum in Kenya, existence of mismatch between the commonly used language and the language of instruction in Physics, most of its content is abstract, and inadequacy of relevant Physics apparatus and conventional books (Cunningham and Villaseñor, 2016). It is also important to note that, due to its low popularity among other science subjects in Kenyan secondary schools, students do not take Physics as an option while they chose other science subjects (Ngari et al., 2017). Therefore, many schools only offer the Physics as mandatory in the first two levels of secondary school education. Additionally, physics has been misunderstood as being difficult, and as a result, the majority of students have a negative perception of the subject, resulting in poor performance (Khaoya, 2015). Surprisingly, students' performance in physics at KCSE has been poor and low, at 39.0% in 2013 and 26.6% in 2018. That is to say, the performance in Physics has worsened over the past five years, with a 12.4-point drop (KNEC, 2019). This is despite the intervention programs that the Ministry of Education, Science, and Technology (MOEST) has implemented to boost its performance.

The government's economic stimulus program and the Strengthening of Mathematics and Sciences in Secondary Education (SMASSE) program are examples of such interventions (Mwambela, 2013). Both of these programs aim to provide selected secondary schools with laboratories that are well-equipped. Therefore, it is absolutely necessary to incorporate a more result-oriented and robust approach into the learning of physics that places the student at the centre of its processes. Buthelezi, (2018) agrees that Interactive learning paradigm supports in meeting this need. There is substantial evidence (Sanders et al., 2017; Hodges, 2018) that demonstrates that active learning outperforms lecture-based, memorization, and recitation methods, as well as teacher-centred classrooms, in terms of learning and outcomes. For instance, Sujana et al. (2016) state that active-learning instructional strategies provide students with a solid conceptual foundation in the subject matter, enable them to reason effectively, and help them master the skills of problem-solving. According to Lumpkin (2015), interactive learning is essential for teaching and learning technical subjects like physics because it involves engaging students in a variety of classroom activities to increase their level of participation with their peers and the instructor. It also places an emphasis on quick feedback and directs students to express and consider their own processes and reasoning. Students must exert effort in constructing their knowledge through interactive learning. Interactive learning is made more fun with ICT because it makes students more involved in the classroom and helps them remember what they have acquired over time (Abeysekera, 2015).

In addition, secondary schools should encourage using ICT in Physics with active learning approaches because it helps students understand difficult abstract concepts, helps them make accurate and reliable measurements, and encourages individualized learning of Physics (Wu et al., 2019). According to John (2015), ICT offers institutions a fantastic opportunity to adopt and utilize technology in order to enhance the teaching and learning process. In contrast, ICT can help students gain knowledge, adapt to ever-changing learning environments, and develop new skills and abilities through technological literacy and a plethora of resources for instruction (Salvetti et al., 2015). According to Conklin (2011); According to Sanmi (2016), incorporating ICT into the study of physics may help students gain a new perspective on the subject and cultivate a positive attitude toward it. Falode (2015) emphasize that effective ICT integration in physics creates an environment conducive to meaningful student-teacher interaction.

As a result, it is necessary to investigate the implications of virtual experiments and the ways in which their adoption will take into account the objectives of both instructors and students. In addition, ICTs will develop a new framework that can support the use of blended-learning methods such as cooperative learning, collaborative learning, and project-based learning as well as encourage their revision and improvement (Monti et al., 2019).

2.4 Leveraging on ICT to Achieve Active Classroom Interaction

According to Tekes (2013), the highest level of independent learning has been observed as a result of the integration of innovation into pedagogy. This has increased the teacher's skill set and made it possible for students to access a wider range of learning resources. Additionally, this method of instruction inspires students with greater working ability on expanding their skills and knowledge beyond the scope of the actively used curriculum. According to UNESCO (2011), methods of Teaching ought to be appropriate for the acquisition of information applicable to particular societies, such as instilling the core values and passing on the cultural legacy of various communities.

Sanmi (2016) says that when ICT is used as a learning tool, In addition to learning a lot about their subjects, students frequently know how to generate knowledge because ICT makes students more motivated and engaged. Guzel (2011) came to the conclusion that students are now able to explore and comprehend mathematical concepts thanks to the integration of computers into the instruction process. The majority of nations, according to UNESCO (2002), consider ICT comprehension and the capacity to master its fundamental concepts to be the core of education. According to Buthelezi (2018), the term "interactive learning" refers to a method of instruction that is primarily learner-centered as opposed to content-centered. Sanders and others (2017) view dynamic advancing as fundamentally when understudies are engaged with different exercises and are pondering the exercises they are associated with. It also means that, as opposed to passively receiving information, students effectively participate in the learning process by participating in activities that foster critical thinking (Hodges, 2018). Interactive learning can include activities that take place both within and outside of the classroom. That is, a variety of activities, such as guided classroom discussions, small group work, role-playing, incorporating multimedia resources and writing exercises, can facilitate active learning in the classroom (Maher et al, 2015). Wu et al (2019) state that dynamic learning can be actually coordinated into the homeroom putting in different ways together to strengthen the growth opportunity of the understudies.

The traditional lecture method, in which the instructor serves as a facilitator, is in direct opposition to interactive learning (Rotellar & Cain, 2016). Innovation and technology works with the capacity to actually take a look at the degree of content understanding in interactive learning. This is very important because it can give students immediate feedback from their assessments (Plump & Larosa, 2017). To increase student engagement, a variety of strategies have been proposed. According to the theory of engagement by Schneiderman and Kearsley (1999), it is important to use various activities to engage learners during the learning process. Shadiev et al (2015) claim that students are more engaged when communication tools provide them with active notifications or alerts. Gaffney et al (2010) observed that students tend to work on and nurture their expectations and goals in order to realize and achieve them during interactive learning in a physics classroom.

This demonstrates that the majority of students enrolled in classes that employ active learning approaches exhibit a wide range of beneficial changes in their understanding and analysis. Freeman et al, (2017) noted that, as opposed to simply listening to lectures, using problem-solving activities in groups within classrooms to implement active learning in a physics lesson produces significantly superior learning outcomes. These active learning methods can prepare learners to learn more from proceeding lessons by making concepts more immediate or relevant when they are deeply engaged in the learning process. According to Finn and Zimmer (2012), Engaged students work harder and have a better learning experience. Through the use of an electronic network, teaching physics through interactive learning increases student participation in the classroom and fosters collaborative learning among students.

Ejimonye (2020) found that the 2D animation method significantly increased students' motivation for the quantitative economics content. Activities with effects that are relevant to the course being studied are also encouraged through interactive learning. Furthermore, Khan et al (2017) confirm that, in comparison to traditional teaching methods, the level of content comprehension increased by 40% to 60% when physics course at college level included active learning. Lumpkin (2015) confirm that effective implementation of interactive learning strategies throughout the course enhances student engagement and contributes significantly to their learning. In interactive learning, engagement is very important because it helps students develop their enhanced thinking skills, which can be helpful in handling sustainability issues at various spatial scales and in a variety of socio-cultural contexts (Straková, 2018). According to Hollie (2017) learners acquire knowledge effectively when they are actively involved in the process and how and when they learn through a discovery-based approach. Students have the chance to move from simply hearing theories in the name of learning to fully participating in interactive learning activities that require decision-making and the acquisition of various types of knowledge (Kim, 2018). A student can explore how to address similar issues that may necessitate various approaches in various socio-cultural contexts through interactive learning. As per Kucherenko (2015), students encounter complex issues during the learning process that do not have straightforward, one-dimensional solutions. Instead, solutions take place in a space with multiple dimensions where variables are not as independent as they seem. The curriculum has the ability to tailor its relevance to a diverse student body and aid in preparing students for the global labour market by incorporating examples from a variety of locations and spatial scales (Zhao, 2012).

According to Conklin (2011), when ICT tools were combined with increased student engagement, higher-order thinking skills were improved. This is on the grounds that such a learning climate improves imagination than in an educator focused climate where educators are viewed as the main wellspring of information. According to Villiers (2007), students are more likely to be creative when creativity is incorporated into instruction. The social constructivist approach to education is linked to collaborative learning and teamwork (Lam, 2015). According to Quintana et al. (2014)., effective integration of ICT enhances collaborative and active learning but also maintain that ICT-integrated learning encourages collaboration in the sense that it encourages communication, cooperation, and interaction as students collaborate with one another through group projects or teamwork during learning processes. Presently being developed technologies support learning through hands-on involvement, are interactive, and immediately provide feedback.

Chan (2015) says that new media animations, interactions, and simulations make existing learning materials more transformative. Because traditional books can be supported by multimedia collections created by local educators and tailored to their own classes, education will change even more. Students' active participation in class activities is also improved by technological advancements (Holmes et al. 2015. As a result, education will change even more because historical old books approach can be supplemented by multimedia collections made by local educators and tailored to their own classes. Students are able to participate actively in classroom activities without worrying about having to respond to a question because of these devices (Deng, 2019).

According to Donia et al (2018), this kind of outcome information not only informs students of the content areas in which they require remediation, but it also provides teachers with insight into the areas in which they should place more emphasis on the material in accordance with the needs of their students. According to Revell and McCurry (2010), students' preparedness and attention span can also be improved through the use of ICT. Furthermore, McLoone et al. (2019) attempted to determine how satisfied undergraduates were with the use of virtual experiments in assessment course in health. The majority of students expressed satisfaction with the use of the virtual experiments and were pleased with the interaction and feedback they received from the virtual labs. According to McLoone et al. (2019), classroom participation decreases when class size and diversity increase, resulting in passive learning modes caused by shyness, peer pressure, and other factors. Although the classroom is already a dynamic and tool-rich environment, successfully introducing tools into it presents challenges, computing technology provides a "safe haven" for student participation.

According to Beatty (2016), the challenge for the lecturer is primarily determining whether or not students understand the fundamental concepts and maintaining their active engagement throughout the learning process. Although it can be challenging to provide students with immediate feedback, ICT integration makes it simple to obtain immediate feedback that can be used to evaluate students' comprehension (Abdurrahman, 2018). According to Acero (2017), various aspects of an active learning environment make it easier for students to collaborate and interact with one another, as well as due to the fact that students are encouraged to be involved in their own education in a meaningful way through active learning, students and content, students and teachers, teachers and contents. As a result, it was discovered that students were more engaged in the learning process when virtual laboratory-based instruction was incorporated into the instruction (Abdurrahman, 2018). As opposed to simply being passive listeners, students were made to actively participate in the lesson.

According to Stowell, et al. (2010), the ability of ICT tools to provide immediate feedback and assess students' comprehension is an additional benefit that they bring to the learning environment. Similarly, ICT tools like VLBI can be used to check that learners understand fundamental concepts and help reinforce teaching and learning experiences (Papadopoulos et al, 2018). Stowell et al (2018) encourage teachers to regularly create virtual labs in order to observe student changes and enhance active learning. Smith et al (2020) also emphasizes the potential for VLBI to foster active and in-depth learning because it gives students the opportunity to discuss concepts in small groups. The respondents also confirmed that they were more attentive when ICT was integrated into the learning process and that they could inquire about additional

information when certain ideas were unclear (Abdurrahman, 2018). Due to the fact that they were aware that they could be questioned, they became more focused during the lesson. The outcomes reflect this with 84% of participants saying that using ICT in the classroom made students more attentive. Most of the respondents (86%) also stated that because everyone in the class had the chance to interact with one another and improve the class's overall performance, clickers increased their classroom participation.
Papadopoulos et al (2018) claim that, the development of VLBI enhances student learning and engagement. Kenya has yet to use virtual experiments, despite the benefits they offer and their impact on active learning (Beatty, 2016).

Another innovation that encourages the use of virtual experiments in a classroom setting is the widespread adoption of interactive whiteboards (IWBs) (Umak et al., 2016).
Teachers and students alike are using interactive whiteboards (IWBs) to replace "ordinary" whiteboards almost entirely. Young et al. claim that (2017), the majority of educators consider IWBs to be a highly motivating teaching tool. Studies like those by Smith et al.2020) demonstrate the positive effects of whole-class teacher-led sessions, including teachers' engagement with interactive teaching's surface features. The use of IWB in classrooms in the UK has improved literacy and numeracy, as demonstrated by studies like Hebing (2017). The studies aforementioned observed that ICT integration, particularly the creation of virtual labs, use of clickers and IWBs in teaching and learning promote active learning through boosting learners' level of participation in various classroom activities. The studies have, however, not shown the effect of integrating VLBI in the course of teaching and learning of Physics, whether the learners are involved in learning or are passive listeners. In addition, there is no experimental study that has

explicitly established how ICT intervention through adoption of VLB in teaching of Physics in secondary schools can advance the learners' level of participation in classroom thus enhancing active learning. The current study therefore aimed at bridging this gap by establishing how VLBI alter learners' level of interaction in a classroom set up.

2.5 Students' Academic Achievement

The quantity and quality of one's success in instilling knowledge mastery, acquiring skills, or comprehending can be regarded as achievement. Examination and Test scores, as determined by the subject teacher, are used to measure academic achievement (Malik et al., 2018). According to Saha et al. (2010), the use of computer-assisted instruction is more effective than conventional classroom instruction on its own. Similarly, Fauzi et al. (2010) observed a positive deviation when mathematical learning softwares were introduced as a strategy in mathematical instruction. Since the majority of students viewed mathematics as difficult, unrelated and boring to their life experiences, student factors such as study attitudes, habits, and interests on mathematics, and management of time had a direct impact on achievement (Suan, 2018). Additionally, Delen and Bulut (2011) found that students' success in math and science was significantly influenced by their use of ICT outside of school hours.

Students are made to accumulate a great deal of facts, skills and procedures which significantly enhance achievement in physics when animated power point presentation (PPT) is used in instruction (Ugwuanyi et al, 2020). Students taught mathematics through computer animation had higher average scores than students taught through the geometrical instructional model, according to Gambari et al. (2014).

Furthermore, Falode et al. (2016) detected in his study that students who were taught Agricultural Science using programs supporting computer animation had better results than students who were taught the same idea through lectures. Academic achievement at the secondary level, according to Lewin, Wasaga, Wandering, and Somerset (2011), is not only a measure of the effectiveness of schools, but also a factor in the overall health of the nation and its youth. Therefore, maintaining Kenya's economic growth necessitates raising the academic achievement of physics students. Effective physics instruction is reflected in high-quality performance. At the KCSE level, the Kenya National Examination Council (KNEC) administers three Physics papers: Papers one, two, and three. The theory papers are Papers 1 and 2.

Paper 1 covers Heat and Mechanics, Paper 2 covers electricity and magnetism whereas Paper 3 is a practical paper. The three papers are used to analyse the competency of students regarding Physics practices, principles, and concepts as set out in the curriculum (KICD, 2012). The overall performance in Physics is determined by how the students perform in all the three papers. Physics has recorded low performance of below 50% in the period of 2016-2019. In the year 2019, Physics recorded an overall percentage mean score of 35.43%. Hayes et al. (2020) highlighted that teaching strategies used by the teacher is among the factors affecting student’s achievement. Therefore, in order to successfully teach and learn about physics, it is necessary to employ a suitable teaching method. According to Muchiri et al. (2018), the majority of Physics teachers' teaching methods are expository and focus on facts, making students passive. While students listen and take notes, teachers disseminate information.

Methods of teaching are rapidly changing to a learning situation where most focus is on the learner (Nilson et al., 2021). Since focus is mostly on the learner during the learning process in the modern teaching environment, the learners are made responsible for their own knowledge. Information communication technology tools are being used to enhance learner-centred techniques. Computer Assisted Teaching is one term used to describe the use of computers in the learning and teaching process. Learning improves when learners are engaged in the learning process. Learners do not just accept what the teacher tells them but instead they identify key principles for themselves (Anita, 2008). It is from interaction with the computers that the students gain knowledge and build their understanding. There has been an indication of good progress in teaching perceived difficult topics with the aid of computers (Tanui et al, 2008). Students' achievement in a variety of subjects is improved when they use computers, according to studies. (Ahiatrogah et al, 2013; Serin, 2011). Computers are being used to enhance content delivery among different subjects.

In Kenya in 2012 and 2013, the Minister of Education, Parents, political leaders, psychologists, and other stakeholders complained about poor performance in sciences in KCSE examinations and as a result a team of experts was appointed to investigate the matter and report for action (KNEC, 2015). However, this has been the trend and previous ministers in the ministry of education have promised to deal with the challenge, but little has been done. This situation raises questions about the methodology employed in Physics instruction in Kenyan secondary schools. It can be deduced from the preceding that none of the aforementioned studies examined the effects of incorporating a virtual laboratory-based instruction method on students' achievement in physics both in Kenya and beyond. Furthermore, according to the Examiner's Report (KNEC-2017), among the reasons for the poor performance are a lack of basic mathematical skills and inadequate abilities to explain drawn tables and graphs. The researcher's aim for this research was to find a solution to these literature gaps. In as much as computers are very effective in improving achievement, there is limited research regarding this on this area in relation to Physics in secondary schools. This is the context in which the current study examined the effects of integrating VLBI on students' achievement in physics in Kenyan secondary schools.

2.6 Use of Experiment as a Teaching Approach

In his article on the role of experiments in science education, Millar (2019) summarized two primary goals of science education as follows: to help students comprehend as much of the established body of scientific knowledge as is appropriate for their interests, needs, and capacities, as well as to develop students' comprehension of the methods by which this knowledge was acquired and our reasons for trusting it. This study only emphasizes and appreciates that use of experiments is important in teaching Physics. However, it does not indicate whether they are put in practice or not. Rahayu (2018) looked into how different teaching methods affected two different groups of grade seven students. Learners in the experimental group received instruction based on their preferences, while those in the control group were taught in a conventional manner. Students in the experimental group, who received instruction tailored to their preferred learning styles, performed better academically than students in the control group in this study

Additionally, the experimental group demonstrated an improved capacity to transfer what they had learned from one subject area to another as well as a more upbeat attitude toward learning. According to Zhang et al.'s (2020) research, students' perceptions of Physics instruction were influenced by the constructivist approach. When students were taught using the constructive approach as opposed to the traditional approach, they placed a higher take advantage of the chance to actively participate in group discussions and investigate the ideas they had previously learned. Isa et al. (2020) discovered that students gain important practical skills when they directly participate in laboratory experiments. These abilities include connecting circuits, putting instruments together, reading instrument scales, recording the results, and figuring out what they mean. These studies explained the fact that use of experimental approach leads to student-centred learning.

However, the study did not indicate whether this motivates teachers to carry out more experiments or not. Majama et al. (2019) reported that lack of basic content knowledge and outdated teaching practices have compromised the use of experimental approach in teaching in Tshwane North in South Africa. The poor teaching standards had also been exacerbated by overcrowded and non-equipped classrooms. In order to achieve educational goals, effective teaching will only be achieved if the classroom learning accommodates and adopts the use of experiments. Moreover, there is substantial research findings that use of experimental approach in learning and teaching improves students' activeness in Physics teaching learning process (Desman et al, 2017). According to Chebii (2019), some science teachers are not well-equipped to teach science effectively. Some of their deficiencies include the use of unsuccessful science instruction methods, a lack of commitment, and inaccurate assessments of students' science learning outcomes. Adeyemo (2010) found out that modern and adequate laboratory apparatus were unavailable in most secondary schools in Nigeria and where they were, they were not functional, hence a few experiments were carried out by physics teachers. Semela (2010) noted that physics in many African counties has been undergoing crisis with no or few experiments carried out in the course of learning. The reasons include inadequate laboratory equipment, weak mathematics background and unqualified teachers among others. The M.O.E. emphasizes the use of practical approach in teaching and learning of Physics as a policy in secondary schools in Kenya (R.O.K, 2006). Since the resources are intended to be used for the benefit of teachers and students, Majama et al. (2019) state that the procedure for allocating resources should be followed. The above research studies showed that limited experiments were carried out, which may be as a result of incompetent Physics teachers or inefficient laboratory equipment, or both.

The studies did not, however, indicate possible experiments that the physics teachers were able to carry out. It is worth noting from the foregoing that while several studies have been done using different teacher variables, few have concentrated on the extent to which Physics' virtual resources for teaching influence the use of experiments as a classroom method in the teaching Physics. The above-mentioned researchers give a general picture of the importance of use of experiments in teaching physics. The studies further acknowledge that very few experiments, if any, are carried out in the course of teaching and learning of physics, more particularly in topics such as Radioactivity and Photoelectric effects that entail experiments that are considered hazardous. However, it could be argued that the studies lack the remedy on measures that should be taken for Physics teachers to carry out experiments in the mentioned topics. The current research has focus on the frequency of use of experimental teaching approach when VLBI is adopted in teaching Physics in secondary schools in Kenya.

2.7 Selected ICT Frameworks

Technology is rapidly growing and becoming an important aspect of our-day-today lives. This can be seen in the lifestyles of younger generations who have grown up using technology. In order to promote active learning in Physics using technology, it is essential that the existing learning frameworks be integrated with ICT towards spurring the participatory aspect of the learners, irrespective of their personality (Eddy-U, 2015). Today's students get immersed in technology from a very early age and spend their lives in smart environments surrounded with computers, smart phones, and digital media that they interact with most of the time (Sefton-Green, 2016). They prefer utilizing media and technology in almost everything they do (Hamid et al., 2015). Therefore, as a good method for them to be engaged in learning, the integration of technology into learning frameworks will create a friendly learning environment that will improve the learners' engagement in the course of Physics study (An, 2011).

According to Dee Fink (2013), learning frameworks assist educators in designing learning objectives in accordance with classroom activities, creating learning environments that are inclusive and motivating, and integrating evaluation into learning. Frameworks provide scaffold, multiple teaching approaches which assist learners to develop knowledge structures that are accurately and meaningfully organized, while making them aware of how and when to apply the acquired skills and knowledge (Ambrose et al., 2015). According to Sortrakul (2009), instructional learning frameworks can be effectively incorporated into the ICT field to create an active platform for teaching performance and learning challenges in a variety of settings and teaching and learning

Physics. In addition, students engage more actively in the created learning environment when an instructional learning model is enhanced with ICT than when traditional classroom instruction is provided. The learning frameworks transform the learning paradigm from teacher-centered to learner-centered. Branch et al (2014) confirmed that ICT-based instruction is replacing talk-and-chalk instruction. Hundreds of teachings and learning frameworks have been developed by instructional designers to meet their requirements. According to Lee and Jang (2014), the primary goal of creating an instructional design framework is to support an understanding of instructional design reality and monitor teaching and design performance.

According to Branch and Kopcha (2014), despite the fact that numerous instructional design frameworks have been developed for both general and specific use, there are still a few significant distinctions between them, allowing instructors to better put theframework into use in accordance with their goals. The reviewed technology enhanced framework includes ICT elements and instructional principles to help students get the most out of their education. Oliver (2005) asserts that there are e-learning frameworks and components that focus on defining the essential elements that can create a meaningful learning environment by influencing e-learning and other factors. This group of frameworks includes the following: The building blocks of functionality (Patten et al, 2006), Eight-dimensional e-learning framework developed by (Khan, 2006), Khan's P3 model (Khan, 2005), the SAMR model (Puentedura, 2012), the TPACK framework (Koehler and Mishra, 2006), and the ASSURE model (Heinrich et al., 1999).

2.7.1 The Substitution Augmentation Modification Redefinition (SAMR) Model

The SAMR model was formulated by Puentedura (2012) as a learning framework to help teachers choose and make effective use of technology in the classroom in meaningful ways. This model not only helps the instructor successfully integrate technology, but it also aids in the creation and evaluation of activities for distance learning (Puentedura, 2012). A ladder, which is based on scaffolding, serves as the framework. According to Puentedura (2013), learning practices that fall on the upper end of the ladder (redefinition and modification) transform learning while those that fall on the lower end (augmentation and substitution) are thought to help students learn. According to Hockly (2013), the use of technology does not improve learning in and of itself. The SAMR model is illustrated in Figure 2.8 below:

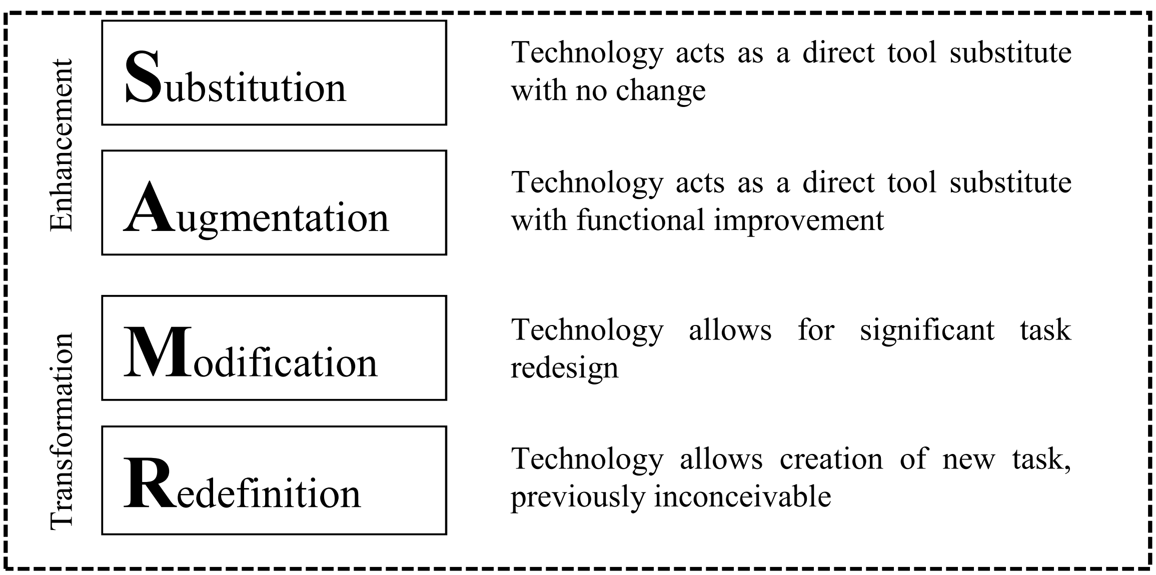

Figure 2.8: SAMR Framework

In the classroom setup, teachers are encouraged to work toward thinking skills of a higher level because of the framework's close connection to bloom's taxonomy. Students who require scaffolding receive support and structure in technology-enhanced classrooms, and those who thrive in challenging environments receive enrichment. As a result, students learn in a task-oriented and predictable learning environment where they know what is expected of them and how to meet it.This model is powerful because it is adaptable, allowing teachers to choose the level at which they want to incorporate technology into their classes. On the paper, the steps of the SAMR framework appear to be simple and offer excellent examples of how to structure the incorporation of technology into education. To put it another way, the framework shows how a learning activity has changed, but it doesn't say how to figure out how valuable that change is or what role students' play in the learning process.

2.7.2 The ASSURE Framework

According to Heinrich et al. (1999), an instructional guideline that can be used by educators to create media and technology-infused lesson plans is the ASSURE framework. This Framework aims to achieve the overall learning objectives and places the learner as the convergence point. According to Lefebvre (2006), the framework embraces a constructivist instructional design that incorporates technology and multimedia to enhance the instruction environment. Since the framework was meant to be used to teach each student for a few hours, it was modified so that it could be used in the classroom by teachers (Smaldino, 2008). According to Gustavson and Branch (2002), this framework does not necessitate extensive instructional design expertise, a high-level of design revision, or a high-level of delivered media complexity.

This framework's main tenet is that it can be used to deliver and plan instruction using technology and media, making it suitable for planning distance education. In addition, it is learner-centered in the sense that the learner's characteristics are taken into consideration and identified at the outset of the process. It is a practical and straightforward framework because it places an emphasis on student participation. However, in contrast to other learning models, such as the ADDIE framework, the model reveals a scant and deficient analysis at the beginning because it does not provide a clear explanation for some instructional issues, such as learning constraints and new behavioural outcomes. Additionally, the ASSURE model is predicated on the existence of an ideal, well-organized learning environment in which all resources and tools for instruction are readily accessible. There is a possibility that the model would completely address the shortcomings if the author had specified the learning media and facilities and extended the depth of analysis.

2.7.3 The TPACK Framework

According to Koehler et al. (2016), one of the learning frameworks that emphasizes the utilization of ICT in teaching and learning is the TPACK framework, which is depicted in Figure 2.9. The framework aims to raise awareness of the need to incorporate technology into teaching while carefully considering pedagogy and content. The importance of teachers being able to use technology and comprehend why they do so is emphasized in the framework. The conceptual framework of TPACK, based on technological, content, and pedagogical knowledge, was proposed by Mishra and Koehler (2017). The integration of Technological Pedagogical Content Knowledge is advocated by the TPACK framework.

The issue of defining the boundaries of various sets of knowledge is contentious, despite the fact that these three areas are straightforward to identify. However, if the author had expanded the scope of the study, there might have been a greater chance that it would have helped to reveal the interconnectedness of the various aspects of knowledge, highlighting the importance of content knowledge and its superiority to pedagogical and technological knowledge. The model's assertion that there are only three areas of knowledge will be dispelled as a result of this.

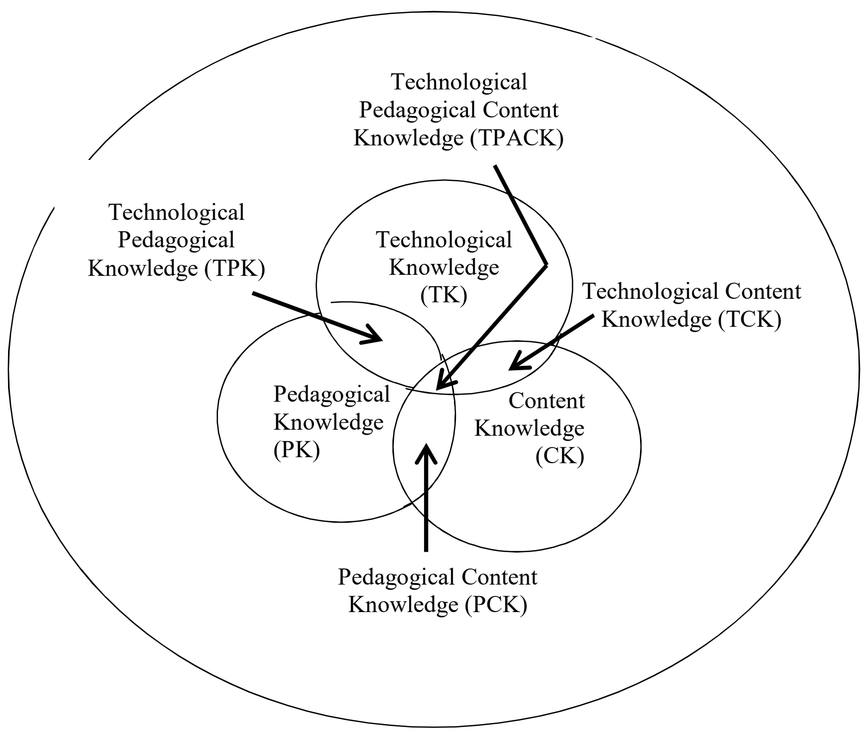

Figure: 2.9 TPACK Framework

In contrast to the current model, which focuses on content-specific pedagogies and is only applicable to language teaching, this could significantly build the model by broadening its subject matter and content. Instructors will find this helpful in stating the learning objectives. As a result, the framework will be useful for teaching a wide range of subjects and will take into account measures of a student-centered approach, which are a major concern in current pedagogy.

2.7.4 Functionality Framework

Patten, Tangney, and Sanchez (2006) came up with this framework as a way to categorize ICT software applications that can be found on handheld devices that are used for education. The framework can monitor how well students are doing with particular skills. Referential applications are included in the framework, allowing teachers and students to store documents and access content in various formats. The lesson can be repeated at any time; anywhere, and this might even make it simpler for students to listen to missed lessons. Students can take part in activities that are focused on question-and-answer games and include information and images thanks to the framework's interactive applications. Using the capabilities of both desktop computers and hand-held devices, applications that collaborate are supported by this framework developed to create a knowledge-sharing learning environment (Chen et al., 2008). These devices' features provide teachers with options essential to student-centered and active classroom learning.

The Functionality framework is illustrated in Figure 2.10 below.

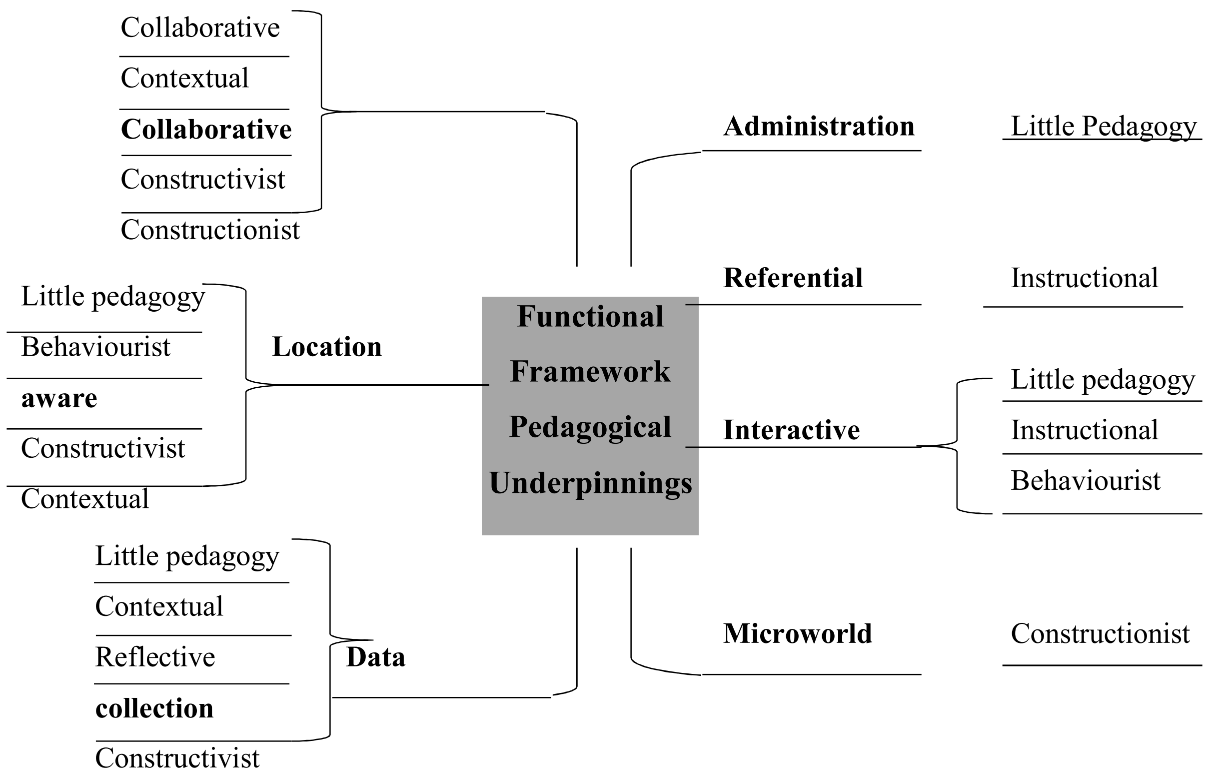

Figure 2.10: Functionality Framework

Patten et al (2006) show that the capability of the ICT applications and programming for empowering information development must be understood assuming the innovation is utilized in a way that matches the educational foundations of cooperative information assortment and miniature universes programming applications. The framework makes micro worlds software applications compatible with both desktop and laptop computers. Students can experiment in real-world domains in virtual environments with restrictions to construct their own artifacts and prototypes with the help of 3D software programs like educational Gerber technology and Lectra-3D Modaris fit.

Having said that, if the author had expanded the study's scope to take into account the processing power of handheld devices and diverted the interactive application's focus from drills and tests to skills and competencies, the model, in my opinion, would have produced better outcomes. Additionally, because it integrates both functionality and pedagogy into a single framework, this has the potential to close the model's gaps and make it an ideal teaching model for the twenty-first century.

2.7.5 People Process Product Continuum (P3) E - Learning Framework

Khan (2005) claims that the P3 Framework provides insight into the stages of the e-learning process, the goals of role players-research, project managers, directors, instructional designers, and design coordinators - as well as their outputs. The activities place a significant emphasis on education by involving the project teams in the creation of a project plan. The primary goal is to make sure that role players stick to the project plan's pedagogical features and keep learner needs at the centre of their attention. Through each stage, the framework identifies the P3 framework's e-learning process system design and demonstrates that learning and pedagogical principles are central components.

It is evident that adhering to meet learning needs using instructional principles isn't just the job of one member of the project team; rather, it's a shared responsibility that needs to be done by everyone on the team. According to the framework (Khan, 2004), an e-learning system is constructed in such a way that its primary focus is on planning for learning requirements. The P3 system is shown in Figure 2.11. A well-designed, learner-centered, interactive, efficient, affordable, flexible, easily accessible, meaningful e-learning environment can be created using this design. According to Rezaee et al. (2016), the P3 framework offers a comprehensive procedure for the e-learning process and aids in determining the roles and responsibilities associated with the implementation, development, design, evaluation, and management of blended learning and e-learning products.

E-Learning P3 Model

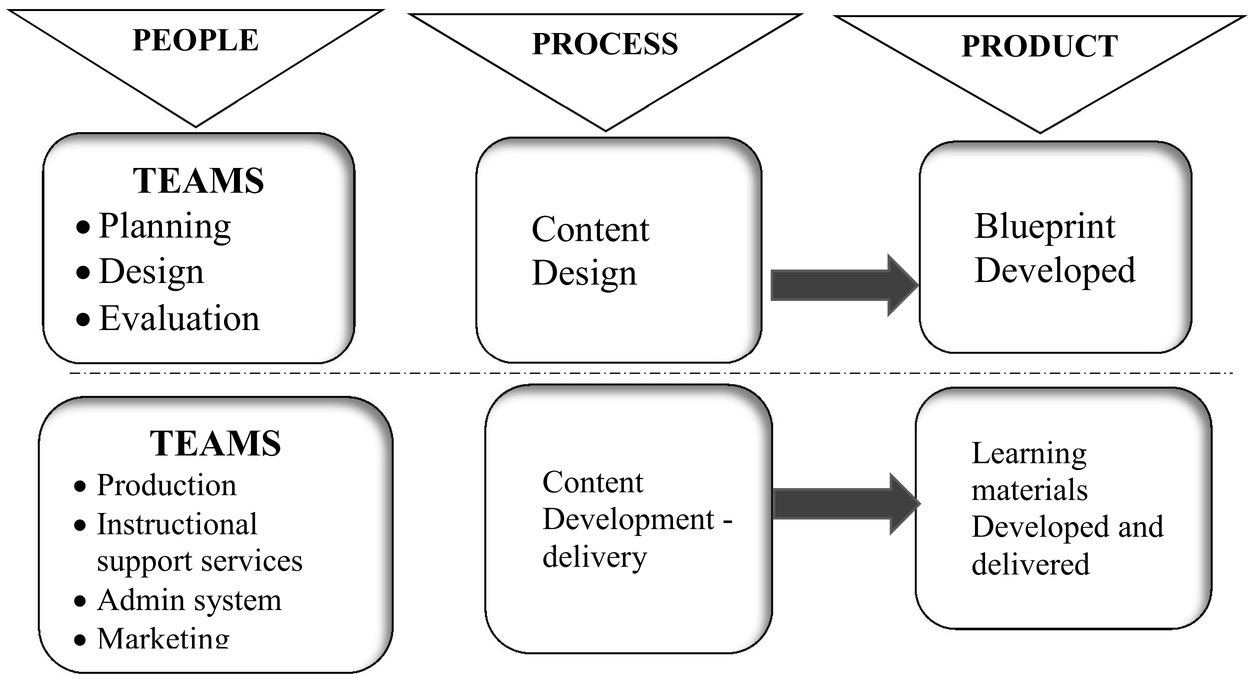

Figure 2.11: E-Learning P3 Model

While looking at important issues, the P3 framework can be used in an e-learning environment and offer useful insights into what needs to be changed or improved. However, the P3 framework could have been more concrete if the author had extended the study to the extent that the model not only puts more emphasis on content delivery, however, it also addresses the requirements of the students and the advancement of the content

2.7.6 The Khan's eight-dimensional E-learning framework

The goal of the study by Khan (2017), eight-dimensional e-learning framework is to create a distributed, open, flexible, and effective learning environment for a wide range of students. According to Khan's research, an effective instructional environment to structure learning requires eight dimensions or components (Khan, 2017). These eight parts are as follows: pedagogical, resource support, institutional, technological interface design, evaluation, management, design interface, and ethical considerations, which are steps in the framework that happen at random and are not arranged in any particular order. Using elements of the eight-dimensional resources, instructional design principles, framework, and technology this framework discusses analysis and investigation.

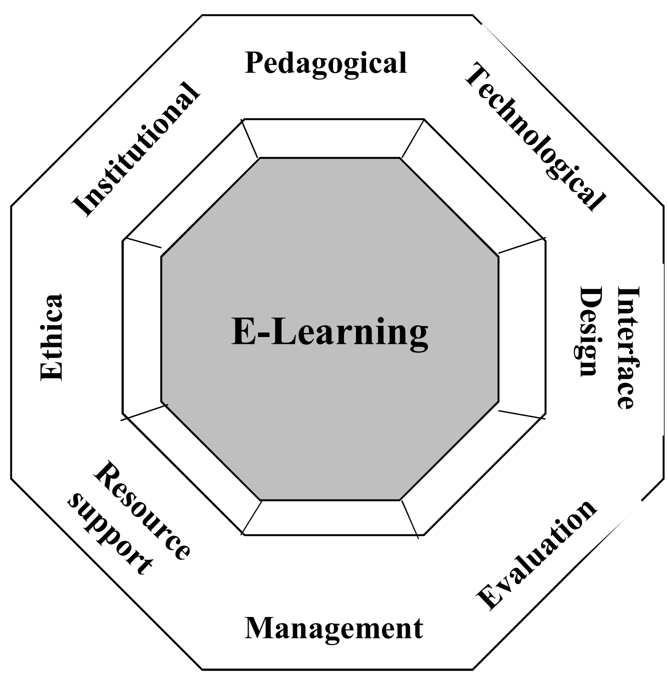

Figure 2.12: The Khan's Eight-Dimensional E-Learning Framework

In my opinion, this framework brings blended learning, which is a continuum rather than just a learning event, and it addresses the issues of equal opportunity for all students irrespective of their gender or socio-cultural background. Nonetheless it is important to point out that the model is silent on the transformation of policies, learning curricula, and strategies, which is a shortcoming that the author should have resolved by extending the study to accommodate the said variables.

2.8 Knowledge Gap

The literature review has highlighted a substantial amount of research supporting the effectiveness of ICT integration when used properly. The studies indicated that students who use virtual classrooms are perceived to be superior to the traditional classrooms however there were no direct studies that have tried to relate the effect of virtual experiments on learner's classroom involvement. Even though the use of animations and simulation, which is one of the primary elements of virtual experiments, promotes understanding of abstract topics, no previous study has looked into how the use of VLBI creates more interactive Physics lessons and improves learner achievement in abstract topics such as Radioactivity and X-ray. According to the reviewed studies, ICT initiatives in education worldwide have demonstrated that ICTs can only be effectively utilized when intended users are competent. This means that the user needs to have the knowledge, skills, and mindset to use the technology when it's needed for the job. In light of this, the purpose of the current study was to determine the expertise and skills of teachers when it came to creating and utilizing virtual experiments. The study looked at a variety of ICT frameworks and found that each one had specific flaws that made them less effective.

The SAMR framework shows how a learning activity changed, but it doesn't say how to figure out how valuable that change was or how students played a role in the learning process. Regarding the ASSURE framework, it reveals a scant and inadequate analysis at its inception because it does not clarify certain instructional issues, such as learning constraints and new behavioural outcomes (Daniyan, 2015). This goes against the idea of active learning, in which materials are made and tested before the learner uses them to figure out what obstacles they might face. Although the TPACK framework promotes the use of technology in education, it does not specify how students should apply their ICT knowledge to enhance their participation and outcomes in physics education. Subsequently, the TPACK model can't defend a coordinated dynamic learning climate since it accepts that the three subject matters exist in disconnection.

In a similar vein, it is essential to note that the P3 framework places no emphasis on the requirements of the students or the improvement of the content, whereas the epicentre of ICT-based active learning is the improvement of the students' learning outcomes. In addition, over the course of the previous five assessment waves, the PISA measures of ICT use have evolved. The questionnaires for the subsequent four cycles were generally more specific and detailed than those for PISA 2000. In terms of programs and software, the variety of applications that are available has also grown dramatically with the rapid development of ICT. These applications range from basic tools like painting, drawing, word processing, spreadsheets, and processing tools to more advanced tools like software for education-related and programming learning software. For instance, the PISA 2000 questionnaire only included three items regarding the frequency with which students use the Internet for entertainment.

However, subsequent rounds included additional items that covered a variety of activities to measure students' ICT use and behaviours. By examining the pedagogical implications of the integration of VLBI in teaching physics in secondary schools, the current study aimed to fill a gap in previous research by examining the potential trend of ICT influence over time. In addition, the current study is informed by the need to seal loopholes identified in the reviewed literature so that the findings are based on a broad global spectrum of students' achievements in Physics. As a result, the study takes into account how students learn skills and competencies and encourages students of all characteristics to actively participate in classroom activities.

CHAPTER THREE
METHODOLOGY

3.1 Introduction

This Section describes the methods that were used in carrying out the study, research design, geographical area, target population, sampling design, data collection, data analysis, research instruments, reliability and validity of the study instruments and ethical considerations. In research, the term "methodology" refers to a method of systematically acquiring nw information through careful planning and interventions for information discovery or interpretation (Peat & Barton, 2005). Methodology embraces the research design, ethical considerations, population, instruments used to collect data, data analysis and its interpretation.

3.2 Research Design

As highlighted by Roy (2014), research design is the plan and procedures for a study that ranges from broad aspects to specific data collection and analysis strategies. The Solomon-Four Group quasi-experimental research design was used in this study. The Solomon-Four group design was adopted since the study involved comparing attributes of a specific group of students and measuring the changes using pre-test and post-test in absence and presence of a defined treatment (intervention) that the study targeted. Solomon's Four Group research design is the most desirable of all the basic experimental design (Kim, 2005). The study sample was divided into experimental group (E) and the control group (C). The students that were chosen to represent the experimental groups were further divided into true experimental group (E_1) and experimental group (E_2). Similarly the students that were chosen to represent the control groups were equally divided into two categories; true control group (C_1) and control group (C_2). A pre-test was administered for true experimental and true control groups. The experimental groups were then taught the chosen topic (Radioactivity) using VLBI while the control groups were taught the same topic using the conventional methods. An achievement test with a test retest reliability of 0.87 was administered for all the groups as post-test. Solomon Four research design adopted for the study has been summarized in Table 3.0 below.

Table 3.0: The Solomon Four Group Design

Group	Pre-test	Treatment	Post-test
E_1	O_1	X (VLBI)	O_2
C_1	O_3		O_4
E_2		X (VLBI)	O_5
C_2			O_6

O= Outcome Measure

Solomon Four entails an investigation of issues as they affect an activity such as ICT integration in teaching, the quasi-experimental research design was determined to be the most suitable for this research. In addition, it provides a comprehensive interpretation of a process by allowing for the examination of a number of research questions (Zamani & Rezvani, 2015). The researcher worked with the existing intact classes, making the quasi-experimental design suitable for this study.Once classes have been constituted (in secondary schools), they are regarded as intact groups and school characteristics do not allow reconstruction for purpose of research.

Shuttleworth (2009), asserts that the design makes it possible for the researcher to have a total control over the variables and to check the impact of pre-test on the results. With the exception of those that are associated with interactions of maturity and history, and maturation and selection, instrumentation and selection, the design controls everything that could threaten the study's internal validity (Kenny, 2019).

3.3 Location of the Study

The settings of this study were selected secondary schools in Kisumu County, Kenya. These involved both rural and urban public schools in Kisumu West, Kisumu Central, Kisumu East, Seme, Nyakach, Muhoroni and Nyando sub-counties. Kisumu county lies on longitudes of between 35^0 20' and East 33^0 20' East and latitudes of between 0^0 20' South and 0^0 50' South. The county borders Vihiga countyto the North, Nandi county to the North East,Kericho county to the East, Nyamira to the South, Homabay county to the South West and Siaya county to the West. The inhabitants of Kisumu County are majorly subsistence farmers who engage in fishing, growing crops such as sugarcane, maize, beans, millet, fruits and rearing livestock. They also run small scale businesses including retail shops, tailoring, carpentry workshops and pottery.

The county's poverty index according to Kenya National Bureau of Statistics (KNBS) stands at 32.5% (2019/2020) with majority of the household owning less than an acre of land. The level of ICT infrastructure in Kisumu County varies from one Sub County to another. Approximately 80% of secondary schools in Kisumu central sub county are well equipped with ICT pedagogical infrastructures in comparison to the other six sub counties (Waga, 2017).

The study brought out the challenges experienced by both rural and urban schools with respect to ICT. Rural schools experience more problems but are ignored by researchers who go to urban schools to carry out research as the research literature has nothing to offer from such areas. Integration of ICT in education requires a requisite ICT infrastructure, yet most schools in rural areas lack such now and in the foreseeable future. Kisumu County launched a number of digital literacy programs for teachers and students in collaboration with some organizations such as Africa Centre for Women, Information and Communication Technology (ACWICT) in order to raise the level of digital literacy among the students and teachers. Kisumu County has 283 public Sub-county secondary schools and was selected due to the different economic and geographical settings in the seven Sub-counties in the county. The sets include; hardship zones, rural zones and urban zones. A map showing location of Kisumu County is in Appendix E.

3.4 Target Population

This research was carried out in Kisumu County, Kenya which has a total of 283 public sub-county secondary schools with an eligible population of 124,738 (61,885 boys and 62,853 girls) with an estimated 2,997 teachers (Kisumu County Education Office, 2019). The target population consisted of Physics teachers who had undergone CEMASTEA in-service course in ICT integration in the teaching of Physics and form three Physics students in the 283 public secondary schools in Kisumu County, Kenya. The county has an estimated 88 CEMASTEA trained Physics teachers in ICT integration in instruction and 3,500 form three Physics students. For the Form three cohort, the topic ‘Radioactivity” was chosen and placed among the top in the hierarchy of difficult topics by students and teachers (Ngari, 2017). The choice of form three was informed by topic of choice that the study focused on. The CEMASTEA trained Physics teacher were chosen since they understood the pedagogical demands that involves E-learning and integration of VLBI in instruction. TSC Code of Regulations for Teachers (2013) which is in line with Career Progression Guidelines of 2018 outlines the functions of CEMASTEA trainers as: supervising and coordinating the ICT training programs at the centre and in the County; guide and supervise the development of ICT training materials; facilitate and evaluate INSET sessions for mathematics and science teachers; conduct and evaluate workshops for institutional administrators; administer monitoring and evaluation tools after training and prepare training modules. All these duties enable the teachers who had undergone CEMASTEA training to have enough experiences hence gave information to address the objectives of this study. Participation of the students in this research was meant to establish the level of ICT preparedness in secondary school and how VLBI is integrated in curriculum implementation. Their participation in this study was handy and quite informative.

3.5 Sampling Techniques and Sample Size

In order to determine the sample size of this study, Taro Yamane formula with 95% level of confidence was used to compute the sample size (Yamane, 1977). Taro Yamane formula was considered appropriate for the study since the study involved a finite population with a known population size. Furthermore, the formula was considered ideal for the study since it considers the degree of variability (50%) in the teachers and students attributes being measured with low margin of error.

The study population was made up of 3500 form three students and 88 CEMASTEA trained Physics teachers. The population was classified in various strata and then random sampling applied to establish the sample that has commensurate attributes present in the population for a quasi-experimental research. Thus, Yamane's formula was deemed most appropriate in establishing the sample size for the study.

The Yamane's formula for the study:

$$n = \frac{N}{1 + N(e)^2}$$

Where - N = the study population

n = represent sample size

e = the acceptable sampling error

*95% confidence level and p=0.05 are assumed.

$$n = \frac{3500}{1 + 3500(0.05)^2}$$

= 358 students

$$n = \frac{88}{1 + 50(0.05)^2}$$

= 72 teachers

The sample consisted of Physics teachers who have undergone CEMASTEA in-service courses on ICT integration in teaching and learning of Physics and form three Physics students who were selected from the target population. For this research, purposive sampling was adopted in the selection of Kisumu County.

The county of study, which is, one of Kenya's 47 counties was selected due to the low cumulative average KCSE Physics means score (35.22) registered between 2016 to 2019, particularly in Kisumu County. A non-probability sampling method known as "purposeful sampling" enables a researcher to make use of cases which are beneficial with regard to containing the necessary information which is in line with the objectives of the study (Cresswell & Clark, 2017).

The schools were chosen using stratified sampling and simple random methods. The researcher listed all the schools in Kisumu County from the seven sub-counties. The schools were stratified into three categories: boys' boarding, girls' boarding and co-education (mixed) schools. By using stratified sampling technique, the researcher ensured that the listed school categories in their sample representation were proportional to the total population (Silverman, 2015). Using this method helped to make the schools' categories more representative and to take into account any differences that were already there. (Clark, 2015). The proportionate stratification method was then used to determine the sample size for each stratum. The population size of each stratum is proportional to the sample size in proportionate stratification. The following equation was used to calculate strata sample sizes:

$$n_h = \frac{N_h}{N} \times n$$

Where,

n_h = sample size

n= the total sample size

N= the total population size

N_h=population size for strata

Therefore, the sample size for each stratum is given in Table 3.1

Table 3.1: Sampling frame

Units	Population	Sample Size
Teachers	88	72
Students	3,500	358
Total	**3,588**	**430**

Source: Researcher (2018)

Simple random sampling was used in selecting three boys boarding school, three girls' boarding schools and four mixed schools from each sub-county. This was a way of ensuring that each member of the target population had an equal opportunity of being selected as part of the sample. Purposive sampling technique was employed to select the Physics teachers from each sampled schools. Physics teachers selected were those that had undertaken CEMASTEA in-service training on ICT integration and therefore well-equipped about ICT integration in teaching and learning. Simple random sampling and Purposive sampling techniques were employed to select student respondents. The form three class was chosen using purposive sampling from each sample school. After that, students who were enrolled in Physics as a subject that could be tested were chosen using simple random sampling. For single stream schools, the form three Physics class was chosen through the use of purposeful sampling, whereas for schools with two streams or more simple random sampling was used to identify the form three stream that participated in the study.

The study established that, a total of 114 respondents were selected from boys' schools and 114 respondents were selected from girls' schools and total of 130 respondents were selected from mixed schools. Therefore, 358 student respondents took part in this study. In total, the study comprised of 430 respondents (358 students and 72 Physics teachers).

3.6 Research Instruments

The study employed questionnaires, lesson observation schedule and Physics Achievement Test. These tools were selected based on the following reasons; the amount of time available for the study, the type of data to be gathered, and the objectives of the study (Bergman, 2015). Through the integration of virtual experiments into the learning and teaching of physics in public secondary schools in Kisumu County, the overall goal of this study was to enhance active learning and improve learning outcomes. The main concern of the study was on students' and teachers' views, attitudes, and opinions about VLBI in learning of Physics. This kind of information can best be obtained through the use of questionnaires, Physics Achievement Test for Student (PATS) and lesson observation (Kothari, 2017). The Physics Student Questionnaire (PSQ) and Physics Teachers Questionnaires (PTQ) were divided into four sections of Tyler's (1949) model of program evaluation: objectives, content, teaching methods, and assessment. (see Appendices B and A).

3.6.1 Physics Students Questionnaire (PSQ)

Physics Students' Questionnaire (Appendix A), was used to collect data on students' motivation on the use of ICT virtual laboratory-based instruction lessons.

The PSQ contains 11-Five point bipolar Likert-type on the various teaching and learning dynamics. All the items were measured on a 5-point Likert scale ranging from ‘‘strongly agree’’ to ‘‘strongly disagree’’. This type of ordinal scale measures the intensity of feelings and the items generate more information as compared to dichotomous scoring, and it is suitable for statistical analysis since it faithfully reflects the individual differences and the attributes (Nunnally & Bernstein, 1994). Before its use in actual study, the PSQ was tried in a group of 40 students from a secondary school in the neighbouring county (Siaya) that posted relatively lower average KCSE mean (36.7). The data was analysed using $K\text{-}R_{21}$ formula and a reliability coefficient of 0.80 was established.

3.6.2 Physics Teachers Questionnaire (PTQ)

The PTQ (Appendix B) was used to gather information about the opinions of Physics teachers on the use of VLBI lesson on teaching and learning of Physics. It had 30-items. The first section consisted of 26 –Five-point Likert bi-polar scale. It was used to assess Physics teachers’ opinions on learners’ level of interaction in the classroom, selected ICT frameworks and the frequency of use of experimental approach as a teaching methodology when VLBI is adopted. Their judgement was rated on a 5-point Likert scale ranging from ‘Strongly Agree’ (SA), ‘Agree’ (A). ‘Neutral’ (N), ‘Strongly Disagree’ (SD), and ‘Disagree’ (D), and the second section of the questionnaire consisted of open-ended questions about gaps and ways to improve objectives, content, teaching methods, and assessment strategies for effective physics education in secondary schools.A reliability coefficient of 0.76 was obtained when teachers’ responses were scored and treated with K-R 21 formula that requires single administration of the instruments (Kathuri and Pals, 1993).

3.6.3 Lesson Observation Schedule (LOS)

A lesson observation schedule is essential in various ways: it eliminates subjective bias if accurately conducted and it directs a researcher to pay attention to certain behaviours and situational features when carrying out the research (Kothari, 2017). Lesson observation schedule (Appendix C), had four sections. It was crucial for both classroom and laboratory data collection. The observer completed the first section of the schedule with information about: the school's name, the subject, the class, the time, and the number of girls and boys in the class or the roll. The second section of the guide was on students' behaviour towards VLBI lessons. The observer filled in data on teaching methods and learners' motivation, curiosity, creativity, level of participation and teaching and learning activities used during the lesson. The observer then asked for consent from the school principal to take some videos and photographs to give a clearer picture of the Physics classrooms (Appendix C).

3.6.4 Physics Achievement Test for Students (PATS)

Physics Achievement Test for Students (PATS) was constructed and standardized by the experts, there after the test was used to assess the learners' achievement level. PATS was administered to know the level of mastery of content before and after the treatment. PATS contained 30-structured questions on the concept of Radioactivity. To guarantee the adequacy of the instrument to assess the effectiveness of virtual experiments lessons on students achievement, PATS test items were judged by six experts (two university educators and four secondary school teachers) knowledgeable in Physics content at the secondary school level. Language and grammar and other noticeable difficulties were corrected before the actual implementation.

The researcher carried out a pilot study in the Kisumu County that is adjacent to the study area in order to guarantee the PATS's reliability. The K-R_{21} formula was used to test PATS's reliability. Accepted was a reliability coefficient of 0.7 and higher. The researcher inducted sampled form three Physics teachers in the experimental groups on the use of VLBI in teaching. Teachers in the experimental groups were expected to teach Physics by integrating ICT virtual experiments while their counterparts in the control groups used the Conventional Teaching (CT) strategy.

3.7 Quality Control

3.7.1 Validity

According to Bostic and Jonathan (2017), the degree to which the instruments measure the intended outcomes is known as validity. When a research instrument's contents are relevant, appropriate, and adequate to the point where they can provide sufficient information to answer the research questions, it is deemed valid. Face, content, criterion, and construct are the four types of validity that were identified by Zohrabi (2013).

According to the research design and instruments, face and content validities were the most applicable forms of validation for this study. (Cohen & Manion, 2013). To establish content validity, the instruments were presented to two experts (advisors) in the School of Education, Masinde Muliro Universtity of Science and Technology (MMUST). One was asked to evaluate the concept that the instrument was designed to measure, and the other was asked to assess whether the collection of items accurately portrayed the idea that was the subject of the study. This was done to make the instruments more reliable, to determine how relevant each item was to the goals, and to give each item a score on a scale of: ‘Not relevant’ (1) , ‘Somewhat relevant’ (2), ‘Quite relevant’ (3), and ‘Very relevant’ (4), This was ascertained before the commencement of the actual research. The Content Validity Index (CVI) was derived as follows: items rated 3 or 4 by both the total number of questions in the questionnaire was divided by the supervisors (judges). Mathematically speaking, this is expressed according to the formula:

$$C.V.I = \frac{Agreed'items'by'both'\sup ervisors}{Total`number`of`items}$$

The content validity index on the simplicity and comprehensiveness for the questionnare items for LOS, PATS, PSQ and PTQ were established as 0.93, 0.92, 0.89 and 0.84 respectively, ranged between 0.83 to 1.00 which is within the CVI accepted values (Vakhshoori et al, 2022). According to Kothari (2017), face validity of research instruments is achieved by having a panel of experts evaluate the relevance and representation of each component of the instrument. To address face validity in this study, my lecturers and supervisors from MMUST, School of Education, who were experts in the subject matter, combined their opinions to improve each of the data collection instruments. Ambiguity was addressed by examining each item based on clarity and readability. This was to ensure that everything met the expected objective. In the first phase of the study, the piloting of the research instruments was used to determine the instrument's content validity. The credibility, relevance, and scope of the data from the pilot study were examined for their ability to respond to the study's research questions and all aspects of the theoretical framework.

Based on the piloting experience, some of the items on the research instruments were changed to make them more effective. During this time, some respondents asked for clarification on some of the items, and experts offered suggestions.

3.7.2 Reliability of the research instruments

Roy (2014) defines reliability as the degree to which a research instrument yields consistent data or results after multiple trials. To establish reliability, the test-retest technique was first adopted to assess reliability of the instruments. The test-retest method involves giving the same set of instruments to the same group of people twice. During pilot study the second test was administered two weeks after the first test, keeping constant the initial variables (Kothari, 2017). To avoid contamination, the schools, teachers, and students who participated in the pilot study were not included in the actual study. (Silverman, 2015). Moreover, to make the instruments dependable, the sample for piloting formed approximately 16% of the study population which is above the 10% minimum (Brooks, 2016). Second, the instruments' reliability was assessed using the internal consistency approach. The internal consistency of the data was evaluated using the scores of a single test that the researcher administered to a sample of subjects.

A score on one instrument item was correlated with scores on other instruments' items using this method. In this research, the reliability coefficient was calculated using the Kunder-Richardson (K-R) 20 formula.

The K-R 20 formula is as follows:

$$KR_{20} = \frac{(K)(S^2 - \sum s^2)}{(S^2)(K-1)}$$

Where: KR_{20} = Reliability coefficient of internal consistency

s^2 = Variance of individual items

K = Number of items used to measure the concept

S^2 = Variance of all scores

KR_{20} scores ranges from 0 to 1; 0 indicates no reliability and 1 represents perfect test reliability. If KR_{20} score is 0.9 internal consistency is excellent, 0.8 implies good, 0.7 is acceptable while 0.6 is questionable, 0.5 is poor finally below 0.5 is unacceptable (Zimmerman,1972). Based on item in the students' questionnaire, and Physics teachers' questionnaire, Lesson observation schedule and Physics achievement test, the study established KR_{20} scores of 0.87, 0.9 and 0.76 respectively. All of the study's measures had reliability coefficients greater than or equal to the minimum acceptable KR_{20} coefficient, which indicated that they were highly reliable.

3.7.3 Pilot Study

A pilot study was done in order to determine the validity and reliability of the instruments before the actual data collection. The pilot study assisted the researcher in determining which areas required modification in the research instruments in preparation for the actual study. Four schools which were not part of the prior selection, took part in this pilot study (Silverman, 2015). Of the four schools, two were of mixed gender whereas two were of single gender (one a boys' boarding school and the other girls' boarding school.

Girls' or boys' day schools were not considered for the study because they are very few). In each of the four schools, one Physics Teacher (PT) was selected and 10 form three Physics students randomly selected, yielding a total of 15 respondents from each of the four schools. Pilot study schools and participants did not take part in the actual study to avoid bias results (Bergman, 2015). The purpose of this pilot study was to test the suitability of items with the intention of improving their validity and reliability (Muoio et al, 1995; De Vaus, 1993). The anticipated problems were detected in the methods and effective changes made before the large-scale study was undertaken. The methodological question(s), guided the development of the research plan and assessed the feasibility of the research report (Leonet al, 2011)

3.8 Data Collection Procedures

An approval of the research proposal by the Board of Postgraduate Studies - MMUST and the senate was sought. Authorization to gather information from the respondents was sought from The National Commission for Science, Technology and Innovation (NACOSTI) and administrators of chosen schools. Data was collected using four instruments; Physics Student Achievement Test (PATS), Physics Students Questionnaire on ICT virtual experiments (PSQ), Physics Teachers Questionnaire (PTQ) on their competencies and opinions about ICT virtual experiments and Lesson observation schedule (LOS). Self-administered questionnaires (PSQ and PTQ) were used to collect primary data from students and teachers. At the same time, lesson observation schedules were filled by the observer to identify the teaching methods used and learners' reaction towards VLBI lessons.

3.9 Data analysis

The independent variables in this research study were students' level of interaction in the classroom, students' achievement, frequency of use of experimental teaching approach, relationship of teachers' knowledge on selected ICT frameworks and use of VLBI while the dependent variable was implications of VLBI on students' learning of Physics.

Therefore, descriptive and inferential statistics were used to collect and analyse both quantitative and qualitative data. (Creswell & Plano, 2012). To make coding easier, field-collected data were compiled and sorted to ensure consistency and accuracy. The coding was done according to the type of data where quantitative data was coded using numbers whereas qualitative data from open-ended questions and lesson observation was organized into themes. Measures of central tendencies and measures of dispersion are used in descriptive analysis. Means and percentages were the descriptive statistics used to analyse quantitative data, whereas inferential statistics were, t-test, ANOVA, Duncan Post Hoc test and multiple regression analysis.

Qualitative data were organized in narrative format and was analysed in themes. One way ANOVA was used to establish the total variation between each group mean and the overall mean and the total variation t-test were used to test if any significant differences existed when VLBI (intervention) was teaching approach was employed compared to the conventional teaching method. In order to establish exactly where the mean differences may lie and the direction of the mean difference, a post hoc multiple comparison test was performed using the Duncan Multiple Range Test for Difference.

Multiple regression was used to determine whether the level of classroom interaction, learners' achievement, use of experiments as teaching approach and the scope to which the major existing ICT framework promote ICT integration together predicted implication of virtual laboratory- instruction on students' learning of Physics in secondary schools. The four independent variables were considered together (in one equation) as predictors of implications of virtual laboratory-based instruction (dependent variable). In multiple regression analysis, the regression model was of the form:

$Y = \beta o + \beta_1 X_1 + \beta_2 X_2 + ...\beta_n X_n + \sum$

Where: Y - is the dependent variable

X_1-n – represents independent variables

βo – represents a constant

β_1-n – represents the regression coefficients

$\sum$ - is the error.

Regression analysis also produced a statistic called coefficient of determination (R^2). The R^2 refers to the amount of variation explained by the independent variable. A computer would provide a t-value and the probability level for each t-test for each value of b (slope) in order to determine regression and test of significance. A probability level and an F-statistic were also produced by regression analysis. At the chosen probability level, the F-statistic indicates whether one or more of the independent variables significantly predicted the dependent variable.

Regression and test of significance was done with the assumptions that:

a) The relationship between the dependent variable and each independent variable is linear.

b) The fact that the observations are unrelated to one another suggests that the sample was selected at random.

c) There is homogeneity of variance because the variance of the Y values remains constant at each level of X.

d) At each level of X in the population, Y values are normally distributed around the mean.

3.10 Ethical Considerations

The ethical issue of concern in this study was mainly on the privacy and confidentiality of the respondents and sample schools. Considerable time was taken to address ethical principle beneficence and non-maleficence, confidentiality, anonymity and the role of the researcher. A letter was written to the Principals of the sampled schools to seek permission to conduct the study in the sampled learning institutions. A covering letter with official authority from the university and a university identity card were used as means of identification (Macdonald, 2016). An authorization from NACOSTI to carry out the research was obtained. Confidentiality was maintained using good data collection and storage practices. This was achieved by ensuring that the team that were involved in the study were trained on ethical issues and understood not to discuss participants outside the research context.

All participants in this study are anonymous and they were asked to participate voluntarily, without disclosing their identity by not writing their names on the questionnaires. This was done to ensure honesty and openness (Wilson, 2016). The information collected is under full responsibility of the researcher as an individual and therefore the researcher has ensured that the information is safely kept and has been used only for the purposes of the study (Macdonald, 2016). Plagiarism in this study has been taken care of by citing accurately and paraphrasing precisely. In order to safeguard academic integrity, the content was checked using Turnitin, an online originality checking service (Childers, 2016).Finally, the was strict adherence to the tenets of non-maleficence and beneficence.

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Introduction

The study sought to establish the implications of integration of virtual laboratory-based instruction on students' learning of Physics in secondary schools in Kenya. In this study, a link was adopted and approved to be used for accessing virtual apparatus that were used to develop virtual laboratory-based instruction for teaching the topic concerning Radioactivity (Phet, 2020). The study thus queried the effects of virtual laboratory-based instruction on the students' level of interaction in classroom, students' achievement, the frequency of use of experimental approach as a teaching strategy and the relationship between the teachers' ICT systems and the utilization of VLBI in the teaching of material science in auxiliary schools. As a result, the study's findings are discussed and interpreted in this chapter.

A total of 358 form three students took part in the study. All the 358 students were exposed to the same content on Radioactivity in Physics (covered in 10 lessons) over a period of two weeks. The experimental group learnt through integration of VLBI in teaching and learning while the control group learnt through the conventional teacher directed methods. Four null hypotheses were tested in the study:

H_{01}: There is no statistically significant difference on students' level of interaction in classroom between students exposed to virtual laboratory-based instruction and those not exposed.

H_{02}: There is no statistically significant difference in student's achievement in Physics between students exposed to virtual laboratory-based instruction and those not exposed.

H_{03}: There is no statistically significant difference on the frequency of use of experimental teaching approach between students exposed to virtual laboratory-based instruction and those not exposed.

H_{04}: There is no statistically significantt difference between the teachers' knowledge on selected ICT frameworks and the use of virtual laboratory-based instruction.

4.2 Administration and Return Rate of Data Collection Instruments

The data in the study was gathered using Physics Teachers' questionnaires, Physics students' questionnaire, lesson observation schedule and Physics achievement test for students. In this study, a total of 72 Physics teachers and 358 Physics students were sampled, giving a total of 430 respondents. Questionnaires and Physics achievement test were administered to the respondents directly and collected. The data collection instruments administration and return rate is shown in Table 4.1.

Table 4.1: Administration and Return Rate

Category of Respondents	Administered	Returned	%
Physics teachers' questionnaire	72	72	100%
Physics Achievement test for students	358	292	81.6%
Physics students questionnaire	358	282	78.8%
Total	**760**	**618**	**81.3%**

According to Table 4.1, a total of 72 questionnaires were given to teachers of physics. All of the questionnaires were filled out and returned, resulting in a response return rate of 100%. 358 questionnaires were distributed to form three Physics students, out of which 282 questionnaires were filled and returned, giving a students' questionnaire response rate of 78.8%. In addition, 358 Physics students were subjected to a sit in Physics achievement test exam where 292 were returned, making it 81.6% return rate. Further, 28 lesson observation schedules were filled from 28 different schools, each from a different Sub-County. Fourteen of them were VLBI lessons (ICT integrated lessons) and fourteen traditional or conventional lessons. The return rate of lesson observation schedules was 100% since they were being filled by the researcher and research assistants.

Most percentages were within the recommended 50% and above return rate (Creswell, 2014). This proves the validity and reliability of the data as a true representation of the entire population. Additionally, Bryman and Bell (2015) state that a response rate of fifty percent is sufficient for analysis and reporting; A response rate of at least 70% is excellent, while a rate of 60 percent is acceptable. Against this background, the response rate was excellent for analysis, reporting and making of conclusions and recommendations regarding pedagogical implications of ICT integration in learning of physics in secondary schools in Kenya.

4.3 Demographic Results

Demographic information such as gender, age, academic qualification, teaching experience, and students' previous scores were implored to determine diverse traits of the respondents.

4.3.1 Gender

It was prudent to establish gender parity of the respondents to enable the researcher draw valid conclusion about the responses made base on the gender. Description of the respondents based on gender is shown in Table 4.2

Table 4.2: Gender Distribution

Gender	Teachers		Students		Total	
	N	%	N	%	N	%
Male	47	65.3	181	50.6	228	52.2
Female	25	34.7	177	49.4	208	47.8
Total	**72**	**100**	**358**	**100**	**436**	**100**

The findings in Table 4.2 indicate that more males take Physics as a subject as compared to females. The results suggest that there were more male (30.6%) Physics teachers than female Physics teachers. This, in turn, leads to a smaller number of female Physics teachers in secondary schools in Kenya. The result of gender distribution indicates that, the predominant attributes and opinions in the findings of the actual study were from male gender. This can distort or skew the results of the study in a particular direction giving a false notion. These results show similarities with a previous study by Semela (2010) on who joins Physics and why.

4.3.2 Teachers' Age

Only teachers were required to provide information on their age since students were assumed to be of the same cohort. The range of teachers' ages is shown in Table 4.3.

Table 4.3: Teachers' Age Distribution

Age (Years)	Male		Female		Total	
	N	**%**	**N**	**%**	**N**	**%**
Below 30	12	25.5	8	32.0	20	27.8
31 – 40	19	40.4	12	48.0	31	43.1
41 – 50	10	21.3	4	16.0	14	19.4
Above 50	6	12.8	1	4.0	7	9.7
Total	**47**		**25**		**72**	**100**

The study found that more than half of the Physics teachers, 51 (70.9 %) were youthful aged below 40 years. Surprisingly, there was only one female teacher of Physics who was above 50 years. These findings point out that, either it is only recently that female teachers started pursuing Physics as a teaching subject, or that when female Physics teachers start aging, they opt to teach their second subject other than Physics. As a result, female students are prone to miss female role models to encourage them to study Physics.

4.3.3 Academic Qualification

The highest academic qualification attained by the Physics teachers was presented indicated in Table 4.4., to show the level of training of Physics teachers who participated in the study.

Table 4.4: Academic Qualification of teachers

Level of Education	Gender			Percentage
	Male	Female	Total	%
Diploma	9	4	13	18.1
Bachelors' Degree	30	18	48	66.7
Master's Degree	6	3	9	12.5
PhD	2	0	2	2.7
Total	**47**	**25**	**72**	**100**

The findings in Table 4.4 indicated that, 66.6 % of Physics teachers had earned a bachelor's degree in secondary education, a 4-year programme for those intending to teach in high school whereas 18.1% had a diploma in secondary education, a 3-year programme. In addition, the findings show that only two teachers accouting to 2.7% had a doctorate degree. The results revealed that all the Physics teachers (100%) underwent professional training as a requirement during time of employment and should therefore be well versed with the best strategies that are involved in the course of teaching . The results did not, however, indicate whether the teachers understood the significance of VLBI integration in teaching Physics or otherwise.

4.3.4 Teaching Experience

The findings that were gathered based on the teaching experience of Physics teachers' in Kisumu County presented in Table 4.5.

Table 4.5: Teachers' Teaching Experience

Teaching experience (Years)	Frequency (N)	Percentage (%)
0 – 5	23	31.9
6 -10	28	38.9
11 – 15	13	18.1
16 and Above	8	11.1
Total	**72**	**100**

From Table 4.5, 70.8% of Physics teachers had taught Physics for at least 8 years with 38.9% of the teachers having an average teaching experience of 5 years. Majority of physics teachers have a longer teaching experience. This implies that Physics teachers selected for the study had adequate knowledge and skills in teaching and learning Physics. These findings are consistent with the study by Adeyemi (2010) who found out that teachers teaching experience is a critical variable in teaching and learning of Physics. Also, a teacher who has taught Physics for a long time is more likely to come up with hands-on activities during the teaching process (Anderson, 2015).

4.3.5 Physics Students' Achievement in Physics

The study aimed at establishing Physics students' previous achievement in terms of percentage.

Table 4.6: Physics Students' Previous Achievement (Form Two End Term)

Students' Score	Frequency (N)	Percentage (%)
A	18	5.1
B	49	13.7
C	85	23.6
D	191	53.4
E	15	4.2
Total	**358**	**100**

The lowest score indicated by the respondents was grade E whereas the highest score was grade A. The average score for all the 358 student respondents, was D. Physics teachers were asked to indicate their school KCSE average mean score and mean grade respectively for the last three years. The results revealed that 57.6% the schools had average mean between 1.0(E) to 3.4 (D), whereas 37.3 of the schools had registered an average means score of between 5.5 (C) to 9.4 (B plain). The results indicated that majority of Physics students grades were below average. This finding in Table 4.6 coupled with the teachers report on the cumulative average score of students at KCSE level, shows low performance in Physics in Kisumu County.

These worrying findings were in line with the findings by Njoroge et al., (2014) who in their studies pointed out that Physics performance over the years in summative evaluation (KCSE) at the end of secondary school cycle had been declining.

4.4 Test for Normality

The normality test was done at 95% confidence interval. If the p-value is less than 0.05, then the null hypothesis is rejected and there is evidence that the data tested is not from a normally distributed population. If the p-value is greater than 0.05, then the null hypothesis stating that the data came from a normally distributed population is accepted. Kolmogorov-Smirnov (KS) goodness-of-fit test and Shapiro-Wilk (SW) test for normality was done to test the hypothesis;

$$H_0: \textit{the data is drawn from a normal distribution}$$
$$H_1: \textit{the data is not drawn from a normal distribution}$$

The findings are as shown in Table 4.7.

Table 0.7: Normality test for Faculty data

Tests of Normality	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	Df	Sig.	Statistic	Df	Sig.
Level of interaction	.110	173	.291	.966	173	.152
Experiments	.065	173	.428	.992	173	.182
Achievement	.117	173	.304	.949	173	.121
ICT frameworks	.083	173	.116	.984	173	.239

a. Lilliefors Significance Correction

The KS results in Table 4.7 indicate that all factors were normally distributed as $p - values \geq 0.05$ and therefore not statistically significant at 5% level of significance and hence the data for the faculty respondents' questionnaire came from normal distribution and was normally distributed. On the other hand, the SW results in Table 4.7 shows that all factors were normally distributed as $p-values \geq 0.05$ and therefore not statistically significant at 5% level of significance. The results imply that we accept the null hypothesis that the data for respondents' questionnaire came from normal distribution and was normally distributed.

The SW results confirmed the KS results that the data on respondents' questionnaire came from normally distributed population and was normally distributed. This means that the tests of normality were significant and therefore parametric test should be used for analysis.

4.5 Homogeneity of Study Groups

Pre-test data was collected from the learners using Physics Student Questionnaire (PSQ), Physics Achievement Test (PAT) and the Lesson Observation Schedule (LOS). This was carried out to ascertain whether or not the students who participated in the study had similar characteristics. Only two groups C_1 and E_1 were pretested using Physics Achievement Test (PAT). To confirm if the groups used were homogeneous, the pre-test descriptive statistics of the mean score and standard deviation was computed. The results are shown in Table 4.8

Table 4.8: Descriptive Statistics for Level of Classroom interaction Pre-test

Schools	Mean	N	Std. Deviation
E1	26.4444	77	7.7509
C1	26.4621	74	7.4592
OVERALL	**26.4533**	**151**	**7.6051**

The pre-test results in Table 4.8 reveal that all the groups had nearly the same mean scores (homogenous) with regard to the learners' level of classroom interaction. A supplementary analysis of the results was conducted to determine whether the difference between the mean scores was significant at the=0.05. A one way Analysis of Variance (ANOVA) was carried out and the findings presented in Table 4.9

Table 4.9 ANOVA Table for difference in Level of Interaction Pre-test

	Sum of Squares	Df	Mean Squares	F	Sig
Between Groups (treatment)	13.968	1	4.324	0.124	0.875
Within Groups (error)	6005.761	149	34.935		
Total	**6018.7643**	**150**			

The findings in Table 4.9 show an F value of 0.124 with a significance of 0.875, which is greater than the acceptable alpha value of 0.05. This implies that the observed differences in the mean score of the pre-test were not statistically significant and therefore the groups had comparable level of participation before the study. To analyse the knowledge of students in Physics prior to the treatment, an analysis of their pre-test scores in PATs was carried out. The mean and standard deviation of pre-test scores on PATs for experimental group E_1 and control group C_1 are presented in Table 4.10.

Table 4.10: Independent Sample t-test results for Pre-test PATs

Cohorts	N	Mean	Std. Deviation	t-value	Df	Significance
E_1	148	5.3001	2.3345	0.0623	290	0.840
C_1	144	5.2783	2.1946			

The results in Table 4.10 show that mean scores for experimental groups E_1 and that for the control group C_1 for the pre-test were 5.3001 and 5.2783 respectively. The means are comparable ($\alpha = 0.840$), implying that the two groups were homogenous and hence suitable for the present study.

To verify if the cohorts used were homogenous for the administration of various experiments in the topic of study, the pre-test descriptive statistics of mean scores and standard deviation were computed.

The results are shown in Table 4.11.

Table 4.11: Descriptive Statistics for Pre-test on number of experiments

Schools	Mean	N	Std. Deviation
E1	6.4444	77	2.7509
C1	6.0032	74	2.4592
OVERALL	**6.2236**	**151**	**2.4083**

The results in Table 4.11 indicate that there was minimal difference in the mean scores of all the four cohorts on the number of experiments administered. A further analysis of these results was critical to determine whether the differences between the mean scores were significant at the $\alpha = 0.05$ level using a one – way Analysis of Variance (ANOVA). The findings are presented in Table 4.12

Table 4.12 ANOVA for Number of Experiments Administered

		Sum of Squares	Df	Mean Squares	F	Sig
Number of experiments Pre-test	**Between Groups (treatment)**	63.421	1	6.324	0.234	0.645
	Within Groups (error)	4211.761	149		26.935	
	Total	**5018.391**	**150**			

The findings in Table 4.12 show an F value of 0.234 with a significance of 0.645, which is greater than the acceptable level of 0.05. This therefore implies that the scores of the pre-test for the number of experiments administered were not statistically different and thus all the groups did the same number of experiments prior to the study.

To confirm if the groups used were homogenous for teachers' knowledge on ICT frameworks, the pre-test descriptive statistics of mean score and standard deviation was computed for teacher' knowledge. The results are shown in Table 4.13

Table 4.13: Descriptive Statistics Pre-test for Teachers' Knowledge on ICT Frameworks

Schools	Mean	N	Std. Deviation
E1	7.321	18	0.987
C1	7.821	18	1.121
OVERALL	**7.571**	**18**	**1.047**

From the outcome in Table 4.13, all the groups had almost the same mean score on teachers' knowledge on ICT frameworks pre-test ascertaining that, the mean difference was minimal. However, a further analysis of these results was needed to establish whether the difference between the mean scores was significant at $\alpha = 0.05$ level using one –way Analysis of Variance (ANOVA).

The results are presented in Table 4.14

Table 4.14: ANOVA Table for Teachers' Knowledge on ICT Frameworks Pre-test

		Sum of Squares	Df	Mean Squares	F	Sig
Number of experiments	Between Groups (treatment)	3.421	1	1.649	0.112	0.945
Pre-test	Within Groups (error)	150.331	16	16.935		
	Total	**153.752**	**17**			

Table 4.14 shows an F-value of 0.112 whose significance (0.945) is greater than the acceptable α=0.05. This therefore implies that the mean scores of the pre-test for teachers' knowledge are not statistically significant and thus the group used had an almost common knowledge of the selected frameworks for the study.

4.6 Students' Level of Interaction in the Classroom

4.6.1 Comparison of Students Level of Interaction by Teaching Method

The first objective of this study was to determine how VLBI affected students' level of classroom interaction during physics instruction in secondary schools. Data on this objective was analysed under the hypothesis. "There is no statistically significant difference on students' level of interaction in classroom between students exposed to VLBI and those not so exposed.'' In order to determine students' level of interaction in classroom when VLBI and conventional methods of teaching were used to teach Physics, data was collected on students' level of interaction using PSQ (Appendix A section (C)), PTQ (section (C)) and LOS (Appendix C section A2). Table 4.15 shows the summary statistics of the results obtained.

Table 4.15: Independent t-test for Levels of Participation between the Two Groups

Methods of Teaching	N	Level of Participation	Std. Deviation	t-value	Df	Sig
VLBI	148	95.5688	11.4678	17.623	290	0.000
Conventional Method	144	62.7643	9.3465			

According to Table 4.15, students who were taught with VLBI were more engaged in the classroom (95.57) than students who were taught with conventional methods (62.76).The statistics also demonstrate that the difference in the two groups of students' mean levels of participation was statistically significant at $\alpha = 0.05$.The results of the study reveal that VLBI create an active learning environment in which small teams of students used computer based dynamics visualization and computer-based simulation as the key teaching aids providing foresight about the sophisticated dynamics exhibited by various radiations. VLBI enable students to control experimental inputs like voltage, light intensity, wavelength and they can in turn register immediate feedback on the variables being moderated.

Students can also create interactive half-life graphs, such as count rate versus time, current against time, and number of counts against time, using this simulation. Because they are able to see these graphs created in real time as they changed the controls on the experiment, students were able to see the relationship between the graphs and the experiment more clearly than they would when viewing static images. These findings are consistent with Manisha (2012) who contends that ICT can act as a catalyst by providing a learning platform which teachers use to improve teaching. Additionally, VLBI gives students access to electronic media that concretise concepts enhancing cognition.

4.6.2 Comparison of Level of Students Interaction across the Groups

To establish the level of students' interaction in the four groups involved in the study, a One Way ANOVA was carried out and the results presented in Table 4.16.

Table 4.16: ANOVA Table for Difference in Students Participation Level Across The Groups

	Sum of Squares	Df	Mean Squares	F	Sig
Between groups (treatment)	54121.568	3	18137.324	123.345	0.000
Within Groups (error)	21165.761	288	147.303		
Total	**62.7643**	**291**			

The results in Table 4.16 present an *F*-value of 123.345, whose significance level was 0.000. The results indicate that the difference in students' level of participation or classroom involvement among the four categories of students was statistically significant at an alpha level of 0.05. This imply that, the level of interaction in classroom among the students differed from one group to another.

To further determine how the variance in learners classroom interaction level is displayed, a post Hoc multiple comparison was done using the Duncan Multiple Range Test whose findings are presented in Table 4.17

Table 4.17: Duncan Multiple Range Test Statistics for Difference in Level of Students Participation Across the Groups

School	N	Subset for Alpha = .05			
		1	2	3	4
C_1	74	60.7649			
C_2	70		64.4210		
E_1	77			101.1100	
E2	71				96.5646
Sig.		**.001**	**.001**	**.001**	**.001**

The findings presented in Table 4.17 show that students in experimental class E_1 displayed highest level of participation (101.1) in the classroom during teaching and learning of Physics followed by students in experimental group E_2 (96.6) while students in C_1 were at 60.7. The high and improved level of students participation in the classroom depicted among the experimental classes can only be attributed to the use of VLBI in their classes since the classes were taken through the same topic (Radioactivity). The hypothesis which stated that "There is no statistically significant difference in students' level of interaction in classroom between students exposed to VLBI and those not exposed'' is thus rejected. The implication is that VLBI motivates learners to have interest in learning Physics.

According to Holmes et al. (2018), the findings support the firm assertion that technological advancements increase students' active participation in class activities. The findings corroborate previous studies (Abdurrahman et al, 2018; Smith et al, 2020; Stowell et al, 2018) which indicated that ICT integration promotes active learning.

Furthermore, Desman et al (2017) observed that, there is substantial evidence that, use of experimental approach in learning and teaching improves students' activeness in Physics teaching learning process. Findings from teachers' and students' open-ended questions appeared to complement the quantitative data established in Tables 4.16 and 4.17. For instance, one teacher commented as follows:

> *''VLBI is a crucial drive towards learning and achievement in KCSE examination. It acts as a positive reinforcement in classroom since it encourages learners to be part of the learning process.''*

One of the students concurred with the teachers' sentiments and reported that VLBI boosted their confidence and understanding during Physics lessons.

As such the problem of the concept of *'RADIOACTIVITY'* being a difficult topic for students to learn and teachers to teach may be resolved by the use of VLBI module that emphasize active learning. It is interesting to note what one female student had to say in regard to motivation:

> *''My teacher motivates me by using VLBI, because it makes me have a taste of the real world inside the classroom, and hence makes me have more interest in the subject.''*

Students gave a variety of other active learning indicators as a result of implementation of VLBI in teaching and learning of Physics which included: participating in class more actively, asking questions with confidence, prompted to explain to peers a given concept among others. Teachers established that introverts participated actively when VLBI were embraced, and the extroverts' dominance in class is controlled. This pronouncement is consistent with the previous study by Deng (2019), who established that ICT integration engaged all the learners in the classroom environment without the fear of being put on the spot to respond to a question.

The findings corroborate the study by Buthelezi (2018) who reported that ICT integration in learning promotes learner-centred instruction unlike the content centred instruction. The finding in the current study concurs with Ghavifekr (2014) who pointed out that, virtual experiments make learners like the subject and build competence and confidence in their abilities hence greatly influence students' achievement.

4.7 Effect of Virtual Laboratory-Based Instruction on Students' Achievement

In order to establish the effect of VLBI on students' achievement in Physics, PATs (Appendix D) was designed and used in the study. In the analysis of data collected, the independent t-test was employed at the beginning of the study to find out whether the levels of the four groups were equivalent in terms of their achievement before the introduction of intervention (treatment). The results established were analysed and presented here-under.

4.7.1 Comparison of students' Achievement based on Teaching Approach

An independent sample t-test was used to compare Physics achievement in the two distinct scenarios in order to test the second hypothesis, which stated that there is no statistically significant difference in students' achievement in Physics between learners who were exposed to VLBI and those who were not so exposed. The findings are presented in Table 4.18

Table 4.18: Independent Sample t-test for Difference in Achievement between Use of VLBI and Traditional Method

Method of Teaching	N	PAT Mean	Std. Deviation	t-value	Df	Sig.
VLBI	148	63.6788	12..3452	20.342	291	0.000
Conventional Method	144	23.2233	7.4245			

Students taught using VLBI had a PAT mean of 63.68, compared to 23.22 for students taught using conventional methods, as shown in Table 4.18.The statistics also show that the difference in the mean score was significantly different at an $\alpha = 0.05$. The results demonstrate that students in classes E1 and E2 who were instructed using VLBI as a method of instruction had significant scores compared to the students who were taught by conventional method. Students who were taught through VLBI teaching strategy were more successful than the students who were taught by conventional method. Spatial images in simulations preserve relationships among elaborate set of concepts and play a central role in scientific creativity.

4.7.2. Comparison of Physics Achievement Tests across the Experimental and Control Groups

To assess the difference in mean across the different groups that took part in the study, a One Way ANOVA was carried out. The outcomes are shown in Table 4.19.

Table 4.19: ANOVA for Difference in PATS Scores Across Classes

Source	Sum of Squares	Df	Mean Square	F	Sig
Between groups (treatment)	57217.795	3	21673.949	115.781	.000
Within Groups (error)	29140.412	288	188.412		
Total	**394.158**	**291**			

The ANOVA results in Table 4.19 show an F–value of 115.8 with a significance level p (0.000) <0.05, which makes the difference significant. These outcomes demonstrate that there was a statistically significant difference in students' achievement between the four study groups. This implies that some schools attained better scores on PATS than others.

Based on the ANOVA results in Table 4.19 the use of VLBI make a number of hidden phenomena more visible to learners (e.g. tracks formed by alpha, beta and gamma radiations) and make it easier for students to carry out and repeat an experiment. The result affirms the assertion that virtual experiments enabled easier and faster manipulation of variables than real experiments; and provide students with immediate feedback throughout the construction of any radioactivity concepts (Bogusevchi et al, 2020).

To establish the point at which the significant difference occurred in the Post test scores, a Post Hoc multiple comparison was done using the Duncan Multiple Range Test. The outcomes are presented in Table 4.20

Table 4.20: Duncan Multiple Range Test for Difference in PAT Scores

School	N	Subset for Alpha = .05	
		1	2
C_1	74	35.1951	
C_2	70	35.0564	
E_1	77		65.6579
E2	71		66.4378
Sig.		.897	.223

*Means for groups in homogeneous subsets are displayed.

According to the findings presented in Table 4.20, Physics students in E_2 had the highest mean score (66.4378) whereas those in E_1 had a mean of 65.6579. The experimental group E_1 had a mean score of 65.6579 far higher than both the control groups C_1 and C_2. The mean scores of the experimental groups was however, not statistically significant (E1= E2) implying that their performances were similar. Students in C_1 had a mean score of 35.1951 while those in C_2 had the lowest mean of 35.0564. Although there is statistically significant difference in PATS means between C_1 and C_2, their means are considerably lower than the means for E_1 and E_2 ($E_1=E_2 > C_1 = C_2$). Consequently, the null hypothesis was rejected. Oliveira and Bastos's (2018) findings are in line with those of this study on the effectiveness of VLBI, particularly on use of simulations in teaching of Physics on students' learning outcomes. The findings demonstrated that the mean differences between the experimental and control groups were statistically significant in favour of experimental groups.

Also the findings of the study indicated that VLBI had positively affected the students' classroom mastery of concepts and skills, which was consequently reflected in their test scores. Similar results were also reported by Mihindo et al. (2017) in a study of students' performance in computer-augmented chemistry lessons in Kenyan secondary schools. These results are in line with those of Chen (2017), who looked at how computer-based instruction affected students' achievement and ability to solve problems in science and technology classes in Turkey. This view is affirmed with Abdjul (2019) who established that computer-based science and technology instruction showed a statistically significant rise in achievement and problem-solving abilities, since it provides opportunities for students to explore.

Similar findings were also reported in Nigeria by Ahiatrogah, Madjoub, and Bervel (2013) after comparing the achievement of students in junior high school who received virtual experiments (VE) lessons to those who received traditional instruction. The study's findings revealed that students who were exposed to VE lessons performed better than those who were exposed to conventional teaching methods. Muchiri and Hillary's (2018) findings on the impact of computer based instruction on secondary school students' academic performance underpin the findings of the current study. According to the study, students who were taught Physics using VLBI performed better than students who were taught Physics using a more traditional approach. These results affirm the view that digital learning has the potential to revolutionize learning. Nevertheless, this potential can only be realised when the gap between the mere presence of technology and its effective integration is bridged.

4.8 Effects of VLBI on the Frequency of Use of Experimental Teaching Approach

In order to determine how VLBI affects the frequency with which the experimental teaching approach in Physics is utilized, PSQ (Appendix A) was designed and used in the study. The independent t-test was used to analyze the collected data to determine whether the groups' achievement levels were comparable. The results established were analysed and presented here-under

4.8.1 Comparison of number of experiments set-up by Teaching Methods

The third objective in this study was to investigate the frequency of use of experimental teaching approach in the topic "RADIOACTIVITY' when VLBI and conventional methods of teaching were used to teach Physics. The data on number of Physics experiments conducted was collected using LOS, PTQ and PSQ. Table 4.21 shows the summary of the results obtained.

Table 4.21: Independent Samples t-test for different number of Experiments Set-up between VLBI Classes and Conventional Classes

Method of Teaching	N	Mean	Std. Deviation	t-value	Df	Sig.
VLBI	148	42.6788	13.3452	18.342	291	0.000
Conventional Method	144	13.2233	11.5434			

According to the results presented in Table 4.21, students who were taught by VLBI approach had higher number of experiments carried out (42.6788) compared to those taught using the conventional methods (13.2233). The statistics indicate that the difference in the (mean of) number of experiments administered between the two cohorts was statistically significant at $\alpha = 0.05$. The significant number of experiments conducted as result of the use of VLBI is an indicator that, the use of a virtual laboratory helps an educational system achieve its goals and solves some of the issues that traditional laboratory applications face. The use of VE for laboratory instruction has numerous obvious advantages, including "portability, safety, cost-efficiency, minimization of error, amplification or reduction of temporal and spatial dimensions, and allows flexible, rapid and dynamic data displays," (Altuna & Lareki 2015).

4.8.2 Comparison of Frequency of Use of Experimental Teaching Approach Across Experimental and Control Groups

To compare the number of experiments that were exposed to Physics students in the four cohorts that were involved in this study, a One Way ANOVA was executed. The results are presented in Table 4.22

Table 4.22: ANOVA Table for Difference in Number of Experiments Carried out Across Groups

	Sum of Squares	Df	Mean Square	F	Sig
Between Groups (treatment)	45212.653	3	15148.452	119.971	.000
Within Groups (error)	19519.014	288	127.412		
Total	**64731.667**	**291**			

The results in Table 4.22 show an *F*-value of 119.971, with significance level of 0.000 indicating that the number of experiments administered among the groups were statistically significant at an $\alpha = 0.05$. This indicate that the number of experiments carried out during Physics lessons differ from one cohort to another among the four cohorts of classes involved in the study. This is an indication that VLBI can be a place for experiments that cannot be done in conventional laboratories and at the same time present related concepts and events. According to Kurt's (2017) study, the use of virtual labs as a teaching strategy leverages the use of real experiments because they are time-consuming and expensive, inadequate lab equipment, and teachers' anxiety about curriculum completion. The higher number of experiments observed in virtual lab classrooms, is an indicator that the strategy aims at raising scientifically literate students, and hence building a strong relationship between science and technology. The students' conceptual understanding of radioactivity appeared to be improved through the use of VLBI, particularly their conceptions of measuring count rate with a GM-tube, a concept that cannot be achieved through actual experimentation in typical physics labs.

To point out how the difference in number of experiments administered is depicted, a Post Hoc comparison was done using the Duncan Multiple Range Test whose findings are in Table 4.23.

Table 4.23: Duncan Multiple Range Test for Difference in Number Of Experiments Across different Groups

School	N	Subset for Alpha = .05			
		1	**2**	**3**	**4**
C_1	74	14.2865			
C_2	70		15.9072		
E_1	77			41.000	
E2	71				39.744
Sig.		1.000	1.000	1.000	1.000

*Means for groups in homogeneous subsets are displayed.

According to the findings presented in Table 4.23, Physics students in experimental cohort E_1 had the highest number of experiments (41.0) done during their lessons, followed by experimental cohort E_2 (39.7) while students in C_1 had the least (14.2865). The findings concur with the study conducted by Semela (2010) which established that Physics in many African countries has been undergoing crisis with no or few experiments carried out in the course of learning, with inadequate laboratory equipment being implicated. The high and improved number of experiments among the experimental groups can be attributed to the adoption of VLBI in these cohorts. Consequently, the hypothesis which stated that "There is no statistically significant difference in the number of experiments carried out between the learners taught Physics through the use of VLBI and those that use conventional methods" is thus rejected. The implication is that virtual laboratory-based instruction permits teachers and students to access practically all the experiments at comparatively lower cost. The power of experiments in enhancing learning may best be captured in the Chinese saying that:

> *"If we hear, we forget; if we see, we remember and if we do, we understand"* (Bishop, 1995).

The use of VLBI further supports Abraham's (2005) assertions that laboratory demonstrations and practical work have long been accepted as essential components of physics education. It is difficult and rationally impossible to imagine teaching physics without experimental work. According to Blundell et al. (2020), despite the widespread use of VE and the potential benefits it may bring to laboratory experimentation, there are arguments against its use on the grounds that it denies students experiences that involve the concrete or hands-on manipulation of physical materials, which are essential for learning.

4.9 Effects of Teachers' Knowledge on ICT frameworks and use of VLBI

Physics Teacher Questionnaire (PTQ) was administered before and after the intervention to determine the significance of teachers' knowledge on the selected ICT frameworks and the use of VLBI in teaching Physics. Each consisted of 15 items, 10 items had a 5-point bi-polar Likert-type scale ranging from strongly disagree to strongly agree. Table 4.24 shows the Physics teachers' awareness of selected ICT frameworks.

Table 4.24: Physics Teachers' Awareness of Selected ICT Frameworks

	Responses					
ICT Frameworks	**Khan 8D**	**FR**	**SAMR**	**P3-Model**	**TPACK**	**ASSURE**
Teacher awareness	7	2	9	6	37	11
Percentage	9.7	2.7	12.5	8.3	51.4	15.4

Table 4.24 show that more than half (51.4%) of the teachers who took part in the study were cognisant of TPACK framework only. The other selected ICT framework in the study were hardly known by the Physics teachers.

4.9.1 Comparison of Teachers' knowledge on ICT frameworks between Experimental and Control Groups

The fourth hypothesis, stated that there is no statistically significant difference between the teachers' knowledge on selected ICT frameworks and the use of virtual laboratory-based instruction. In order to test this hypothesis, the differences in teachers' knowledge were compared using an independent samples t-test on the selected ICT frameworks between the teachers using VLBI and those using the conventional method.

The findings are represented in Table 4.25

Table 4.25: Independent Samples t-test for difference on Teachers knowledge on ICT Frameworks between VLBI and Convectional methods

Method of Teaching	N	Teacher Knowledge Mean	Std. Deviation	t-value	Df	Sig.
VLBI	148	25.0122	3.012	0.733	70	0.464
Conventional Method	144	26.2233	2.978			

According to the results presented in Table 4.25, teachers that used conventional teaching methods depicted more awareness and the objectives of the selected ICT frameworks compared to their colleagues who taught the experimental groups using VLBI. The statistics however, show that the difference in teachers' knowledge of ICT frameworks between the two groups was not statistically significant at alpha level of 0.05. Therefore the hypothesis which stated that, there is no statistically significant difference between the teachers' knowledge on selected ICT frameworks and the use of virtual laboratory-based instruction is confirmed. The implication is that whether the teachers are informed about the ICT frameworks or unaware they generally have the same bearing on the use of VLBI in teaching and learning of Physics in secondary schools.

4.9.2: Comparison of Teachers' knowledge on ICT Frameworks Across Experimental and Control Groups

To compare the teachers' knowledge on the selected ICT frameworks and the use of VLBI in the four groups involved in this study, a One Way Analysis of Variance (ANOVA) was carried out. The results are presented in Table 4.26.

Table 4.26: ANOVA Table for difference on Teachers' knowledge on ICT Framework and use of VLBI

	Sum of Squares	Df	Mean Square	F	Sig
Between Groups (treatment)	140.403	3	47.468	1.174	.317
Within Groups (error)	122.014	68	17.712		
Total	**2094.417**	**71**			

The results in Table 4.26 show an F-Value of 1.174 whose significance level was 0.317. In this study, the teachers' knowledge on ICT frameworks and the use of VLBI were compared. The four groups, E1, E2, C1, and C2, did not differ significantly, according to the findings. The finding contradicts Koehler et al (2016) who underscore the effects of a valid ICT learning framework. Comparatively, the results show similarities with previous studies, that indicated that the use of VLBI does not require deep instructional design knowledge or high revision of design (Gustafon & Branch, 2002). The general view of the Physics teachers, coupled with the significance test (at $\alpha=0.05$) result, led to the inference that the teachers knowledge on the selected pedagogical ICT framework has no influence on the use of virtual laboratory-based instruction in learning Physics in secondary schools.

4.10 Multiple Regression on implications of Virtual Laboratory-Based Instruction On Learning of Physics

4.10.1 Collinearity Diagnostics

Prior to conducting regression analysis, a diagnostic test was conducted to confirm that the data was reliable for regression analysis to be done. This was done in line with the model assumption that must be met before conducting the analysis. Collinearity diagnostic test sought to reveal if multi-collinearity existed among the predictor variables. When independent variables in a regression model have a correlation, this happens. The variables must be independent; otherwise, a problem could occur from a significant degree of correlation between them (Brooks, 2008). The results are as shown in Table 4.27.

Table 4.27: Collinearity Diagnostics

Independent Variable	Tolerance	VIF
Level of learners interaction in the classroom	.402	2.485
Number of Experiments conducted	.362	2.761
Learners Achievements (scores) in PATs	.353	2.832
ICT frameworks	.582	1.867

a. Dependent Variable: Virtual Laboratory based Instruction

Source: Field Data (2020)

From the results in table 4.27, teachers' knowledge in ICT frameworks had the highest tolerance level of 0.582, while learners' achievement in PATs had the lowest tolerance level of 0.353; Learners level of interaction had a tolerance level of 0.402 while number of experiments conducted had a tolerance level of 0.362. In order to establish if there is no multi-collinearity, the tolerance values of all predictor variables have to be more than 0.2 (Brooks, 2008). The tolerance level for all independent variables was greater than 0.2 and hence absence of multi- collinearity problem.

Similarly, Learners Achievement in PATs had the highest Variance Inflation Factor (VIF) of 2.832, followed by number of Experiments carried out with VIF of 2.761, Level of learners' interaction in the classroom had Variance Inflation Factor (VIF) of 2.485 and Teachers' knowledge in ICT frameworks had the lowest VIF of 1.467. VIF values are supposed to be more than 1 but less than 10. From table 4.26, VIF for all the variables were within the range hence multi- collinearity was absent among the independent variables. This suggests that all the independent factors should be included in the prediction model because they all significantly contributed to the variation.

Multiple Regression was performed in an attempt to determine whether a group of variables (level of interaction in classroom, learners' achievement in Physics, number of virtual experiments conducted and the teacher knowledge on the selected ICT-frameworks) together influence implementation of virtual laboratory-based instruction in learning of Physics. The Regression model summary is shown in Table 4.28.

Table 4.28: Multiple Regression on implications of Virtual Laboratory-based Instruction on Learning of Physics

Model	R	R Square	Adjusted R Square	F	Std. Error of the Estimation (∑)
1	.803	.645	.575	9.102	1252.76

a. Predictors: (Constants),achievement, experiments, ICT frameworks, level of interaction

Predictors: Level of interaction in classroom, learners' achievement in Physics, number of virtual experiments conducted and the major ICT-frameworks. Dependent variable: virtual laboratory-based instruction. Control variables were age, academic qualification, teaching experience and gender. As shown in Table 4.28, the regression model was significant. The coefficient of determination (R^2) was 0.645. In the model $R^2 \times 100 = 0.645 \times 100\% = 64.5\%$. This implies that 64.5% of variance in the virtual laboratory-based instruction was explained by learners' interaction in the classroom, learners' achievement, number of virtual experiments conducted and the teachers' knowledge on the selected ICT frameworks that promote ICT integration.

These findings indicated that there are other implications of VLBI; including those hidden in the error term contributing up to 36.5% variance in the learning of Physics that were not included in the model. Based on the findings the predictors were significant and are therefore dependent as opposed to being independent of each other. Since the results were significant it meant that all the predictors in this study are critical in predicting implications of VLBI in the process of learning Physics.

To point out the implications of individual predictors on the use of VLBI in teaching and learning of Physics, a multiple regression was done for each of the predictors. Table 4.29 gives a summary of the findings established.

Table 4.29: Multiple Regression for Individual Predictors

Model	Coefficient	Std. Error	t-test	p-value
Intercept	352.9	1837.22	19.106	6.110
Level of interaction	4.1763	1.4921	2.484	0.0256
Experiments	4.6176	1.664	2.5234	0.01281
Achievement	4.79064	1.7892	2.6773	0.01186
ICT frameworks	0.06593	1.224	1.2408	0.3871

Table 4.29 revealed that the computed regression p- value results were below p= 0.05, except the p-value of ICT frameworks. The implication of these results is that the four predictor variables are important determinants of use of VLBI except, the teachers' knowledge on the selected ICT frameworks. From Table 4.29, it can be deduced that for every one point increase in the level of implementation of VLBI, frequency of use of experiments increases by 4.62 points, learners' level of interaction in classroom increases by 4.18 points and students' achievement level increased by 4.8 points. These results were consistent with the findings reported by Mkandawire (2010) who concluded that there are many factors that affect implementation of curriculum in schools in developing countries. Mkandawire (2010) identified national economy, teaching learning materials like books, in-service training of teachers, and the number of pupils in the class, education monitoring

and the learners' home environment as some of the factors influencing implementation of curriculum. The finding that the students interaction levels increased by 4.18 points also supports those of Hollie (2017), Lumpkin et al (2015) and Strakova (2018) who reported that there is a positive relationship between ICT integration and interactive learning. However, Kumar, Che-Rose, and D'Silva (2008) found no significant correlation between ICT integration and science teaching and learning in junior secondary schools, which is consistent with this study's findings. This could be because they went to urban or semi-urban schools that had adequate resources and other structural facilities and teachers were used to them, whereas the majority of the schools in the current study were rural.

4.11 Summary of the Study

This chapter presented and discussed the findings that supported or negated the hypotheses posited for testing with regard to the effects of incorporating VLBI into physics instruction in secondary schools in Kisumu, County. The study sought to establish whether there exist any significant difference in terms of classroom participation, number of experiments conducted and learners' achievement when virtual laboratory-based instruction are integrated in the instruction. The study also focused on how the selected ICT frameworks support the use of VLBI in teaching and learning of Physics. The findings of this study on achievement, learners' classroom interaction and frequency of use of experimental teaching approach are in the affirmative. The subjects exposed to the use of VLBI performed significantly better on PATS, classroom interaction and conducted a higher number of experiments than those not exposed.

However, the existing ICT framework had minimal influence on the use of virtual lab in teaching and learning of Physics. It can therefore be concluded that integration of VLBI is more effective than conventional teacher instruction methods on students' achievement in learning and teaching of Physics in Kisumu County. Simulations in VLBI were more attractive to students than the normal conventional procedure applied in teaching the various concepts in 'Radioactivity'. The VLBI introduces the realia and excites the students' imagination that makes them go beyond the teacher's lesson. Because it improves retention, students enjoy being involved in the lessons in a variety of ways, such as through role-playing and hands-on activities. According to Daniel et al. (2019), the incorporation of ICT into education provides students with a more conducive learning environment, fosters interest, fosters a student-centered learning environment, and boosts motivation. This finding is consistent with several related studies suggesting that the use of well-designed ICT framework enhances interactive learning in the classroom during science lessons (Gemechu, 2019). Similarly, it corroborates Hodges (2018) and Kipyator (2017) findings demonstrating that students perform better when ICT integration is used in the classroom. By being able to relate to and manipulate the various formulae for determining half-life, students demonstrated conceptual understanding. The ability of the students to recall, explain, and apply novel scientific concepts improved.

According to Linder et al. (2014), the strong assertion that ICT in education is consistently linked to higher efficiency, productivity, and educational outcomes including the quality of cognitive, creative, and innovative thinking in science and math teaching and learning is supported by these findings. According to Nicol et al (2018) technology active learning research has demonstrated that computer animation in chemistry promotes active learning and has positive effect on students' conceptual understanding of chemical processes. In another study where concepts and capabilities taught to students using computer-based algebra system software, students aged 10 to 12 were taught by adults over the age of 15, there performance was similar to that of students in a university engineering course but tested in the conventional way of pen and paper (Sanders et al, 2017). However, Chawinga and Zozie (2016), observe that this may not always be the case. They argued that it all depends on whether technology is used well or poorly, and thus its effectiveness is dependent on how it is used, by whom and for what purpose. However, conventional teaching methods have been cited as one of the contributing factors towards students' poor learning strategies and, as a result, poor exam scores (Jordan et al., 2015).

This is evident in the control groups' ($\bar{X} = 35)$ academic performance that was far much below the experimental groups ($\bar{X} = 66$). Digital learning has been globally recognised as having the potential to revolutionalize learning. Nevertheless, this potential' can only be realised when the gap between the mere presence of technology and its effective integration is bridged.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter entails a summary of the conclusions, major findings, and recommendations. Similarly, the implications of the findings and focus of some areas that warrant further research are presented. This study aimed at answering four major research questions. First, it tried to establish the impact of virtual experiments on students' level of classroom interaction in learning of Physics in secondary schools. Secondly, it sought to establish the frequency of use of experimental teaching approach when Physics teachers' employ VLBI in learning of Physics in secondary schools. Thirdly, it was meant to discover the impact of VLBI on secondary school students' achievement in physics. Last but not least, the goal of this study was to determine how teachers' familiarity with the chosen framework supports the use of VLBI in teaching and learning of Physics in secondary schools in Kenya.

5.2 Summary of the Findings

5.2.1 Effects of Virtual Laboratory-Based Instruction on Students' Level Of Classroom Interaction

Students' level of interaction in a classroom is one of the key determinants of active teaching and learning of Physics. The high and improved level of students' interaction in classroom depicted among the experimental classes can only be attributed to the use of Virtual laboratory-based instruction in their classes. The repetitive attribute of virtual laboratory-based instruction enables learners to participate and interact in inquiry-based classes where they can implement and analyse their own experiments.

The study's findings pointed out that introducing virtual laboratory-based instruction in classroom instruction will have immense value in boosting students' interest, motivation and understanding, particularly in abstract topics such as '*RADIOACTIVITY*, compared to the conventional teaching methods.

5.2.2 Effects of Virtual Laboratory-Based Instruction on Students' Achievement

The third objective in this study was meant to discover to what extent virtual laboratory-based instruction impact on students' achievement in Physics in secondary schools in Kisumu County. From the study's findings, the role of virtual laboratory-based instruction was affirmed by the mean posted by experimental groups (65.65 and 66.43) vis–a-vis the mean score attained by the control groups (30.19 and 30.05). As such, the notion that the concept of radioactivity is a difficult topic for students to learn and teachers to teach may be resolved by the use of virtual labs, and students will be able to achieve higher scores. This research has also demonstrated that virtual laboratory-based instruction enhances interactive learning, thereby promoting active learning among peers within the classroom. In addition, the study revealed a statistically significant increase in students' achievement and problem-solving abilities in the experimental groups that incorporated virtual laboratory-based instruction into their classroom instruction.

5.2.3 Effects of Virtual Laboratory-Based Instruction on the Frequency of Use Experiments as a Teaching Approach

According to the findings, Physics students in experimental cohorts were exposed to higher number of experiments (42) compared to their peers in the control cohorts (13). The high and improved number of experiments among the experimental groups in the topic 'RADIOACTIVITY, which is challenging to teach as result of unavailability of the teaching and learning resources due to a policy prohibiting the use and storage of radioactive materials in the school laboratory, can only be attributed to the adoption of virtual laboratory-based instruction in the experimental cohort. As a consequence, the hypothesis that "There is no statistically significant difference in the number of experiments carried out between the learners taught Physics through the use of virtual laboratory-based instruction and those that use conventional methods" is thus rejected. The implication is that virtual laboratory-based instruction permit teachers and students to access practically all the experiments at comparatively lower cost, particularly in schools in rural setup that lack major apparatus required in conducting basic experiments.

5.2.4 Teachers Knowledge on ICT framework and use of Virtual Labs

Lastly, the study explored how various existing ICT frameworks promote the use of VLBI in teaching of Physics in secondary schools in Kisumu County. Under VLBI module the learning environment changes. The ICT frameworks are the platforms that direct the implementation of digital learning in schools. The frameworks give schools and teachers structures on how ICT integration programmes should be rolled out.

The general view of the Physics teachers, coupled with the t- test, indicated that there was no significant relationship between ICT framework and implication of VLBI in learning Physics in secondary schools in Kisumu County. This is a pointer that, Physics teachers were oblivious of the selected ICT frameworks. The study further noted that, the teachers who were informed about the frameworks lauded the flexibility of frameworks which allow the teacher to employ varied teaching approaches.

5.3 Conclusions

The study aimed at investigating implications of VLBI on students' learning of Physics in ssecondary schools in Kenya. Four variables were investigated, namely; effect of virtual laboratory-based instruction on students' level of classroom interaction in learning, effects of virtual laboratory-based instruction on frequency of use of experimental approach as a teaching strategy, effects of VLBI on Physics students achievement in PATs test and the relationship between teachers' knowledge of selected ICT frameworks and the use of virtual labs in virtual lab-based instruction. Based on the objectives, the following conclusions have been drawn.

5.3.1 Effects of Virtual Laboratory-Based Instruction on Students' Level Of Interaction

The study established that, due to unprecedented classroom environment, coupled with repetitive attributes of virtual labs, the VLBI in teaching and learning elevated students' level of classroom interaction and this could be observed in their level of classroom interaction, interpretation and consequently application of the learned concept.

5.3.2 Effects of Virtual Laboratory-Based Instruction on Students' Achievement

To this end, both the qualitative and quantitative findings showed that virtual experiments enhance students' achievement and consequently problem solving skills in Physics. This is also attributed to the fact that virtual laboratory-based instruction changed the teachers' role from a domineering one to that of a facilitator.

5.3.3 Effects of VLBI on the use of Experiments as a teaching strategy

The study has revealed that using virtual laboratory-based instruction permits teachers and students to access practically all the experiments at comparatively lower cost, thus promoting use of experimental teaching strategy. Virtual laboratory-based instruction enable students to access practical aspects of learning, irrespective of the location and status of the school.

5.3.4 Teachers Knowledge on ICT framework and use of Virtual Labs.

The findings indicated that there was no statistically significant difference in the mean across the four groups, E_1, E_2, C_1 and C_2. The study thus concludes that the use of VLBI in teaching does not depend on the teachers' knowledge on the selected ICT frameworks in the study.

5.4 Recommendations

The following suggestions are made in light of the study's findings and conclusions: Blended learning (virtual labs) improved student's motivation to actively participate in learning and therefore, a follow-up policy ought to be developed by the education ministry to overcome implementation challenges involved in setting up blended teaching pedagogies.

Schools should be equipped with adequate ICT teaching-learning materials since ICT integration elevates active learning, learners' interest and achievement and changes a teacher's instructional practices from that of a dispenser to a facilitator.

CEMASTEA should focus on training science teachers on adoption and use of virtual laboratory-based instruction since they supplement learning resources in schools that lack equipment and laboratories, or have defective lab conditions which limit both the teacher and learners from performing practical work and simple lab activities.

There is need to develop a prototype for technology-enriched ICT framework for VLBI in learning of Physics that will provide teachers and students with an interactive platform to promote learning Physics in secondary schools in Kenya.

5.5 Suggestion for Further Research

For further research, more recommendations are hereby made. These are:

Studies with a larger sample size of participating counties, schools, teachers, and students to verify the validity of the current findings.

Further research is needed to explore how students' socio-economic factors affect the integration of VLBI in learning and teaching of Physics in secondary schools in Kenya.

A long-term study, preferably on another longer topic than r*adioactivity* be carried out to factor in more variables such as the learners' socio-economic background and establish the impact of VLBI integration on such variables.

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APPENDICES

Appendix A: Physics Students' Questionnaire (PSQ)

A. Introduction

You have been specially selected. to participate in the study: Implications of ICT integration on students active learning of Physics in Kisumu County, Kenya. Your contributions will help much towards the success of the study and will be treated with the highest level of confidentiality. Please do not write your name on this questionnaire.

Please tick (√) in the appropriate box against the number that best describes your response to the question.

B: Background information

B1. Please indicate your gender. Male ☐ Female ☐

B2. What is your present class? ---------

B3. What was your previous performance in physics? ----------- %

C: Rate the following statements to indicate your motivation in During Physics Lesson (RADIOACTIVITY)

KEY: Strongly Disagree (SD), Disagree (D), Neutral (N), Agree (A) and Strongly Agree (SA)

C :	**Statement**	**SD**	**DA**	**N**	**A**	**SA**
C1.	Experiments lessons were interesting and enjoyable.					
C2	I participated in class actively during the sessions and was prompted to ask more questions					
C3	I was more attentive in class since lessons were highly captivating					
C4	I love redoing experiments learnt after the normal lessons					
C5	The learning environment create conditions that stimulate students' need to know and boost effective classroom interaction					

D: Indicate in the number of Experiments carried out in the various sub-topic of the topic 'RADIOACTIVITY' during teaching and learning of in your school.

E	**Sub-topic**	**Experiments Carried Out**				
D1	Types of Radiations	**{0}**	**{1}**	**{2}**	**{3}**	**{4}**
D2	Properties of Radiations	**{0}**	**{1}**	**{2}**	**{3}**	**{4}**
D3	Radiation Detectors	**{0}**	**{1}**	**{2}**	**{3}**	**{4}**
D4	Half life	**{0}**	**{1}**	**{2}**	**{3}**	**{4}**
D5	Applications of Radioactivity	**{0}**	**{1}**	**{2}**	**{3}**	**{4}**
D6	Nuclear reactions	**{0}**	**{1}**	**{2}**	**{3}**	**{4}**

G: Open-ended question

G1. How could your physics class be improved so that you learn more?

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THANK YOU FOR ACCEPTING TO GIVE THE INFORMATION!!!!!

Appendix B: Physics Teacher Questionnaire (PTQ)

A. Introduction

You have been specially selected to participate in the study: Implications of ICT integration on student's active learning active learning of Physics in Kisumu County, Kenya. Your contributions will help much towards the success of the study and will be treated with the highest level of confidentiality. Please do not write your name on this questionnaire, all responses are anonymous. Please put a tick (√) in the appropriate box to the right that best describe your response.

B: Background information

B1. Please indicate your gender: Male ☐ Female ☐

B2. What is your present age? Under 30yrs ☐ 31-40yrs ☐ 41-50yrs ☐ Over 50yrs ☐

B3. Which is your highest academic qualification? Diploma ☐ Bachelors ☐ Masters ☐ PhD ☐ other ------------------

B4. For how long have you been teaching Physics? 0-5yrs ☐ 6-10yrs ☐ 11-15yrs ☐ Over 16yrs ☐

B5. What has been your school average performance in Physics at KCSE for the last 3years? Mean score ………………. Mean grade ……………….

B. For each statement, put a tick [√] in the appropriate box to show the level of involvement of your students during the Teaching and Learning of the Topic radioactivity under the study.

Key: Strongly Disagree (SD) Disagree (D), Neutral (N), Agree (A) Strongly Agree (SA).

C :	Classroom practices	SD	D	N	A	SA
C1	Student enjoyed the lesson					
C2	There was higher level of classroom Participation evident.					
C3	The learners were more curious and attentive					
C4	Learners to carry out Experiments with ease.					
C5	There was higher level of classroom interaction, among the learners and between the teachers and the learners.					
C6	The learners' recorded improved subject scores in this topic					

D: Indicate the number of experiments /demonstrations that were carried out by your students in the course of the topic radioactivity under the study. Please indicate by ticking [√] the appropriate boxes.

D :	Sub Topics	Experiments Carried Out				
D1.	Types of Radiations	**{0}**	**{1}**	**{2}**	**{3}**	**{4}**
D2	Properties of Radiations	**{0}**	**{1}**	**{2}**	**{3}**	**{4}**
D3	Radiation Detectors	**{0}**	**{1}**	**{2}**	**{3}**	**{4}**
D4	Half life	**{0}**	**{1}**	**{2}**	**{3}**	**{4}**
D5	Applications of Radioactivity	**{0}**	**{1}**	**{2}**	**{3}**	**{4}**

E. For each statement, put a tick [√] in the appropriate box to show your opinion of ICT policy and existing ICT frameworks on the effectiveness of the ICT integrated lessons in Teaching and Learning of Physics.

E :	**Classroom practices**	**SD**	**D**	**N**	**A**	**SA**
E1	I am aware of the National ICT policy of 2006					
E2	Iam cognisant the selected ICT frameworks.					
E3	The selected ICT frameworks do not vividly addresses the issues of VLBI.					
E4	There is little that has been highlighted about the selected ICT framework by the ministry of education and teacher training colleges.					
E5	I think that the existing ICT teaching frameworks' encourage use of virtual experiments ICT in teaching					
E6	The adaptation of ICT Framework guidelines leads to promotes VLBI					
E7	I can easily link the selected ICT frameworks with the VLBI					
E8	I am cognisant of the strength and weaknesses of AT LEAST two of the selected frameworks.					
E9	I am cognisant of the strength and weaknesses of at UTMOST two of the selected frameworks.					
E10	I have no idea of what the selected ICT frameworks underpin/support					

F. For each statement, select [tick-√] the Framework that in your opinion best advance the features of Virtual laboratory-based instruction in learning Physics

		Khan 8D	**Functionali**	**Khan P3**	**TPACK**	**SAMR**	**ASSURE**
F1	Teacher awareness of ICT learning framework						
F2	Flexible						
F3	Simplicity and Versatility						
F4	Promote CBI simulations & animation						
F5	Provide students with interactive applications						
	TOTAL						

G. Open-ended question

G1. What do you think are the major challenges that hinder VLBI during Physics lessons?

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G2. What do you think should be done in order to improve learning achievement in Physics?

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THANK YOU FOR ACCEPTING TO GIVE THE INFORMATION!!!

Appendix C: Physics Lesson Observation Schedule (LOS)

School Code………..Date………………..Class:……….. Time………..

Roll:………..Boys………..Girls………..

A	Performance Indicators	Max Score	Observer's Score	Observation comment
A1	**Teaching methods/Technique** a) Use of Demonstration or Experimentation b) Use of appropriate teaching aids c) Ability to stimulate learners d) Demonstrate innovation and creativity in teaching	**4** 1 1 1 1		
A2	**Learner involvement and communication** a) Answering and asking questions b) Discussion and presentation c) Observation d) Experimentation/demonstration/discovery/QA	**4** 1 1 1 1		
A3	**Classroom Management** a) Cleanliness of the classroom b) Movement in class to observe students work c) Arrangement of desks d) No chorus answers	**4** 1 1 1 1		
	Total	**12**		

Appendix D: Physics Achievement Test (PAT): Radioactivity

1. Define radioactivity. (2mks)
2. What is meant by unstable nuclide (1mk)

3. State **one** use and **one** source of gamma rays.(2mks)

4. The following is part of a radioactive decay series.

$$^{234}_{83}Bi \xrightarrow{\beta} {}^{a}_{84}X \xrightarrow{\propto} {}^{230}_{b}Y$$

   Determine the values of a and b (3mk)

5. $^{233}_{90}$**Th** disintegrates into radium (Ra) by emission of two alpha and two beta Particles. State:
   (i) the atomic number of the daughter nuclide (2mks)
   (ii) The mass number of the daughter nuclide (2mks)

6. A typical nuclear fission reaction in a nuclear reactor is given below.

$$^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{148}_{57}La + {}^{85}_{35}Br + x\,{}^{1}_{0}n$$

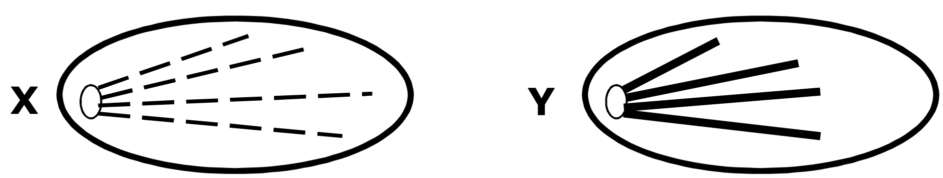
   (i) What is meant by nuclear fussion? (1mk)
   (ii) Find the value of x. (1mk)
   (iii) How are the neutrons produced used in the reactor? (1mk)

7. Equation below shows a decay series of a radioactive isotope

$$^{319}_{73}P_O \xrightarrow{X} {}^{315}_{71}T \xrightarrow{Y} {}^{315}_{72}K$$

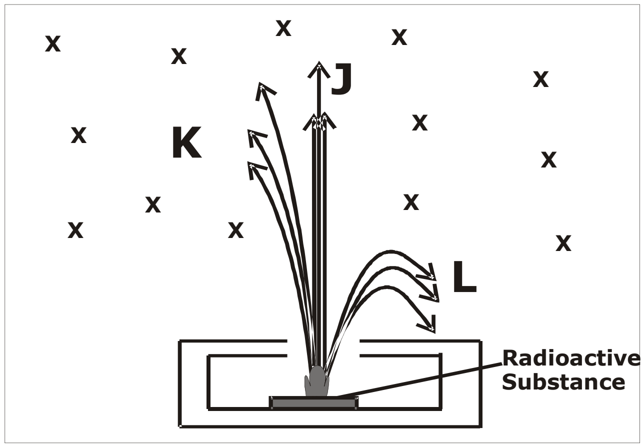
   Identify X and Y (2mks)
8. State what is meant by background radiation as used in radioactivity (2mks)

9. A Geiger – miller tube registers some effects even in the absence of a radioactive source. Explain this observation and state one cause. (2mk)
10. Alpha particles (∝) are more ionizing than Beta (β) particles. Give **two** reasons for this. (2mks)
11. Identify the type of emissions that formed the tracks in each case below.(2mks)



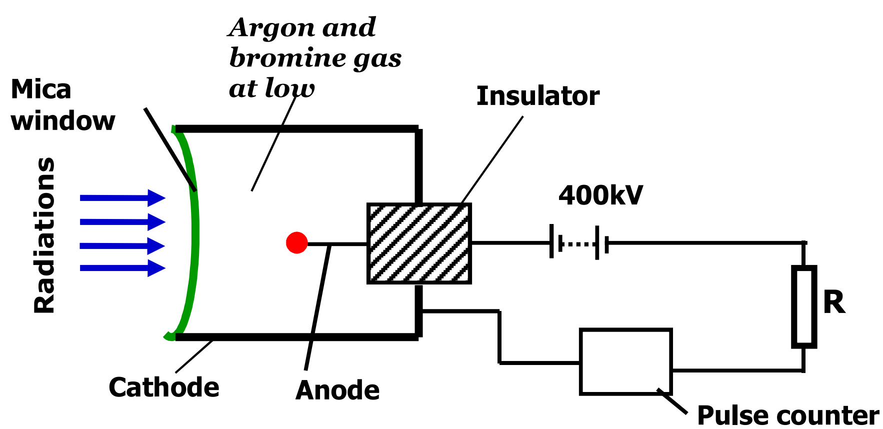
X: --------------------------------
Y: ---------------------------------

12. Radiations from a radioactive isotope were subjected to a strong magnetic field.The results are represented in the figure below.



Identify the radiations J and K giving a reason for your choice. (4mk)

13. The below shows the diagram of a Geiger–Muller tube connected to a power supply and a pulse counter.

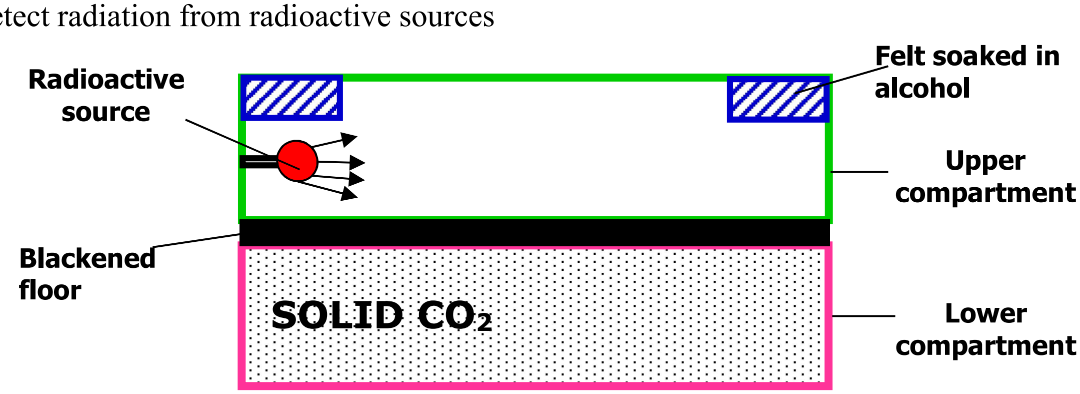


(i) Why should the Argon gas be at low pressure? (1mk)

(ii) Briefly explain how the Geiger–Muller tube detects the radiation emitted by a radioactive. State the purpose of the bromine gas in the tube (4mks)

(iii) Suggest one way of increasing the sensitivity of the tube (1mk)

14. The figure below shows the cross section of a diffusion cloud chamber used to detect radiation from radioactive sources



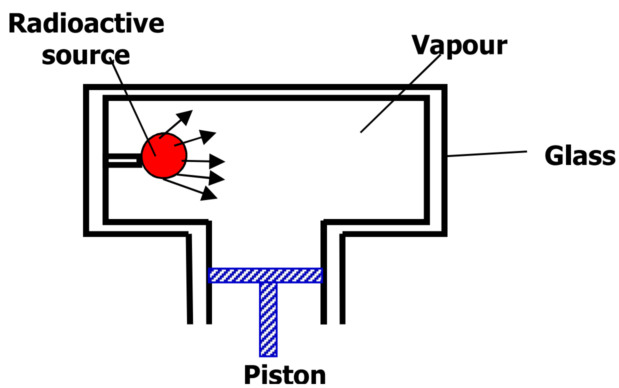
(i) State one function of each f the following ; 2 mks

(a) Alcohol;

(b) Solid CO_2;

(ii) When radiation from the source enters the chamber, some white traces are observed. Explain how these traces are formed and state how the radiation is identified.

15. Fig below shows an expansion cloud chamber.



(i) What is the purpose of the Vapour? (1mk)

(ii) Explain how the radiations emitted by the radioactive source in the chamber are detected. (4mks)

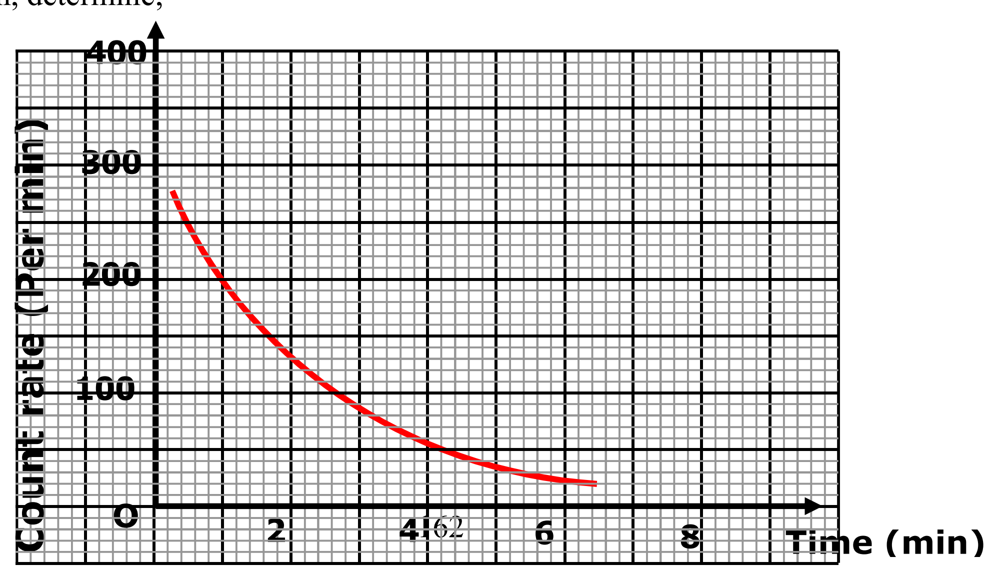
16. The half-life of a certain radioactive substance is 57 days. Explain the meaning of this statement. One of the isotopes of Uranium has a half life of 576 hours.

i) Complete the table to show how the mass varies with time from an initial mass of 1280 mg.

Time (Hours)	576	1152	1728	2304
Mass (Mg) 1280				

ii) Explain whether the mass of the isotope will eventually reduce to zero.

17. The graph in Fig shows the activity of a radioactive sample against time. From the graph, determine;



(i) The initial count rate at t = 0 minutes. (1 mk)
(ii) Half – life of the radioactive substance. (1 mk)

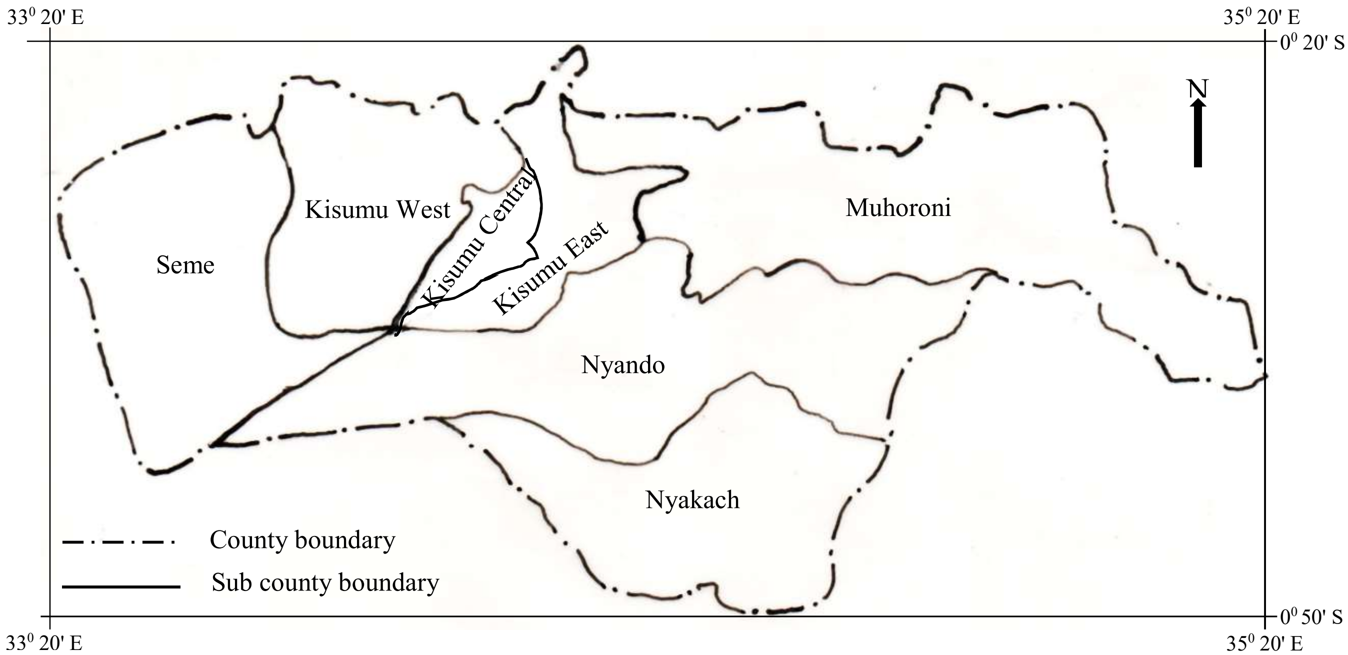
18. Geiger Muller tube without a radio active substance near it recorded a count rate of 50 counts per minute. When a radio active substance was held near it the following data was obtained.

Count rate /min	**950**	**750**	**550**	**400**	**300**	**230**	**170**	**130**
Time in days	**0**	**2**	**4**	**6**	**8**	**10**	**12**	**14**

(a) In the graph provided, plot a suitable graph of count rate per min (y-axis) against time in day (4mks)
(b) Use your graph to determine the following questions
(i) Half life of the substance used. (1mk)
(ii) Approximate count rate on the 11th day.(1mk)

(Grand Total 50 marks)

Appendix E: The Map of Kisumu County



Appendix F: Approval of Proposal

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY
(MMUST)

Tel: 0702597360/61
: 0733120020/22
E-mail: directordps@mmust.ac.ke
Website: www.mmust.ac.ke

P.O Box 190
50100 Kakamega
KENYA

Directorate of Postgraduate Studies

Ref: MMU/COR: 509079

4th June, 2021

Okono Elijah Owuor,
ECI/H/01-52389/2018
P.O. Box 190-50100
KAKAMEGA

Dear Mr. Okono,

RE: APPROVAL OF PROPOSAL

I am pleased to inform you that the Directorate of Postgraduate Studies has considered and approved your Ph.D proposal entitled: ***"Pedagogical Implications of ICT Integration on Active Learning of Physics in secondary Schools in Kenya"*** and appointed the following as you supervisors:

1. Prof. John.O Shiundu - Department of Curriculum and Instructional Technology
2. Dr. Eric Wangila - Department of Curriculum and Instructional Technology
3. Prof. Elizabeth Abenga - Department of Curriculum and Instructional Technology

You are required to submit through [illegible] copied to the following: Chairman, School of Education Graduate Studies Committee and Chairman, Department of Curriculum and Instructional Technology. Kindly adhere to research ethics consideration in conducting research.

It is the policy and regulations of the University that you observe a deadline of three years from the date of registration to complete your Ph.D thesis. Do not hesitate to consult this office in case of any problem encountered in the course of your work.

We wish you the best in your research and hope the study will make original contribution to knowledge.

Yours Sincerely,

DEAN
SCHOOL OF GRADUATE STUDIES
MASINDE MULIRO UNIVERSITY
OF SCIENCE & TECHNOLOGY
Date.............. Sign..............

Dr. Consolata Ngala
DEPUTY DIRECTOR DIRECTORATE OF POSTGRADUATE STUDIES

Appendix G: Ministry of Education Research Authorization

REPUBLIC OF KENYA

MINISTRY OF EDUCATION
State Department of Early Learning & Basic Education

Telegrams:"schooling",Kisumu
Telephone: Kisumu 057 - 2024599
Email: countyeducation.kisumu@gmail.com

When replying please quote

COUNTY DIRECTOR OF EDUCATION
KISUMU COUNTY
PROVINCIAL HEADQUARTERS NYANZA
3RD FLOOR
P.O. BOX 575 – 40100
KISUMU

REF: CDE/KSM/GA/3/24/ (201)

13th July, 2021

TO WHOM IT MAY CONCERN

RE: RESEARCH AUTHORIZATION
ELIJAH OWUOR OKONO – NACOSTI/P/21/11622

The above named is from Masinde Muliro Univesity.

This is to certify that he has been granted authority to carry out research on ***"Pedagogical Implications of ICT Integration on Active Learning of Physics in Secondary Schools in Kenya"*** for the period ending **9th July, 2022.**

Any assistance accorded to him to accomplish the assignment will be highly appreciated.

For :County Director of Education
Kisumu County
P.O Box 575 - 40100,
KISUMU

EUNICE A. OUKO
For: COUNTY DIRECTOR OF EDUCATION
KISUMU COUNTY

Appendix H: Ministry of Interior Research Authorization

OFFICE OF THE PRESIDENT
MINISTRY OF INTERIOR AND COORDINATION OF NATIONAL GOVERNMENT

Telephone: Kisumu 2022219/Fax: 2022219
Email: ckisumucounty@gmail.com

COUNTY COMMISSIONER
KISUMU COUNTY
P.O. BOX 1912-40100
KISUMU

CC/KC/RES/1/3/VOL.IV(45)

13th July, 2021

All Deputy County Commissioners
KISUMU COUNTY

RESEARCH AUTHORIZATION: MR. ELIJAH OWUOR OKONO

Reference is made to a letter from NACOSTI ref NACOSTI/P/21/11622 dated 9th July, 2021 on the above subject matter.

Mr. Elijah Owuor Okono of Masinde Muliro University of Science and Technology has been authorized to carry out a research on ***"Pedagogical Implications of ICT Integration on Active Learning of Physics in Secondary Schools in Kenya."***. The research ends on 9th July, 2022.

Kindly accord him any assistance that he may need.

JOSEPHINE OUKO
COUNTY COMMISSIONER
KISUMU COUNTY

Copy to

Mr. Elijah Owuor Okono
Masinde Muliro University of Science and Technology

Appendix I: NACOSTI Research Licence

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **322205** Date of Issue: **09/July/2021**

RESEARCH LICENSE

This is to Certify that Mr.. Elijah Owuor Okono of Masinde Muliro University of Science and Technology, has been licensed to conduct research in Kisumu, Siaya on the topic: ""Pedagogical Implications of ICT Integration on Active Learning of Physics in Secondary Schools in Kenya"" for the period ending : 09/July/2022.

License No: **NACOSTI/P/21/11622**

322205

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

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