INFLUENCE OF THE VIRTUAL PHYSICS LABORATORY ON TVET TRAINEES' LEARNING OUTCOMES IN TERTIARY EDUCATION: A CASE OF THE KISII NATIONAL POLYTECHNIC

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DEDICATION

I dedicate this work to my late parents for introducing me to education. I also want to dedicate this work to my wife, Jackline and our children; Newton, Rubby, Blessings and Stacy. Their moral support and patience were an inspiration.

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May God bless you abundantly.

ABSTRACT

Though laboratory work is important in the learning of science, it is not often carried out in some schools because not all schools have equipped labs. To alleviate this problem, virtual laboratories (v-labs) have been suggested. However, researchers do not fully agree on the utilization of v-labs in the instruction of Physics. Guided by David Kolb' experiential learning model, the study compared the learning outcomes of trainees instructed using the virtual Physics laboratory (VPL) with those in the conventional Physics laboratory (CPL). The specific objectives guiding the study were, to investigate any differences in the; a) academic achievement between the CPL and the VPL trainees, b) mean retention of content between the CPL and the VPL trainees, c) accuracy of connecting physical circuit components and equipment between the CPL and the VPL trainees and d) speed of connecting physical circuits between the CPL and the VPL trainees; in the Craft Certificate in Science Laboratory Technology (CCSLT) in Physics in Kenya. The target population was all the 1940 Year II CCSLT trainees in the country and their 96 trainers. The sample was fifty three (N=53) Year II Physics trainees and four trainers from The Kisii National Polytechnic. A mixed research design was applied in the study with the quasi-experimental and a survey applied on randomly assigned intact classes to the experimental (N=27) and control (N=26) groups. Within a six-week period the VPL trainees practised in a v-lab while the non-v-lab trainees were exposed to CPL. Both groups were subjected to a Physics Achievement Test (PAT) at pretest (PAT 1) and two post-tests, PAT 2 and PAT 3. A lab test was also conducted. A survey using a trainees' questionnaire; and a trainees' interview were conducted. The research instruments were expert-validated and piloted before use. A Spearman's Correlation Coefficient was calculated for each instrument and obtained as; $r = 0.84$, $r = 0.86$, $r = 0.88$ for PAT 1, PAT 2 and PAT 3 respectively; for the trainees' questionnaire, $r = 0.79$; for the trainers' interview schedule, $r = 0.75$ and for the practical test tool, $r = 0.93$ and $r = 0.94$ for pretest and post-test respectively. All instruments were accepted for use since $r \geq 0.7$ preset. Qualitative data was analyzed and presented thematically. For quantitative data; means, standard deviation, t-tests for four null hypotheses at $\alpha = 0.05$ were applied. The trainees across groups and genders were similar before treatment. The first null hypothesis, H_{01} was rejected, $t = 2.019$; $p = 0.049$; VPL trainees scored significantly higher than the CPL trainees in PAT 2. The users' insights imply that v-labs lead trainees learn content better, but they influence learning similarly in male and female trainees. H_{02} was rejected; $t = 2.308$; $p = 0.025$, thus VPL trainees retain content better than those in CPL. Users perceived v-labs as boosting content retention, but no influence on retention by gender. At $t = 0.056$; $p = 0.956$, H_{03} was retained, so VPL and CPL trainees had similar connection accuracy. However, users perceived the v-labs to increase trainees' connection accuracy. H_{04} was rejected as $t = - 4.391$; $p = 0.000$; the v-labs enhance the speed of connection. V-labs were perceived to increase trainees' connection speed. The study recommended that trainees be engaged in v-labs during practical sessions and that there should be a longitudinal study on the influence of v-labs in learning physics. This research will benefit educationists interested in use of v-labs in instruction of Physics as a useful reference.

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LIST OF ABBREVIATIONS

CPL:	Conventional Physics Laboratory
2D:	Two Dimensions
3D:	Three Dimensions
ICT:	Information Communication Technology
Lab:	Laboratory
PAT :	Physics Achievement Test
PAT 1:	Physics Achievement Test (pre-test)
PAT 2:	Physics Achievement Test (post-test 1)
PAT 3:	Physics Achievement Test (post-test 2: Retention test)
p-value:	Probability of obtaining a test statistic
P:	Examination performance/achievement in Physics
p:	Level of significance
r:	Spearman's Correlation Coefficient; a constant
t:	Time
α:	alpha; a constant; level of significance
V-Lab:	Virtual Laboratory
VPL:	Virtual Physics Laboratory

LIST OF ACRONYMS

CCSLT:	Craft Certificate in Science Laboratory and Technology
CPL:	Conventional Virtual Physics Laboratory
ICT:	Information and Communication Technology
IVPL:	Internet Virtual Physics Laboratory
KNEC:	Kenya National Examinations Council
MOEST:	Ministry of Education, Science and Technology
NACOSTI:	National Commission for Science, Technology and Innovation
PC:	Personal Computer
VPL:	Virtual Physics Laboratory
SAGAs:	Semi-Autonomous Government Agencies
SDGs:	Sustainable Development Goals
SPSS:	Statistical Package for Social Science (SPSS)
STEM:	Science, Technology and Mathematics
TVET:	Technical, Vocational, Entrepreneurship and Training
TVETA:	Technical, Vocational, Entrepreneurship and Training Authority
UNESCO:	United Nations Educational, Scientific and Cultural Organization
WITED:	Women in Technology Education and Development

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Technology is an indicator of modern knowledge-based economies. According to the World Bank Survey of 2018, 70% of the jobs are going to be for persons with technical skills (World Bank, 2018). For the advancement of any nation, the understanding of science and technology are critical. How well these areas are mastered by the populace of any nation predicts the success and development of its economy and quality of living (Republic of Kenya, 2010; Gicharu, 2018; Government of Kenya, 2007). Education in science and technology enables an individual to become knowledgeable and develop relevant skills that enhance individual productivity and quality living (Farooq, Chaudhry, Shafiq, & Berhanu, 2011).

It is on this strength that the Kenyan government conceived a development plan that is referred to as the 'Big Four Agenda' in December 2017. It is a road-map that is meant to guide the country in its development between 2018 and 2022. Kenya has prioritized universal health care, housing that is affordable, food security and manufacturing and aiming at reducing unemployment (Republic of Kenya, 2017). To achieve this, training in skills in Science, Technology and Mathematics (STEM) is of pertinent importance. By engaging in meaningful activities in the Technical Vocational Education an Training (TVET) institutions the trainees get an on-job training either formally or informally which they can use to innovatively solve day to day problems. Physics is and will remain the crucial science for the advancement of the other sciences (Aluko & Olorundare, 2011). The other sciences and technology are heavily dependent on Physics as the equipment used to study them are products of knowledge of Physics. The understanding of Physics concepts, laws, principles and theories are based on the perception of the Physical phenomena (Ayoubi, 2018).

Several challenges that face the modern society, need Physics knowledge so that they can be handled rationally. These include but not limited to: climatic changes, emerging diseases (such as HIV/AIDS, Ebola, COVID-19), security, terrorism, genetically modified organisms, global market competition, energy and population crises and others such as biotechnology among other critical issues (UNESCO, 2010). However, among the fundamental sciences, understanding Physics concepts is the most challenging for students (Arvind & Heard, 2010). This is due to the fact most Physics concepts are perceived as abstract (Jian-Hua & Hong, 2012).

Despite the great importance attached to the training of Science laboratory technologists in any nation that wants to improve her science and technology base and therefore it's economy, trainees' performance in it has been poor in The Kisii National Polytechnic, Kenya. Physics being a practical subject, the low enrollment and dismal performance in it at The Kenya National Examinations Council (KNEC) of Craft Certificate in Science Laboratory Technology (CCSLT) Physics Techniques has made educational researchers, parents, sponsors and other stakeholders to be concerned about the quality of training in the technical training institutions. This implies that the way the practicals are handled needs to be re-looked at (KNEC, 2010; KNEC, 2012; Ongeri, 2010). Unfortunately, these trainees are the ones to be assisting in the handling of Physics practicals at the secondary and the tertiary levels of education. The recurrent complaint aired every time the CCSLT examinations nationally are released is that performance in Physics Techniques is low (Government of Kenya, 2007; KNEC, 1999; KNEC, 2010; KNEC, 2012; KNEC, 2018).

The performance of the trainees in the CCSLT Course at the Kisii National Polytechnic have remained low. However, when trainees from this course leave The Kisii National Polytechnic and go to repeat in other TVET institutions they do much better as compared to when they re-sit the same examinations from the same Polytechnic. Table 1.1 shows both the overall percentage pass for The Kisii National Polytechnic CCSLT course in The Kenya National Examinations compared to percentage overall pass for technical courses at The Kisii National Polytechnic (KNP) for seven years.

Table 1.1. Trainees' performance in Craft Certificate in Science Laboratory Technology course between 2012 and 2018

Year	2012	2013	2014	2015	2016	2017	2018
% Overall Pass in Science lab technology at KNP	30.0	30.0	18.2	10.0	0.00	3.03	4.88
% Overall Pass for Technical Courses at KNP	47.5	62.8	68.2	43.0	29.1	37.0	49.3

Source: The Kisii National Polytechnic Examination Office (2012 - 2018)

As can be seen from Table 1.1, the percentage pass has been consistently far much below the polytechnic's percentage pass for the technical courses, with the best overall performance being 30% for the years 2012 and 2013. It is worth noting that in 2016 not even one CCSLT trainee passed in Physics. The low achievement is an indicator that learning of Physics at this level is wanting. This means that the subject pulls down the colleges performance in examinations. There is therefore a need for looking for ways and means of improving the learning of the CCSLT course and therefore improve students' performance. How trainees have been performing in the Physics techniques subject at The Kisii National Polytechnic over a ten years' period is presented in Table 1.2 below.

Table 1.2. Trainees' performance in Craft Certificate in Science Laboratory Technology Physics Techniques between 2010 and 2019

Year	Entry	Distinction (1-2)	Credit (3-4)	Pass (5-6)	Referral (7 - 8)	Fail (9)	CRNM	X	Y	(% Pass)	(% Fail)	% Overall Pass for CCSLT at The KNP
2010	14	00	00	06	06	02	00	0	0	42.9	57.1	28.6
2011	00	00	00	00	00	00	00	0	0	0.00	0.00	0.00
2012	10	00	01	07	02	00	00	0	0	80.0	20.0	30.0
2013	20	00	01	17	01	00	01	0	0	90.0	10.0	30.0
2014	33	00	03	26	02	01	01	0	0	90.9	9.10	18.2
2015	30	00	01	17	16	02	00	0	0	60.0	40.0	10.0
2016	24	00	00	06	18	00	00	0	0	25.0	75.0	0.00
2017	33	00	00	12	21	00	00	0	0	36.4	63.6	3.03
2018	41	00	04	24	13	00	00	0	0	68.3	31.7	4.88
2019	61	00	01	20	40	00	00	0	0	65.6	34.4	3.28

Source: The Kisii National Polytechnic Examination Office (2010 - 2019)

The KNEC has a system of grading in which Grades 1 and 2 are considered a distinction; grade 3 and 4 as a credit; grades 5 and 6 as a pass; grades 7 and 8, a referral and grade 9 as a fail. Another category is Course requirements not met (CRNM). X means absentee for a given examination while Y represents cheating in examinations. From Table 1.2 it can be observed that the enrollment has been increasing slightly it is still low up to recently. The performance in the Physics Techniques subject in KNEC examinations for the ten years has been poor. The wastage rates in Physics Techniques for some of the years are worrying. For example, in 2010 the waste rate was a high of 57.1%; 40% in year 2015; 75.0% in 2016; 63.6% in 2017; 31.7% in 2018 and 34.4 in 2019.

The overall performance is low, which means that the number who successfully exit the training is minimal. There is therefore need to look for innovative ways of making trainees learn Physics Techniques better. From Table 1.2 it can be seen that the number of trainees who take the course is small and therefore we expect that the contact hours between the trainees and the trainer should be high. This should make the trainees perform well, but that is not the case. There could be reasons that make the enrollment and achievement low. These could include the utilization of outdated teaching strategies, inadequacy of instructional materials especially an equipped laboratory, lack of their use and poor attitude towards the subject (Akala & Changilwa, 2018). Instruction and acquisition of knowledge of science by inquiry is being promoted as the best way to help learners to construct information by themselves, understand inquiry in science, and apprehend how to have interaction in the investigative procedures

(Blanchard, 2010). It is evident that the inability of science instructors to use inquiry strategies is hinged to issues which include: lack well equipped laboratories in schools, overcrowded classes with very few science teachers and with competency issues springing from teacher training (Marshall, 2011; Ngesu, Gunga, Wachira, & Kaluku, 2014). Furthermore, Opateye (2012) and Odawa, Okwara, Murundu and Bantu (2013) have indicated that many science instructors choose the normal expository methods of instruction, lecture being the most preferred method of teaching.

The place of laboratory in science (especially Physics) and engineering courses cannot be overemphasized it has been well documented (Fiscarelli, Bizelli, & Fiscarelli, 2013; Hofstein & Kind, 2012; Hofstein & Lunetta, 2004). The hands-on approach in the laboratory is a typical form of experiential leaning, which countries who wish to keep abreast with technology must embrace by elevating the individuals who not only have analytical but who are productive and are very well skilled in the basic sciences (Çalışkan, Selçuk, & Erol, 2012). Lateh and Vasugiammai (2011) assert that when laboratory hands-on activities are performed either individually or in small groups, learners are enabled to learn permanently. Constructivism does not make the learner a passive recipient of information but one who actively constructs it by oneself (Khan, Hussain, Ali, Majoka, & Ramzan, 2011; Leman, 2014).

The laboratory supplies students with real world practical aspects that can be applied to real workplace (Balamuralithara & Woods, 2009; Çelik & Karamustafaoǵlu, 2016). When the theoretical information in a hands-on activity is not comprehended by the students, they do not retain it and accordingly, this leads to disappointment in the subject they are studying (Wingate, Andon, & Cogo, 2011; Trundle & Bell, 2010). Thus, they create negative attitude towards the subject. Physical laboratories cannot be used effectively due to reasons like few schools have them, the value of setting them up and maintain and the inadequacy or lack of tools (Tatlı & Ayas, 2011; Wolf, 2010). Performance by trainees throughout the experiments in laboratory session cannot easily be checked by the teacher due to the fact that, the classes may be overpopulated, it is time consuming and laborious particularly were massive numbers of students are concerned (Tüysüz, 2010; Wolf, 2010). These cannot effortlessly be afforded with the aid of the already heavily resource constrained technical training institutions.

Onyesolu (2009), sees constructivism in science as hindered by the inadequacy or lack of experimental materials and equipment in schools. In developing countries as in the case in Africa, the training of technicians and engineers in technical training institutions is constrained by the lack of capability in presenting laboratory sessions (Kessy, Kabemba, & Gachoka, 2006). Akeyo and Achieng (2012) observe that practicals are not carried in TVET institutions because of the same reasons. When these challenges are taken into consideration, it becomes inevitable that an alternative that may work better be looked for, hence, the use of virtual laboratories (v-labs) have been suggested (Trundle & Bell, 2010).

Virtual laboratories are computer simulations that copy and replicate the physical world so that a learner performs experiments using a computer as if performing them in a physical laboratory (Corter, Nickerson, Esche, Chassapis, & Ma, 2007; Tatli & Ayas, 2011; Tatli & Ayas, 2013; Zacharia & Olympiou, 2013). When the outputs are motion pictures and sound, like in games, the user is afforded virtual reality. This makes it not only experiential but immersive segment of simulations making it appear more appealing for instruction in the STEM disciplines (Adams, 2010). Simulations give feedback that is immediate to the user so that if there is any need for changing of a variable, the user can vary it and observe the effect or result (Smetana & Bell, 2012). Researchers appear not to agree wholly on the influence of v-labs on students' learning outcomes (Corter et al., 2007; Sabah, 2011). There is a big debate on the effectiveness of v-labs in the education of practical skills (Ma & Nickerson, 2006; Kapting'el & Rutto, 2014). The analysed literature included studies that are from conference proceedings and published in journals up to start of the year 2021.

There are limitations noted in the reviewed literature. Much of these are of the descriptive type where much of the information was obtained utilizing qualitative data obtained via interviews and participants' data-obtained by use of questionnaire. A couple of investigations investigated the influence or effectiveness of v-Lab, which could look at and think about the attitudes, the results of learning and the aspects that deal with interaction on an experimental level and all that is seen to be of importance in research methodology. Not many of the studies have delved into skills transfer which are a result of utilization of v-labs. Hence the need for this research. Prior to the utilization of a given technology, it is necessary to find out whether it is capable of attaining what it claims to achieve.

This research basically dealt with the influence of virtual Physics laboratory on the learning outcomes in Physics in Kenya, one of the nations that are still developing. Here there is real scarcity of physical components and equipment while personal computers are ever increasingly penetrating our educational institutions. This happens as the population of trainees in TVET institutions keeps soaring, following the introduction of capitation by the Government of Kenya and introduction of Higher Education Loans Board (HELB) loans, but there is no increase of equipment to take care of the increase in enrollment, thus the monetary assets are not sufficient to procure the required training materials and gadgets to merge with the multiplied population.

1.2 Statement of the problem

Physics experiments are not often carried out in some tertiary technical training colleges in Kenya. Among the reasons for the existing state of affairs is the inadequacy or lack of physical equipment. Female trainees shy off from taking STEM courses because they perceive the training kits and outdated and manual machines therein as requiring a lot human power and are not appealing to them. Virtual laboratory has been suggested as one of the methods that can be used to alleviate the laboratory capacity problem, complement classroom demonstration, where competences can be practiced by trainees in v-labs when real physical tools are inadequate or are unavailable. Further, that the v-labs have got immense benefits for the users, which include performing experiments that normally pose danger, allowing for repetition at will, they have multiple representations and that they can assist in technical skills acquisition. However, researchers seem not to agree wholly on the pedagogical effectiveness of virtual laboratories with some researchers feeling that the v-labs contribute positively while others see the otherwise. There is little literature on the influence of use of v-labs in TVET on learning outcomes at the tertiary level, especially on transfer of skills. Of the reviewed literature, the studies revolved around either the secondary or university segments of education.

Prior to the utilization of a given technology, it is necessary to find out whether it is capable of attaining what it claims to achieve. This study was conducted to establish how use of v-labs influences the training outcomes of CCSLT trainees. Specifically, it examined how v-labs influence the acquisition of conceptual and technical skills in electric and electronic circuitry while using quantitative strategies above the qualitative ones in an attempt to improve the learning outcomes in the Physics Techniques subject in TVET at this level of education.

1.3 Justification of the Study

The study intended to find out how virtual Physics laboratories influence learning outcomes of trainees in the TVET segment of education and training in Kenya. By doing this, the findings of this study adds to the current body of knowledge on the influence of v-labs on the learning of Physics. It was essential that the influence of v-labs in electric and electronic circuitry skills be investigated for the reasons that follow: (1) The question of the influence of v-labs on skills transfer is still not resolved and remains a matter of contention though it is gaining popularity in utilization. It is hoped that the findings of this study, with its delimitation to training of skills has made this issue clearer. (2) A similar investigation on the influence of v-lab on the transfer of circuit mastery and connection abilities in Physics has not been conducted for TVET. (3) Kenya needs to train its youth to possess high competencies at a low cost. However, this usage should not lower the quality of competences among graduates produced by this training as this could be ineffective.

Using this knowledge, the trainers of Physics and other STEM areas, trainers at tertiary TVET will benefit optimally from the utilization of the Physics virtual laboratories as resource for learning and teaching. The stakeholders in the education sector in the country, Technical, Vocational and Entrepreneurship Training Authority (TVETA) will also find the findings of great use, for they supply feedback that is much needed to be provided and possessed by the trainers who train teachers of sciences in training colleges, a factor which is likely to enhance the education and training of teachers of Physics. The study findings may again be of immediate gain to the designers, developers and evaluators of tertiary science and technology curriculum and textbooks, such as the Kenya Institute of Curriculum Development (KICD) and The Kenya National Examinations Council (KNEC). Further, future researchers who want to do similar or associated studies will use the results of this study as it will serve as a source of documented literature. It indeed has exposed gaps that need to be researched further.

1.4 Purpose of the Study

The study sought to answer the question as to whether or not utilization of v-lab in training influences the acquisition of understanding Physics concepts and transfer of practical skills at the tertiary phase of schooling in Kenya. Specifically, the study sought to find out how v-labs influenced academic achievement, retention of content and the transfer of electronic and electric circuitry competencies – connection accuracy and connection speed in the trainees who used them.

1.5 Objectives of the Study

The study was guided by the following four objectives:

1. To investigate differences in academic achievement between the trainees who were taught Physics using virtual Physics laboratory and those taught using conventional Physics laboratory.

2. To examine differences that could exist in the mean retention scores of trainees exposed to virtual Physics laboratory and those exposed to physical laboratory as measured in second post-test.

3. To examine any differences in the accuracy of connecting physical circuit components and equipment between trainees who practiced in a virtual lab and trainees who did not practice in a virtual lab.

4. To find out if there exist differences in the mean times taken to connect physical circuit components and equipment between trainees who practiced in a virtual lab and trainees who did not practice in a virtual lab.

1.6 Research Questions

The study sought to answer the following six questions:

1. What differences exist between the academic achievement of trainees taught Physics using virtual Physics laboratory and those taught using conventional Physics laboratory?
2. To what extent is the retention of content by trainees exposed to virtual Physics laboratory different from those exposed to physical laboratory?
3. To what extent is the accuracy of connecting physical circuit components and equipment between trainees who practiced in a virtual lab and that of the trainees who did not practice in a virtual lab different?
4. What differences exist between the mean times taken to connect physical circuit components and equipment by trainees who practiced in a virtual lab and those trainees who did not practice in a virtual laboratory?

1.7 Research Hypotheses

The following research hypotheses were formulated and tested in this study at significance alpha level of 0.05:

H_{01}: There is no statistically significant difference between the mean academic achievement scores of trainees taught Physics with virtual Physics laboratory and those taught with conventional Physics laboratory.

H_{02}: There is no statistically significant difference in the mean retention scores of trainees exposed to virtual Physics laboratory and those exposed to conventional Physics laboratory as measured in second post-test.

H_{03}: There is no statistically significant difference in the mean score in accuracy of connecting physical circuit components and equipment between trainees who practiced in a virtual lab and trainees who did not practice in a virtual lab.

H_{04}: There is no statistically significant difference in the mean time taken to connect physical circuit components and equipment between trainees who practiced in a virtual lab and trainees who did not practice in a virtual lab.

1.8 Scope of the Study

This investigation essentially dealt with influence of v-lab on Craft Certificate in Science Laboratory Technology trainees' learning outcomes in Physics at The Kisii National Polytechnic. The investigation used two research designs; a survey research design and a quasi-experimental research design with a single National Polytechnic among the ten existing in Kenya presently. This study was restrained to one tertiary TVET institution in Kenya out of a whole of one hundred forty-two (142) (MoE Website, 2019) established at the time of sampling. The target population was all the Craft Certificate in Science Laboratory Technology trainees and their trainers in Kenya with the sample being those who are in their Second Year of training and their trainees at The Kisii National Polytechnic. Therefore, the research findings cannot be generalized to trainees in other TVET institutions, though can guide in implementation of v-labs in institutions with similar characteristics to it. The investigation was restrained to four (4) Physics trainers. Only, Physics (Techniques) among the subjects that the trainees learn in this course was used for the study. Pretest-Post-test was used to check the impact of the treatment. Equally, a practical test was used to check the transfer of the practical skills. Further, a trainees' questionnaire and a trainers' interview were used.

1.9 Limitations of the Study

The findings of this study were impacted by the following constraints. First, the researcher had confined control on the trainers' mind-set toward Physics practicals which may also have had an effect on the influence of the trainees' gaining knowledge of outcomes as measured by way of the research tools. Similarly, there was little or no control on number of trainees in the classes of the sampled institution. The size of the class may have affected the quality of Physics practicals. This in turn may have had an impact on the influence of the trainees' learning outcomes. There may have been other variables confounding the trainees' performance. To tackle this, the researcher did randomization, tho check whether the groups involved in the study could be treated as similar at the start of the treatment using analysis of pre-test using the t-test to explore Pretest versus post-test effects and statistically controlling variables which have now not been done so physically.

1.10 Assumptions of the study

The following assumptions were made for this study;

1. The trainees who participated in the study were assumed to be similar in every aspect such as learner type, quality and behaviour.

2. The Physics trainers were similar in qualifications, skills and experience.

3. The respondents answered questionnaire items truthfully.

4. Additionally it was assumed that the trainees did not change behaviour due their participation in the study (experiment) itself, that is, there were no Hawthorn Effect.

1.11 Theoretical Framework

The model applied in the study was centered on the experiential learning theory proposed by David Kolb (Kolb, 1984) and which was improved by Novak (2010); which is one of the constructivist theories and a modification of the early ideas that of British empiricism and John Locke (1690), John Dewey's philosophy of pragmatism (1938), the idea of cognitive development as put forward by Piaget (1952), among others (Kolb, Boyatzis and Mainemelis, 2001). According to Locke humans can only learn based on what experiences they have been taken through (Locke, 1690). The empiricism philosophy views science as a process in which humans make physical sensory observation of their environment through hands-on activities, to verify hypotheses and theories. Dewey explains that when a learner progresses through a four-stage cycle, effective acquisition of knowledge and skills is observed. These four cycles are specifically, (1) being exposed to a concrete encounter accompanied with the aid of (2) observing and reflecting on that encounter thus being led to (3) the formation of abstract concepts (analysis) and generalizations (conclusions) which are then (4) applied to hypothesis testing in new environments, ensuing in new situations (Kolb, Boyatzis, and Mainemelis 2001). according to Kolb (1984) such learning is a process which is cyclic in which there is increment of concrete encounters, gazing and reflection about, formation of abstract ideas, and checking out the said ideas in new environments.

Acquisition of technical skills usually includes hands-on, which essentially is a process of learning in which feedback is required through involvement in activities, internalizing the steps, rearrangement, and testing. This is because trainees are afforded an opportunity and permitted to construct knowledge through private interaction, to discover understanding or reinforcement or skills (Kolb, Boyatzis and Mainemelis, 2001). Noting weakness in this theory, Lewin and later Kolb (1984), in coming up with the theory of social learning added to it the possibility of feedback and problem solving. In Kolb’s model, the process of learning is considered as continuous and an action facilitated by a goal and with evaluation at various stages in it (Kolb, 1984). This means that what new information is dependent on the learners interaction with a similar situation in the past. Learning is seen as a cyclic process in which the learner's impulse is after the previous cycle. Figure 1.1 graphically demonstrates the model.

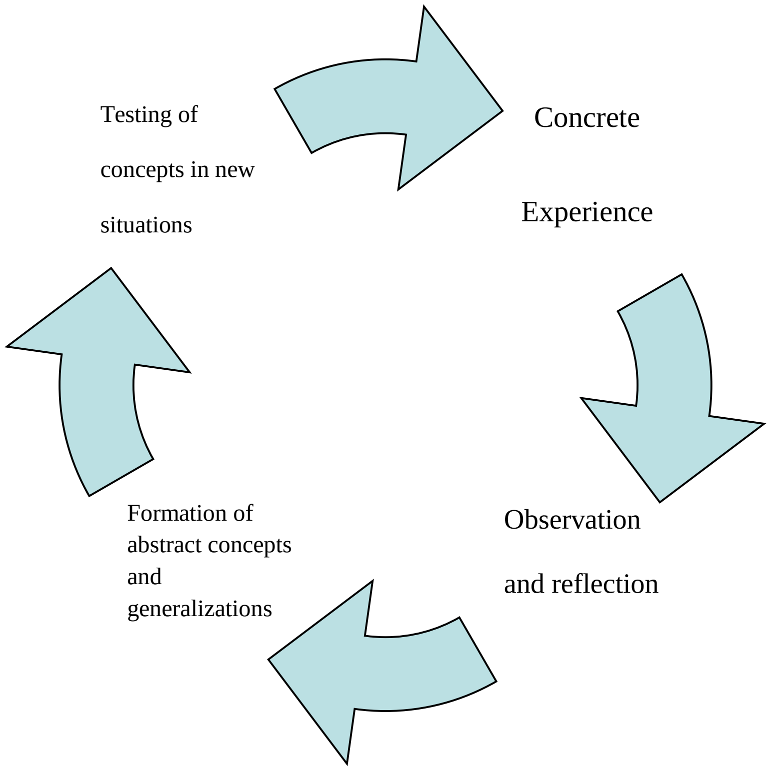


Figure 1.1. Lewinian experiential gaining knowledge of model (Kolb, 1984)

In the learning model proposed by Piaget learning is treated as developmental process proceeding from childhood to adulthood (1952). Piaget distinguishes between how a child and an adult view the world with the child having a concrete view while an adult incorporates abstract conceptualization. He further perceives as occurring depending on how the individual has interacted with the environment. The acquired information from the person's surroundings can get accommodated or assimilated into one's prior schema. When the existing model (schema) is altered to give explanation to the new information which fits not to the existing schema, it is called accommodation. However, when new information fits or is assimilated to a model (schema) that is already existing this is termed as assimilation. As far as laboratories are concerned, accommodation is the situation whereby the experimental results do not fit the hypothesis and an adjustment to the hypothesis is made while when the results fit to the expectations such information is said to have been assimilated to the existing model (schema).

Concrete encounters are improved via material perceptions, which are mirrored upon to frame abstractions (conceptualizations) and generalizations. Then these two are executed in new environments by means of examination of discovered and foreseen material outcomes. In this perspective, actions are surveyed by way of perception and the outcomes are utilized to have an impact on therapeutic adjustments for future actions. The meaning of newly acquired information is established by associating it with the earlier attained experiences. The learning cycle is such that the next cycle builds on the past experiences (cycle).

V-labs are generic environments with attributes that consist of interactivity in real time, remark Zacharia and Olympiou (2011). The acquisition of the technical skills usually comprises of practising the skills, in which feedback is of great necessity and the learners are required to be thoroughly involved via hands-on, internalization, rearrangement and evaluation of the results. The characteristics of the v-lab fit into these descriptions as they simulate the hands-on activities in the real world and also provide timely feedback (Zacharia & Olympiou, 2011). This makes virtual laboratories alluring for education and training that require hands-on, for example, scientific and technical skills. This way trainee is permitted to construct knowledge, skills and attitudes through interacting with the system to establish new information (Kolb, 1984).

The researcher in this study is in agreement with the modified Kolb's experiential learning theory and further feels that the v-labs, if well designed and developed have the capability of taking the trainees through the four stages of learning and training. This is because the v-labs have several capabilities that the human teacher may not be able to patiently do as allowing for repetition of the practical activities and attending to the learners questions and in reinforcing appropriately. But this is only applicable if and only if they are well applied, with some cases the v-labs being used as hybrid with the real hands-on laboratories.

1.12 Conceptual Framework

Figure 1.2 presents the conceptual framework for the interaction between variables.

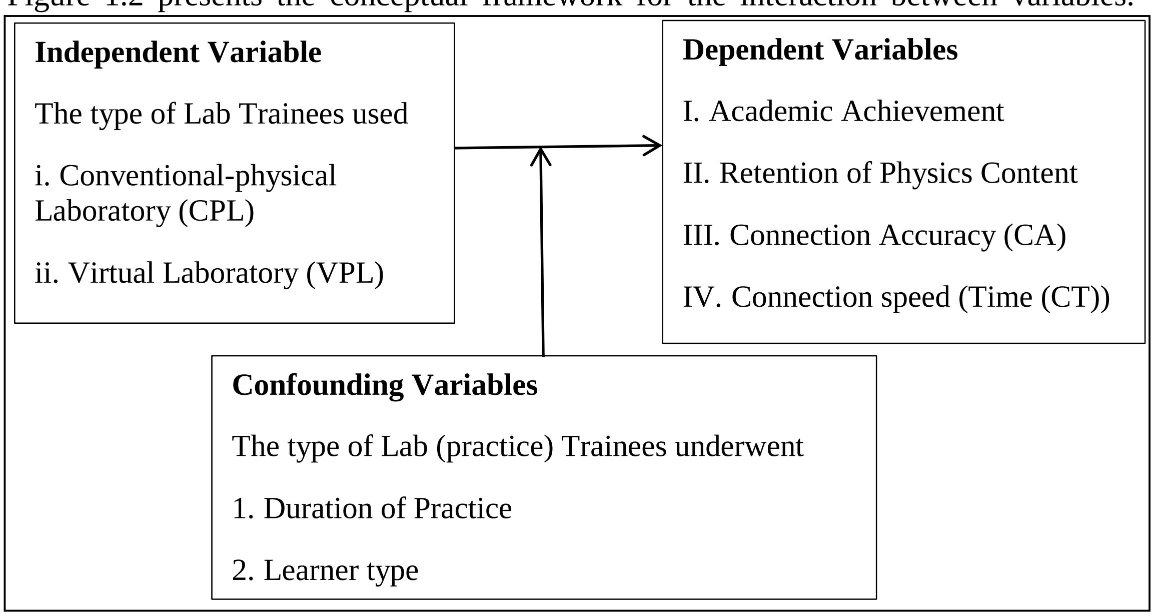


Figure 1.2. A Conceptual Framework for the Research

The research had one independent variable and four dependent variables. Based on Figure 1.2, the independent variable was the type of laboratory college trainees were exposed to – either v-labs or physical labs. The four dependent variables were academic achievement by group, retention of content, and transfer of training as measured by connection accuracy (CA) and connection time (CT). Both connection speed and connection accuracy suggest transfer of training. How each of the four mentioned dependent variables were affected by application of the v-lab were explored.

It can be considered that practice time and learner type may have had an effect on the result of the research (Clark, 1983; Clark & Vogel, 1985). These variables would confounded the effects of the experiment have to be controlled at some stage in implementation. To reduce the effects of these extraneous variables, the learners in the study were taken from same TVET college were assumed to be having same characteristics, including learning styles, the experimental group and the control group were taught the same content within the same length of time so that it can be established that any difference in the achievement is due to the difference in the mode of delivery of the Physics practicals. To triangulate the results of the theoretical tests a survey and interview were conducted in getting what the feelings of the sample is like. The effectiveness of any method for instructing in the accomplishment of particular performance objective is subject to a wide range of variables. For this situation the performance targets were the capability to answer theoretical questions, connect electronic and electric circuits accurately and within meaningfully a short time. The intervention of the utilization of v-labs as an educational innovation. It is normally hard to confine how much each of these elements contribute and now and then every one of them is neither independent nor its interaction with the others. For example, students' earlier encounter with virtual labs may influence their interactions. Additionally, each of these elements may be having mutual dependencies with one another.

1.13 Operational Definition of terms

The following definitions were identified and operationalized for use in the progress of this study:

Academic Achievement: Performance as measured by the scores in an examination. In this study, it is used to mean scores obtained in Physics Achievement Test (PAT).

Connection accuracy (CA): How precise a trainee connects a set circuit in the practical test.

Connection time (CT): How long in minutes a trainee takes to connect a set circuit.

Conventional Laboratory: A laboratory whereby the physical devices and equipment, the trainees are both confined and present in the physical laboratory room. The learner and the facilitator are also not separated by time and distance.

Gender: This is how society associates being either male or female with the socio-economic, political and cultural attributes and opportunities.

Information Communication Technologies (ICTs): All those technologies that are closely related to computer hardware and software that are applied in the present world.

Learning Outcomes: Are all those behaviours as a result of instruction or exposure to some learning experiences. In this study they are; academic achievement, retention of content, accuracy in connection and speed of connection of real/physical electronic components and equipment

Physical Laboratory: A classroom where learners, equipment and materials are physically present at the time a practical session is on.

Retention: How much content a learner/trainee can be able to remember after some time has elapsed

Simulation: A computer system that replicates the real world and represents it dynamically.

Technical education: Structured system aimed at providing recipients with the necessary knowledge and skills to perform practical and industrial tasks.

Tertiary education: Education at a level beyond the secondary school education. Normally, it is used to prepare people for the actual workplace skills such as plumbing, electrical installation and building technology among others.

Trainee: A learner being trained in technical skills, which involves practical skills mainly but there is also theory infused to make the practical skills better understood.

Trainer: A person who facilitates the learning of technical skills and knowledge. S/he is a teacher/instructor.

Treatment: An academic intervention given to learners in the experimental group so as to determine its effect on learning outcomes.

Virtual laboratory: A computer simulation that replicates a physical (real) laboratory. These can be 2D or 3D models, simulations and a variety of graphics within interactive means to support learning activities.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents the review of relevant literature on the utilization of virtual laboratory as a tool of instruction. Literature reviewed was divided into four related sub-sections each presenting a review of the research done in thematic areas. These thematic areas are; virtual laboratories and academic achievement, virtual laboratories and retention of content, and virtual laboratories in skills training – accuracy and speed of connection of electric circuits resulting from exposure to virtual laboratories.

2.2 Virtual laboratories and Trainees' Academic Achievement

Information Communication Technologies (ICTs) play an important role in the enhancement of learning and instruction in science (Fathima, 2013) and in the evolving field of classroom teaching (Sasidharakurup et al., 2015). ICTs are practically feasible in improving diverse computational methods (Young, 2011); evaluating learning result accomplishment and giving feedback. This is as however, though PCs and ICTs are ever getting more into the learning institutions including those of developing countries such as Kenya, they are rarely utilized in actual instruction.They are however, utilized mainly to facilitate clerical tasks, to process examinations, to timetable and record keeping of the institutions (Kirimi, 2014).

In his study the perceptions of students and faculty's utilization of social media in Higher Education, Zgheib (2013) established a myriad of challenges for non-utilization of ICTs in curriculum instruction in Lebanon. They include but not limited to the inadequacy or the lack of appropriate hardware and software, deficiency in knowledge, poor skills and low attitudes towards use of ICTs and technology in general in instruction. Back home, Kenya ICTs are rarely utilized in the delivery of the curriculum. In a study carried out in West Pokot County, Kenya, Chesitit (2015) strongly recommended that the Ministry of Education, Science and Technology (MOEST) should work towards integration of ICT skills with other strategies of teaching in the secondary school curriculum and digitize curriculum content, but it is yet to be integrated in instruction. The TIVET ICT baseline survey report of 2011 exposed the inadequacy of ICT devices and trainers in the area of ICT (Hooker, et al. (2011). This could be hampering the infusion of ICTs, especially v-labs in instruction, despite being an important facet in STEM instruction.

V-labs have been suggested and in some cases used as an innovative trend for carrying out of laboratory work in science subjects. In fact, artificial intelligence (AI) uses machines which copy the activities and behave just like human beings to carry out and to simulate, expand and extend human intelligence. Such activities which AI has been designed to simulate recognition of speech, learning, planning, and ability to manipulate and navigate objects, alongside problem solving, and mapping. AI is best exemplified by robotics and v-labs (Xinhua & Lin, 2018). The utilization of simulations (especially 3D) are capable of encouraging more students towards carrying out self-studies because they make one to be immersed, therefore leading learners to learn in a flipped classroom as well as consolidation of the main points happen amid class time (Esson, 2016). V-labs provide learners with a non-boring environment for carrying hands-on which foster and maintain the learners' interest (Mejías & Andújar, 2012). Ma and Nickerson (2006), suggest that virtual laboratories are different from real labs in that real labs include investigation processes that are real. Just like the learners are physically present in a physical world, so are the equipment to be utilized as a part of a hands-on lab.

The use of v-labs have several advantages in developing students' knowledge and skills. Part of these are; executing time-consuming experiments within a shorter time, completing dangerous experiments in a safe to fail environment, reproducing situations that are difficult to observe in a real laboratory in a virtual environment, being an alternative answer for expensive labs, empowering learners to advance at their own speed, giving learners quick feedback so that they can check what they have learnt, students can repeat many times any inaccurate trial or to extend their proposed encounters (Smetana & Bell, 2012; Trundle & Bell, 2010; Pols, 2020; Rutten, Joolingen, Jan & Van der V, 2012; Tatlı & Ayas, 2011; Sypsas et al., 2019; Fiscarelli et al., 2013; Zabunov, 2013; Rotimi, Ajogbeje, & Akeju, 2012). Use of v-labs in teaching Physics expands the learner's interest and gives learning some fun (Clarke, 2010; Gambari, Gbodi, Olakanmi & Abalaka, 2016).

Others include accessing remotely the training programme at a distance, minimal cost, security, reliability, adaptability, and giving the learner convenience (Auer, Pester, Ursutiu, & Samoila, 2003). Simulations offer the user the chance of interacting with it, manipulate situations and values, get immediate feedback, and utilization of multiple representations (Mwamba, George, Moonga, & Pondo, 2019). Virtual laboratories supporters propel the possibility of virtual lab being utilized to enable students in learning at appropriate level of difficulty (Penn & Umesh, 2019; Alneyadi, 2019).

Ausbel (1968) sees learning as a continuous process of changing from novice to expert. The v-labs assist the learners in attaining this step-wise as they practice the skills starting with simpler tasks and progress to more challenging ones while learning. Vygotsky's proximal development zone refers to a circumstance in which a learner nearly understands an idea yet can't arrive without intervention or outer assistance (Vygotsky, 1978). Instruction must be custom fitted to the level that learners can get it. In topics that include a lot of deliberation of complex environments, for example, electric and electronic circuitry, this can be a challenge. V-labs have been found to be effective in that they allow users to go through the experiments individually and that they can repeat any number of times as need may arise (Aljuhani et al., 2018).

Nance, Hay, Dodge, Seazzu and Burd (2009) affirm that v-labs do not only help learners to meaningfully engaged in their studies, but also in conceptualizing ideas and constructing knowledge by their own thus expanding learning. The experiment by Zacharia and Olympiou (2011) suggests that v-labs can be of great effectiveness in promoting learning of concepts. Milo, Christine and Edith (2011) argued that the capacity for students in seeing the internal working of the system and have the capacity of changing or modifying conditions, makes the v-labs capable instruments for students to form internal schema. The virtual laboratories allow users to flexibly work at their own pace by delaying what is supposed to be played, replayed (wound), or ceased at a specific time to look at the system’s condition. Alneyadi (2019) opined that v-labs significantly affected the students’ knowledge, skills, attitudes, and achievement.

It is now a standard practice in technology and engineering, in the production of machines or by machines to model virtual systems before making the physical ones (Hutchinson, 2007). V-labs have the capability to present a simpler version of the system which are to the level of the user. Finkelstein, Adams, Keller and Kohl (2005) have demonstrated that students engaged in a v-lab have a tendency to be more mindful to the job needing to be done than in hands-on labs. Tatli and Ayas (2012) in their study on effect of v-labs on students’ achievement in Chemistry realized significant improvements in the performance by students subjected to v-lab than their non-v-lab counterparts. Tüysüz (2010) and Al-Hasan (2018) maintain that virtual laboratory builds the learners' academic achievement and attitudes. Çelik and Karamustafaoǵlu (2016) found virtual labs to be more fruitful than the instructing actualized by customary laboratory technique.

V-labs help learners increment their insight with respect to imperceptible molecular-level phenomena and obtain better theoretical comprehension (Kollöffel & de Jong, 2013; Tsihouridis et al., 2014; Olalekan & Oludipe, 2016). Tsihouridis et al. (2015) studied third year secondary school students and established that the sequencing of the physical and the v-lab in the procedure of teaching influence the comprehension of the ideas in electric circuits. Tsihouridis, Vavougios and Loannidis (2016) discovered that the cyclic procedure of physical and v-lab, kept students' enthusiasm by upgrading their basic reasoning and enhancing the process of learning, if the repetition does not appear to be straight. Kapilan, Vidhya and Xiao-Zhi (2021) in their study on virtual laboratory utilization during the Covid-19 pandemic on students of mechanical engineering education found that v-labs assist learners to enhance learning process by making them conceptualize the content and majority of them indicated that there is necessity of introducing v-labs in engineering curriculum. This was made necessary by the ever increasing number of COVID-19 infections so making online classes to be preferred as from the academic year 2020–2021. The v-labs are seen as an alternative of physical labs in helping the students to complete their laboratory classes without affecting the quality of learning.

To summarize the pros for virtual labs; first, v-labs are student-centered, enable students to get prompt feedback and correct their misconceptions of an idea (Smetana & Bell, 2012). Secondly, v-labs are a low cost (either cost of instrumentation or supplies) venture for hands-on activities that are complicated or even harmful and can be reproduced in a virtual environment in a safe way (Achuthan & Murali, 2015). Thirdly, remote labs are utilized as supplementary devices for supplementing face to face laboratory instruction (Mejías & Andújar, 2012). Fourth, it provides a chance for learners to work freely, at their own particular pace on the web, figure out how to utilize instruments and other materials and do a pre-lab experiment prior to doing it in the lab (Borrás, García, Quirantes, Segura, & Fernández, 2011). Fifth, they can be applied in training complex skills. Wong et al. (2020) add that v-labs assist in reduction of equipment needed, experiments can be conducted from anywhere and at a convenient time for the learner, and also provide the users with an opportunity of learning at their own pace as they explore interesting or difficult concepts. Utilization of v-labs enables learners to learn concepts in science and gain new skills anytime and anywhere by applications on their gadgets such as smartphones, tablets and laptops (Ramesh, 2019).

These advantages are summarized in Figure 2.1, adapted from Hatherly, Jordan and Cayless (2009).

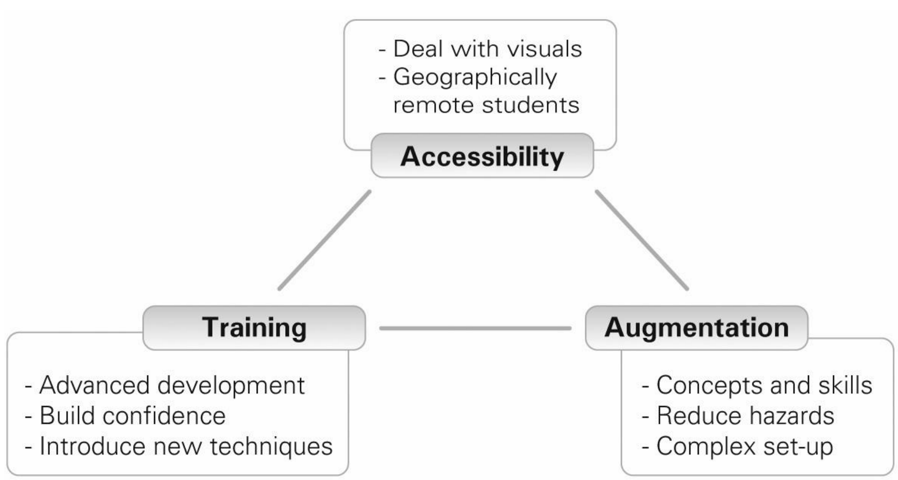


Figure 2.1. *Selection of potential advantages of a Virtual Laboratory (Source: Hatherly, Jordan & Cayless, 2009)*

The review also established a number of weaknesses in the v-labs. Bayrak, Kanlı and Kandilingeç (2007) in effectiveness of computer-based instruction discovered no statistically significant difference in achievement between of students subjected to the virtual lab and those who used the conventional lab. They see v-labs to be making students to build up a shallow perception that might be lacking in situations where new circumstances emerge. Real life situations frequently deliver diverse results at various examples of an experimental trial, regardless of whether the inputs are same. Subsequently, students dealing with a real life situation will be presented to an assortment of circumstances that may not be imitated in a virtual reality (Brinson, 2015). It has been found further that there are inconsistencies between the goals of the teachers, expectations by the learners and outcomes out of the learning across the domains of meaningful learning (affective, psychomotor and cognitive) have been revealed by numerous researches (Brandriet, Ward & Bretz, 2013; Galloway & Bretz 2015a, 2015b).

There are worries about students getting tied up in figuring out how to associate with the PC simulator as opposed to investigating the topic (Frezzo, 2009). Additionally, Dalgarno, Bishop, Adlong and Bedgood (2009) in their study - effectiveness of v-lab for chemistry students in Distance education affirm the fact that the real lab was more viable than the v-lab; real lab learners are seen to be scoring better than v-lab students. Critics have pointed out that when external stimuli are oversimplified it may lead to learners viewing reality incorrectly (Barnard, 1985). The connection between reality and simulation has been formulated by Gagne (1962) as relationship:

Simulation = (Reality) - (Task irrelevant elements).

Additionally, numerous comparison studies fail in discovering differences among physical and virtual experiments as far as academic performance is concerned (de Jong et al., 2013; Jolley, Wilson, Kelso, O'Brien, & Mason, 2016; Kapici et al., 2019). Additionally, Ambusaidi et al. (2018) in their study on the impact of utilizing v-labs on

9th grade students' achievement showed no impact on students toward student's achievements.

V-labs can only respond to the challenges experienced with real labs and supplement them but not replace the conventional labs. Students can gain by v-labs when discovering about their real environment, as they gain content and create science process skills (Jaakkola, Nurmi & Veermans 2011; Lampi, 2013). There is evidence that a combination of physical and virtual laboratories work better than any one singly (de Jong, Linn, & Zacharia, 2013; Chiu, Dejaegher & Chao 2015). There is some proof to propose that lone and adjusted blend of physical as well as v-labs can improve learning of science and support practices that are scientific (Verlage et al., 2019; de Jong, Linn, & Zacharia, 2013).

The term gender though sometimes referred to as sex is a term that differentiates male from female as per their physiological and biological orientation. Gin (2011) observes that in classifying persons as men or women is a society in which partriachial values occupy the contemporary world; it is a world where women are believed to be inferior to men. The 'gender gap' as it has come to be known as the disparities in academic achievement between learners of different genders is of great concern not only to researchers in education is a concern in the political and economic perspectives (UNESCO, 2015a; Hausmann, Tyson, & Zahidi, 2009). Globally, UNESCO having considered it of great importance, declared equality across the gender as one of the most pertinent educational goals (UNESCO, 2015b), hence it has been incorporated in the sustainable development goals (SDGs) framework (UNESCO, 2017).

Gender issues influence most aspects of our lives and societies. It why they were incorporated into the United Nations' Sustainable Development Goal 5, *"to achieve gender equality and empower all women and girls,"* (UNESCO, 2017; Odagboyi, 2015; Okereke & Onwukwe, 2011; Republic of Kenya, Constitution, 2010).

It has also been established that the number of unemployed youth in the whole world stood at 73 million in 2015 (UNESCO, 2015). According to the International Labour Organization (ILO) (2015), in Africa the female youths are affected more by unemployment than their male counterparts with 6.4% female against the 5.7% for male youths. These could be attributed to socio-cultural and religious beliefs and practices that bar male or female from engaging in given activities. Attainment of gender parity and empowerment of women is of great importance if a nation is to develop socially and economically. In matters education women and girls need quality education just like their male counterparts. Sustainable Development Goal (SDG) number four (4) targets at doing away with inequalities in provision and acquisition of education and training, be they based on gender, socio-economic status, origin or vulnerability (UNESCO, 2017).

For more than a century debate on issue of gender equality and equity in education has been in the air. At the time of introduction of schooling, in many countries the educational landscape was dominated by single-sex schools. Here the subjects that were taught to male learners were different from those taught to their female counterparts (Trueman, 2015). For instance, subjects leading to science and engineering fields were taught to male students while those dealing with cooking and the like were aimed at female students (Trueman, 2015). In the present world, male as well as female learners have been afforded almost equal opportunities in learning in all subjects in almost all of nations of the world. Unfortunately, still the patterns that were at the time of introduction of education influence the lines of training learners of both gender take. For instance boys opt to train in the STEM subjects and the closely related careers whereas girls go in for those that deal with care and related to the home (Trueman, 2015). Girls and women are quite underrepresented in the STEM education and related career paths because of ‘gendered’ education, with all the societal and environmental factors (Hill, Corbett, & Rose, 2010; Hyde & Lindberg, 2008; UNESCO, 2017). The attraction and participation in STEM fields, students’ choices are influenced by teachers, fellow learners, parents, siblings and relatives (Dalgety & Coll, 2004). Males are easily attracted because this is how society has nurtured them but female learners are influenced more by these people to opt for STEM courses.

The Trends in International Mathematics and Science Study (TIMSS) 1995 and 2015 reports were analyzed so as to give a 20-year trend for countries that participated in both at the at fourth and eighth grades in science and mathematics and in the TIMSS Advanced for 1995 and 2015 for students in the final year of secondary school enrolled in special advanced mathematics and physics programs or tracks (Mullis, Martin, Foy, & Hooper, 2016a, 2016b; Mullis, Martin, & Loveless, 2016). Students’ achievement in Mathematics and Science at fourth and eighth grades have been monitored closely by TIMSS every four years since 1995. As for matters gender, the 2015 TIMSS compared to 1995, the disparity between gender reduced from a difference of score of 9 to 3 points for the difference in average score for boys and girls (Mullis, Martin, Foy, & Hooper, 2016c). For the eighth grade, in 1995, the difference in science achievement score between boys and girls being 21 points and had fallen to just 2 points by 2015 (Mullis et al., 2016b; Mullis et al., 2016c).

In the TIMSS Advanced 1995 in physics, the gender imbalance in 1995 was more pronounced at 64 percent male and 36 percent female and little changed in 2015 (62% versus 38%). In the 1995 TIMSS boys scored 53 points more than the girls but this difference appreciably reduced to 28 points by 2015 (Mullis et al., 2016a). Basing on these results spanning more than 20 years male learners were found to frequently outperform their female counterparts (Baye & Monseur, 2016; Bergold, Wendt, Kasper, & Steinmayr, 2016). Bergold et al. (2016) add that male students are again over-represented in the lowest performing students.

Students' preferences in specific subjects differ sometimes in relation to their gender. For instance, in Germany it was found that of the total students registered for STEM courses in year 2014, just 21% of female students were pursuing engineering (Statistisches, 2016). There are studies that have documented that male students possess higher manipulative skills in mathematics as compared to female ones whereas girls have reading, writing and verbal skills slightly higher compared to boys (Halpern, 2012). With the gender gap in STEM having been acknowledged some years ago, efforts are being made to lure more women and girls to the fields. The efforts are either global, regional or national, for example, UNESCO's STEM and Gender Advancement (SAGA) is a global initiative with the overall aim of reducing the gender gap in STEM fields at all levels of education (UNESCO, 2010).

For long there has been a ‘gender challenge’ of boys performing better as compared to girls. The ‘terrain’ for what gender equality means ranges from the school environment, the community environment, the teaching and learning process and interactions which can be conceptualized in varied contexts. From this view, girls or boys are not obstacle to obtaining quality education, rather, gender inequality are results of form of unfair rising from social, political cultural and even economic processes and organization which work against the provision of quality education for women (Aikman & Unterhalter, 2012; Miller & Halpern, 2014). Boys perform better in sciences than girls at all levels of education; elementary, junior high and senior high school in science achievement (National Center for Education Statistics, 2009; Nwona & Aogun, 2015). Women have been found to be inadequately prepared for STEM courses at post-secondary level of education (Nsofor, 2012; Miyake et al., 2010). Female learners have been found to possess lower operative arithmetic competences compared to their male counterparts (Halpern, 2012). These abilities are of great importance to the mental development when using virtual experimental approach in learning STEM. In the late years of elementary schools, females have been found to outperform males on several verbal skill activities – reasoning, fluency and understanding logical relations (Atadoga & Lakpini, 2013; Joseph, 2011). Obeka (2013) found that utilization of some instructional methods favoured male students in matters academic achievement.

Quite a number of STEM trainees in TVET institutions hold stereotypic believes about the STEM courses; about doing experiments, wearing of white coats, overalls and workshop work. They have negative attitudes as far as the cognitive load of these courses are concerned (Salta & Tzougraki, 2004). Research has shown that learners' interest in the STEM fields are enhanced by the people who cause them to learn, the teachers (Xu & Corno, 2011). They do this through guidance and scaffolding. Similarly, Sjaastad (2012) sees that the learners can be influenced by two kinds of people into choices in STEM courses. They include those who the learners see as role models and those who are perceived by the learners as definers. The STEM professionals, teachers of STEM, their parents and all those people around them who display a STEM professional entity act as role models while those who give the young persons a helping hand in the learning and choice of career, direct them towards forming ethos are referred to as definers. These may be parents or other people.

In the Kenyan situation, there are serious disparities in gender as far as enrollment, retention, performance and transition in STEM fields is concerned (Akeyo & Achieng, 2012). There has been rapid growth of TVET education especially between 2012 and 2017 as is evident from the Kenya Economic Survey (Republic of Kenya, 2018). This has seen the enrollment to increase by 58.6% from 127,691 trainees in 2012 and 202,556 trainees in 2016. As far as gender is concerned it was established that out of the total number of trainees, the female trainees' number had increased from 50,431 (39.49%) to 120,558 (42.80%) in 2017. This increase can be attributed to the establishment of more TVET institutions and the implementation of the TVET Act 2013. The Act advocates for equality in TVET education and training irrespective of gender, background and ethnicity of a trainee (Republic of Kenya, 2013). The government has a vision of having one Public National Polytechnic in every county and one Public Technical Training Institute (TTI) in every constituency so as to boost TVET training (Gicharu, 2018). Table 2.1 below summarizes the participation of TVET trainees in these institutions.

Table 2.1. Proportion of women participation in Technical Vocational Education and Training between 2012 and 2017

	2012	2013	2014	2015	2016	2017
Male	77260	88064	89765	92309	113693	154,581
	(60.51%)	(59.49%)	(60.73%)	(60.21%)	(56.26%)	(43.8%)
Female	50431	59945	58056	61005	88593	120,558
	(39.49%)	(40.51%)	(39.27%)	(39.79%)	(43.74%)	(43.8%)
Difference	26891	28119	31709	31304	25370	34023
Total	127691	148009	147821	153314	202556	275139

Source: Republic of Kenya (2018)

Despite all the efforts that have been taken to achieve gender equality, there are still serious disparities which do not match with the efforts that have been put in place. This is because the number of female trainees is still lower that of their male counterparts. This is as the percentage of female trainees was 39.49% in 2012, 40.51% in 2013, 39.27% in 2014, 39.79% in 2015, 43.74% in 2016 and 43.8% in 2017. From the table it can be evidently seen that women are underrepresented in TVET STEM. The gender disparities and misconceptions of role of gender and TVET training has made the gaps to still exist and this disadvantages girls and women in as far as STEM careers and employment are concerned (Omukhulu, Ogbanicael, & Kimamo, 2016).

On the other hand, research shows that the female trainees who have persistently and consistently been in the STEM fields of study comfortably discuss course content with their peers, are able to join field related student associations, and do projects comfortably just like their male counterparts. They can also accomplish demanding researches just like their male counterparts (Espinosa, 2011).

Anagbogu and Ezeliora (2007) in their study on how Students' Academic Performance in Biology is affected by problem-Solving teaching approach established that that young ladies do better than young men when utilizing science skill technique for instruction. In any case, Gambari (2010) observed that gender of learner has no impact in academic achievement of learners. In a comparison study, Abubakar and Dogubo (2011), found insignificant difference between performance of male and students. Odagboy (2015) observes that if female learners get to school while possessing an attitude and gendered thinking that they are inferior to their male counterparts, their interest to learn is affected. A study by Ssempala (2005), established existence of imbalances among genders in laboratory work. Previous achievement, interest and sex-based stereotypical orientation in the course may be affecting female learners' approach of studying sciences and the zeal of pursuing degree in related fields.

Though that being the case, other researches revel that those differences in cognition change depending on the task characteristics. In contradiction to the assumption of the essential differences, Hyde’s (2005) gender-specific researches shows female and male show similarities on some psychological variables; this yielded in formulating of a gender similarity hypothesis. There is evidence of continued gender stereotyping in science education from the society, textbooks, teachers and even students themselves. Olalekan and Oludipe (2016) found that learners using computer simulations are afforded the opportunity to visualize, comprehend and develop a high knowledge retention rate. Gunawan, Suranti, Ekasari and Herayanti (2017) on their research in high schools also found that the application of virtual laboratory in the learning of Physics improves figurative creativity and enhances verbal ability of the students. Male students have high figural creativity whereas female ones have high verbal creativity than male students.

There could be difference in the sensitivity of competences in male and female learners in virtual science learning despite the fact that they differ marginally in competence (Hyde, 2005). If the minor differences can be disregarded and the similarities that are impressive, so that customized learning situations created for women thus giving them a chance where male dominance and its implications is removed and competitive environment that is gender specific. Due to this some courses in engineering have been set up in select universities that admit exclusively female students (Statistisches, 2016). These courses involve virtual environment for learning STEM that enables them to undergo individualized instruction that does not have the social competition in co-educational colleges thus preventing the effects of multifaceted mechanism of gender discrimination. In Kenya there has been established a women’s only university, the

Kiriiri Women University for Science and Technology for the sole purpose of encouraging more women into STEM.

Studies have shown that when female students utilize virtual laboratory the outperform their male counterparts (Gunawan et al., 2017; Koksal, 2014). Keter, Wachanga and Anditi (2016) obtained similar results in a study by that found computer assisted experiments motivate girls as well change their attitudes of learning chemistry. Research has shown that if the appropriate strategy is chosen for a given set of students then the best results will be achieved irrespective of gender. This leaves a lingering debate on the influence of v-labs on academic achievement by either gender at the TVET tertiary level of education.

Meinck & Brese (2019) report that different countries have taken and are adopting various initiatives to address the issue of women under-representation in STEM, and the findings indicate that some may have shown success. UNESCO (2017) has a compilation of the various programmes and interventions targeting the individual female student and outcomes as concerns differences in gender in STEM education. For example, the United Kingdom has the single-sex workshops for girls to act as scientists led by female tutors aimed at facilitating the girls' interest in STEM subjects and careers. Countries in the African continent have come up with programmes such as the "STME (Science, Technology and Mathematics Education) Clinics" (Ghana) which brings secondary school girls together with role model being female scientists. Kenya conceived and is applying STEM campus, a one-week STEM activity in which school girls carry out experiments and make academic visits to establishments involved in

STEM jobs (UNESCO, 2017). At the tertiary level, a programme known as Women in Technology and Engineering Education (WITED), as part of the activities of the Commonwealth Association of Polytechnics in Africa (CAPA, 2013) is in operation. The main objectives of this programme is among others: to increase enrollment of female all programmes that are taught in TVET institutions, leading to attainment of equity in education, empower women with both formal and informal skills with an aim to improve the economy.

The review of literature investigated the possibility that virtual laboratories could be utilized as potential for replacement of real physical laboratories by using simulations in situations, that are unrealistic, costly, impossible, or excessively hazardous, making it impossible to run and/or in getting to data in a safe way. The literature continues to show that the debate on whether virtual labs influence academic achievement based on gender. This area of research is of great importance to STEM education in science because of the existing controversies over whether there are differences in achievement based on gender (Scantlebury, 2012). Other than the fact that the debate about the virtual labs being inconclusive, there was little literature available as concerns the utilization of virtual labs in the TVET tertiary level. Besides, e-labs application in educating and learning physics, electricity and electronics specifically, fails in meeting the TVET segment requirements, as most virtual laboratories in physics are made for secondary schools and universities. There are very few virtual laboratories that can be used for teaching the selected topics in Physics (electricity and electronics) at the tertiary level.

Thinking about this constrained application, the researcher feels that e-labs cannot replace conventional labs yet they can respond to the current difficulties and advance the process of learning. The choice and approach in the application of simulations and virtual environments needs to be considered as these will influence the results on the learning outcomes in the learners or trainees to whom these are applied to. So it is important to know what to look for in a virtual laboratory and how it is applied in actual classroom at the tertiary level of education, before one can use any of the virtual labs. Hence the need for this research – aiming to establish the influence of virtual labs on academic achievement in Physics at tertiary level in Kenya.

The researcher views science laboratory technologists and technicians as an important element in the terrain of quality, yet their agency and gender identities are often neglected both professionally and individually. The attention towards this technical team and their training especially as in how they infuse technology, virtual labs included has also been assessed. Consequently, school principals, community leaders, parents and educational officers have roles and responsibilities based on gender identities that influence upon and intersect with those of learners inside and outside the school environment. The talk about both gender and utilization of ICTs, especially v-labs is equally needed to come from all players so that girls and women also find reason why they should use them. Same to the talk of science and technology by and for both gender should fill the air.

From the point of view of methodology, several descriptive research studies depended fundamentally upon reported data of student, for example, questionnaires and interviews administered to students, to decide whether the utilization of a v-lab assisted them in learning (Nance et al., 2009). In particular, the experimental researches reviewed depended on different methods of research such as tests or questionnaires for estimating learning results. The vast majority of the studies that utilized learning based websites, particularly virtual laboratories in instructing science were done in either secondary school or in a university setting (Zacharia & Olympiou, 2011; Rutten et al., 2012; Smetana & Bell, 2012; Rotimi, et al., 2012; Tatlı & Ayas, 2011; Trundle & Bell, 2010; Fiscarelli et al., 2013; Zabunov, 2013; Zacharia & Olympiou, 2011). The past researches are related to this research in that they have separately looked at the aspects that this research set out to study, though it delved to measuring the skills transfer at the tertiary level which most of the other studies never looked at. Again the researches that exist were in either university or secondary school settings. Minimal literature exists on influence virtual laboratory on academic achievement at the tertiary level of education not only in Kenya but the world.

This study set out to study how the v-labs influence the acquisition of knowledge and technical skills as far as learning of Physics is concerned. Hence the need for this research – aiming to establish the influence of virtual labs on learning outcomes in Physics at tertiary level in Kenya.

2.3 Virtual laboratories and Retention of Content

Retention of content means what human beings are to reproduce after sometime of learning some content. It is to relegate the experiences of the past in the mind's subconscious which takes place when the learning experience has been coded into memory (Suleiman, 2011). Retention is what remains within the learner's cognition after instruction and experiences the leaner is presented to and learning has taken place. This allows the learner to recall and recognize the said experiences. Suleiman further says it is the persistence of the behavior that comes as a result of the learning that the learner was exposed to, long after the same experience is not being practiced.

For the purpose of this study retention has been treated as the holding to information that was taught in class for a long time. Mangal (2011) sees retention as one among the four elements of memory, learning, recall and recognition which have been replaced by three distinct stages namely encoding, storage and retrieval. The stage of storage concerns itself with retention power of information that is encoded. Retention is considered by educational psychologists as some criteria for use in the distinction between short term and immediate memory (Ladan, Dantani, Ayas & Adamu,2009). Retention has been defined by Suleiman (2011) as a base model that the brain processes meaningful stimuli to a deep level. Retention is therefore made up of not only learning, but recall. Mangal (2011) opines that for one to retain more for long, four main aspects contribute greatly. These are; Not having excessive anxiety, reduction of emotional factors such as fear which may block memory; possession of self-confidence; linking of ideas to real life; and never straining oneself for too long to recall something.

There are several strategies that have been suggested to enhance learners' content retention. They include but not limited to: repetition and practice at intervals; utilization of humour, making the learners to present information that was done in class in a different format, modifying the conditions under which learning takes place, facilitating learners to recognize underlying assumptions, linking to the learners' environment and prior knowledge, recognizing that what students recall soon after learning influences what they learn later, applying "less is more" practice for long term retention, creating "doing" activities, integrating materials with prior experience, future context and encouraging self-assessment of knowledge (Suleiman, 2011).

An essential aim of schooling is to cause lasting information loading and repossession, not simply fading memories after classes or attending of a given conference. Consequently, a question is posed on how we can brilliantly transfer knowledge from short-term to long-term memory (Raman, 2010). The system of recollecting knowledge is quintessential for learners to end up successfully in mastering science. Science ideas tend to build on one every other at some point in the grade tiers and create a long-lasting perception and retention so assisting learners maintain prior knowledge and to construct new one about scientific concepts.

There is a noteworthy amount of research associated with the retention of the science syllabus (Morgan, 2012). The gap in academic achievement and retention of content in science has been linked to numerous issues. Elliott, Welsh, Ibeck and Mills (2007), in their investigation documented that prepared fire fighters utilizing virtual laboratories found that despite the fact that there were a few improvements in conceptualization with students utilizing virtual laboratories they were negligible after some time. Still with the challenge that the gap in retention of content in science is result of several factors which include lack of parental involvement, gendered education, and availability of resources for education that are availed to the child and administrative support, the college and its instructors can have full-size effect on a student's education (Morgan, 2012). The teachers should organize the learning process so that meaningful learning experiences cause the learners to construct information for themselves so that they are connected with their real life (Skamp, 2007). The theory of use and disuse elaborates that gaining knowledge is the result of exercise or use, while forgetting occurs at some point of retention intervals when the information learnt is now not used. Retention is a fundamental issue in gaining knowledge of science concepts.

When the theoretical information in a hands-on activity is not comprehended by the students, they do not retain it and accordingly, this leads to disappointment in the subject they are studying (Trundle & Bell, 2010). Thus, they create negative attitude towards the subject. Teachers should repackage the content of the subject in such a way that the learners do not perceive it as a collection of prolonged mathematical calculations but as a body of knowledge that is applicable in daily life, whose facts, laws and principles are gained through the scientific process in the laboratory (Çelik & Karamustafaoǵlu, 2016). Once demotivated, the learners will boost a negative mind-set towards the challenge, therefore retain little content (Wingate et al., 2011).

Inquiry based learning shifts the instruction from teacher-centeredness to learner-centeredness so that trainees are involved more in information construction (Connell et al., 2016). It has been found that there was an appreciable increase in the rate of retention when learners have been exposed to virtual laboratory (Kara, 2008; Lux, 2002). However, they did not find out any sexual orientation distinction in achievement and retention of students trained with virtual laboratory methodology and computer-assisted instructional bundle with microbiology and science.

Milo et al. (2011) argued that the capacity for students in seeing the internal working of the system and have the capacity of changing or modifying conditions, makes the v-labs capable instruments for students to form internal schema. In some studies the learners who practiced their experiments in the v-labs were found to score negligibly lower than their non-v-lab counterparts in terms of academic achievement (Cobb, Heaney, Corcoran, & Henderson-Begg, 2009; Javidi & Sheybani, 2006; Kapici et al., 2020). This suggests that either of the types of labs were effective as regards understanding and retention. They see the v-labs as a complement to the physical labs and not as a substitute.

Gender was found to influence retention of content according to Nwankwo and Madu (2014) in their study utilizing the delayed Physics achievement test (PAT) in which they reported that female students outperformed their male counterparts. Akpoghol, Ezeudu, Adzape and Otor (2016) hold a similar stance by reporting that when lecture method was supplemented with either music or computer animations, the female learners had higher retention scores than their male counterparts. Nwankwo and Achufasi (2019) in their study of retention by Nigerian students of content in thermal Physics discovered no significant difference in retention scores of male and female students. Contrary to this it has been reported by Udo and Ubana (2013) that there is no statistically significant difference in physics retention ability between male and female students. Similarly, a study on gender differences in achievement and retention in

Mathematics in the topic of algebra utilizing Problem-Based Learning (PBL) method shows that the results do not differ significantly across the gender (Ajai &Imoko, 2015). These diverse findings by different researchers as pertains to what influence gender has on retention of content as measured by the scores in the retention tests in the science subjects is clear indication that the disparities in gender in the sciences has nothing to do with biological factor.

From the foregoing, researchers seem not to fully agree on the influence of virtual lab on retention of content in a subject. Equally, there is not a single stand on how the v-labs influence retention of content across gender. Again, minimal literature exists on influence virtual laboratory on retention of content in science and technology at the tertiary level not only in Kenya but the world. Very limited researches on the measurement of TVET trainees' retention of content in Physics exist. The ones available aimed at the effects of teaching approaches and students' achievement in science at the university and secondary school levels and in some cases the primary school.

The researcher views the whole scenario as that whose results, the underrepresentation and achievement and retention gaps, could be as a result of many factors of gendered education such as attitude, perceived difficult nature of physics among students, laziness on the part of the students concerned and many others. To attract and maintain the female trainees' interest in STEM carriers, it has been suggested that educators look for and apply such innovative teaching approaches and infusion of technology such as virtual laboratories in the delivery of content in science, technology and mathematics.

The v-labs can assist the female trainees do better in their studies because of multiple representation of content. However, it is important that before a technology can be implemented on large scale, it be test to see the effect it will have on academic achievement and retention scores of male and female students, in this case in Physics.

The researcher is of the feeling that v-labs could be used to aid in forming schema and therefore make trainees retain more content in physics topics that have been covered using them. Before the utilization of the v-labs in in actual classroom at the tertiary segment of education in Kenya, it is important to know how virtual laboratory influences retention of content. Hence the need for this research – aiming to establish the influence of virtual labs on retention in Physics at tertiary level in Kenya. It is against this backdrop that the researcher got moved to investigate the influence of virtual Physics laboratories could have on retention of content on conventional and virtual labs counterparts in the TVET Physics courses. It again investigated the influence of virtual Physics laboratories could have on retention of content on both male and female trainees in the TVET Physics courses.

Virtual Physics laboratory is an innovation in Kenyan TVET tertiary level of education, therefore, this study examined the influence of virtual laboratory on the retention of content by trainees in tertiary in Physics Techniques in Kenya. Therefore, the retention test (examination) was administered after a month from the date of first post-test 1 as recommended by Cresswell (2012). Virtual lab is an innovation in Kenyan education system particularly at tertiary level. This study examined the influence of virtual laboratory on the retention of content by trainees in tertiary in Physics in Kenya.

2.4. Virtual laboratories in skills training-connection accuracy

Virtual labs have typically been utilized as a part of training abilities in fields requiring safety before trainees are permitted to practice on the real equipment. Pilot training, military equipment training, medical training and nuclear power plant training have relied on these simulators or v-labs as suggested in research (Gredler, 2004). Between the year 1940-1950 training of pilots in simulators had started, a long time earlier than PCs had been even available (Jacobs, 1975). A flight simulator is a virtual world in which an aircraft is simulated with its environment and all events occurring where it flies. It presents an almost real world where those who intend to know how to drive a plane, or just to play in absence of the original plane. Because the requirements are that the simulator needs to be as close as possible to the real plane, trainee pilots are aided to learn more easily. The simulator is required to obey equations of flight for planes, the behaviour of controls when they are triggered, effects of other aircraft systems, and reaction of aircraft to external factors such as damping, gravity, air density and turbulence. It has now become a regulation, such as in Federal Aviation Administration, for pilot to adapt flight simulator in their training (Haslbeck, Kirchner, Schubert & Bengler, 2014).

Because of the rapid advancements in computer programming and computing power, simulations have been made open to more fields of study by lowering costs, for example, in STEM at all levels of learning (Akpan & Strayer, 2010). Regardless expansion of virtual laboratory software, there always have been few publications trying to gauge skills attainment in virtual laboratories (Aggarwal et al., 2007). This is to be ascribed to the difficulty in measuring the transfer of technical skills (Aggarwal et al., 2007). Nevertheless, some technical skills using v-labs laboratories have been measured for example in medical and surgery training (Issenberg & Scalese, 2008).

On account of a virtual lab, its motivation is to give students experiential interaction that will prompt learning (Akpan & Strayer, 2010; Gambari et al., 2016). In this manner, while considering the usage of virtual laboratories in a training program for gaining competencies, their viability in conveying these aptitudes must be resolved. Cannon-Bowers (2007), posit that to address the issue of optimal utilization of innovation, the confluence of innovation, content, student qualities and pedagogical principles must be basically considered. Virtual laboratories have been touted for bearing novices the fail-safe module capacity errors (Duarte, Butz, Miller, & Mahalingam, 2008). Amateurs in the training of skills are more likely to make errors in their execution of assignments. In sensitive systems, for instance, PC networks, students are not given a real lab system to exercise and fail as it is being utilized by clients on the other end (Duarte et al., 2008). In the physical experimental lab, it can be a test to incorporate learning by way of disappointment in the training for a few reasons. The potential to rapidly arrange, disconnect and reconfigure circuits supposedly is a component in improving mistakes made by the trainees and aiming towards perfection in learning of skills (Mayer & Johnson, 2010). Dissections of a virtual frog have been previously compared with real life specimen in real laboratories; with these numerous studies having mixed results; with some showing that physical dissections are superior (Cross & Cross, 2004), while others (Akpan & Strayer, 2010) suggest otherwise. A number of studies propose that in engaging learners in activities in which both labs are integrated, is beneficial to expose the learners to the v-labs before the real hands-on activities (Akpan & Strayer, 2010).

With the advancement in technology most devices (gadgets) have the capability of being carried anywhere and at any time, efforts should be made to make the systems housing simulators to be conveniently portable. These efforts would make it possible for people of all ages and stages in training, including specialties such as pilots and medical students to make use. Simulators are applied for instance in training how to fly, with some even making part of curricula, in for example, a flight school (United States Department of Transportation, Federal Aviation Administration, 2016). Students' training in technical skills that encompass monitoring and maintenance of systems that require elite dependability needed to accomplish the capacity to perceive, investigate, and settle flaws. These flaws might be commonplace or new to them. Training and consequent working experience ought to open students on the other hand many disappointment instances as would be prudent (Kluge, Sauer, Burkolter & Ritzmann, 2010). Transfer of training is the extent of retention and utility of the knowledge, skills, and attitudes from the training environment to the place of actual job environment (Kluge et al., 2010). Handling of unfamiliar occasions due to the past presentation of comparable ones in training is termed adaptive transfer (Kluge et al., 2010).

Technicians who maintain and repair electric and electronic equipment are required as a routine to correct faults in systems. Training along these lines, must form in the student the ability to investigate both commonplace and new faults in equipment. Access to physical equipment and real life circumstances of failure can be a hindrance in this undertaking. The literature review established that pilot test software making ready has over and once more exhibited that if the check gadget creates the proper prompts for activity, skills won in the test gadget will be transferred just like the physical plane (Goettl, 1993). "There have been a few inquiries about the transfer of training estimation of simulations as far as pilot training is concerned, the nearly consistent conclusion of which are that there is positive transfer of training associated with practice in a simulator" (Jacobs, 1975).

Gaining skills to operate actual equipment depends on how accurate the feedback the virtual laboratory provides through fidelity of function (Jacobs, 1975). The feedback needs to supply activity prompts that are like the humans who would possibly be experienced in real circumstances (Issenberg & Scalese, 2008). If a virtual lab gives incorrect feedback which could prompt negative transfer, a circumstance of training really accomplishes more damage than good in competencies transfer. Schwartz, Bransford and Sears (2005) portray that transfer is in this way subject to learning in context. Virtual environment needs to be of ample situational details to enable students to visualize imaginatively the real-life state of affairs with minimal cognitive effort. There is a slight departure in this study as compared to others in that it aims to gauge the amount of skills transfer from virtual lab to real equipment and the eagerness for this training. This is typically estimated utilizing the transfer effective evaluation method (TEE). A TEE consist of an experiment for learning and a transfer experiment (Morrison & Hammon, 2000). "The easiest means to estimate the extent of studying that has occurred is to measure and compare the performance before the treatment and after treatment has occurred" (Hammon and Morrison 2000). Choosing whether utilize v-labs in training trainees is reliant on in the case of the training on the virtual laboratory would cut back the degree of time anticipated to formulate on the actual gear. The learner in this situation is taken from one controlled environment to another one. This minimizes with convenience the effects of factors that confound the determination of the actual transfer of skills that actually took place. To measure the transfer of technical skills the Hammon and Morrison equation presented below is applied:

$$T = \frac{E - c}{c} \times 100\% \quad \text{(Hammon \& Morrison, 2000, p. IV 11)}$$

where c represents mean scored by the control group and E is the mean scored by the experimental group. This investigation done by the department of defense established that trainees practicing in virtual laboratories improved transfer to real-world setting (Hammon & Morrison, 2000).

The experimental group executed in the virtual laboratory while control group underwent training in the actual lab. The calculation supplies a positive transfer if the mean score in the experimental group is higher than that of the control group. As such, if the control group's mean score is higher than that of the experimental group's average score then negative transfer has occurred. If, However,the calculated value is equal to zero, then no transfer has occurred. All the participants operated the same number of trials so as to ensure no group or a learner who takes undue advantage of the time taken or the number of trials is taken by any one of the participants.

Electrical and electronic circuitry are routine skills. A trainee needs to be able to take into account the process steps needed to accomplish the skills practically in which the most effective technique in training is by repetition and rehearsal (Ericsson, 1993). Virtual laboratories as per Akpan and Strayer, (2010) can likewise be utilized in an intermediate method sandwiched between theory and practice for example in demonstrating the working principle of a four stroke engine, a v-lab can be presented before the real engine experience. Pyatt and Sims (2012) clarify that the usage of virtual lab expands imagination and want for the instructors and laboratory during the time utilized in learning. Anisetti et al. (2007) explains that when used as a piece of training in vocation and specific training programs, virtual laboratories are used to make trainee capacity in the execution of practical skills. The training should provide trainees with the skills to work out career related assignments that trainees may additionally be meeting in real work setting. For instance, in PC net technicians are equipped with the capabilities that will make them able to configure, manage, troubleshoot, and monitor actual PC networks (Anisetti et al., 2007).

The conceptual and hypothetical performance of PC networks is integral and no longer adequate (Frezzo, 2009). Learners ought to have the capacity to function hands-on tasks (Frezzo, 2009). In a classroom-based case study, Frezzo (2009), used the Cisco's computer network virtual lab (Packet Tracer®) found that students securing arranging, actualizing, and troubleshooting skills when taught in an activity-based technique. Likewise, learners could develop elaborate network models in self-coordinated request sessions. In any case, occasionally the clarity of the objective of using v-labs could be hindered by effort taken in learning how to utilize the software (Frezzo, 2009).

However, with all stated about the merits of use of virtual laboratories in training, there have been recognized susceptible factors about them such as the lack of context in which they have to be performed (Akpan & Strayer, 2010). It costs a fortune to put up a full-scale flight simulator as compared to doing it in a virtual reality device. In actual life, assignments are carried out in atmospheres that have several associating aspects that cannot be incorporated into a virtual laboratory (Akpan & Strayer, 2010). The outcomes of communal interaction, different apparatus, and contextualized challenges are absent in the v-lab. It is important to reflect on consideration on the execution goals of the training when selecting the practicality of virtual laboratory training on specialized skills (Issenberg & Scalese, 2008). For electrical circuitry learners ought to actualize practical assignments of connecting, measuring and recording; and troubleshooting circuits precisely more so beneficially with physical equipment after doing them in v-labs (Finkelstein et al., 2005).

Virtual laboratory opponents contended about the degree of fidelity had frequently not indicated the distinction of execution and skills actualization in the real world. Gredler (2004) posit, various low fidelity virtual laboratories never created acceptable results in the execution by students in various studies. The virtual laboratory enhances the theory with the aid of giving a dynamic feel of the idealized system (Akpan & Strayer, 2010). Phenomena besides the confusion and effects of noise can be evidently demonstrated by the simplification of the conceivable results (Gagne, 1962). Brinson (2015) audits empirical studies in the post-2005 reports inconsistencies between the goals of the teachers, expectations by the learners and outcomes out of the learning across the domains of meaningful learning: affective, psychomotor and cognitive have been revealed by numerous researches (Galloway & Bretz 2015a, 2015b).

An additional reason related to one's duties is contention that v-labs lack all the constituting sensual signals present in the real atmosphere. Altitude of the real ride, angular acceleration and the sense of acceleration is not received by the individuals using flight simulators on a PC (Jacobs, 1975). Somebody who is using such devices can also no longer understand and respond to instances consisting of signals of psycho-motor sensors. One of the common issues in the debate on the capacity of utilizing incomparable laboratories setting up of real laboratories has been the use of virtual laboratories with the capability by which real labs have to necessitate (Anisetti et al., 2007).

The interaction of students with the actual system in the long run, get natural feelings of these errors bringing about fitting mental modifications. According to Wolf (2010), some researchers have attested that students who get trained in virtual laboratories do not experience the commotion and obstruction that goes with actual measurement. Subsequently, they may incorrectly build up a mapping or model of the system that is unrealistic and their response to the real system might be inaccurate. Students may hence build up a false feeling of reality.

Unlike this study, past studies did not report effect sizes, apart from the investigation by Métrailler, Reijnen, Kneser and Opwis (2008). Issenberg and Scalese (2008) indicate that in the training of vital skills where errors are inadmissible; the virtual laboratory needs a high practical and physical fidelity. For example, skills required in laparoscopy surgery consist of competency in ambidextrous movements with unfamiliar instruments, needing hand-eye harmonization and depth perception (Issenberg & Scalese, 2008). Simulator applied in this training is routed on a dummy with an implanted microchip with screen. The final product is that the training incorporates psychomotor tactile records in the simulator. Sadly, price of this high fidelity virtual laboratory is over $30, 000, contradicting the proclamation that virtual laboratories are lower-priced (Issenberg & Scalese, 2008).

From the literature reviewed, the researcher has a feeling that there are situations in which the practical skills may not be learnt purely by v-labs as they may not at times meet the needs of learners fully for hands-on experience. Again v-labs sometimes create a misconception in practical work, in that learners may not realize where really dangers may arise in the actual situations, therefore transfer from virtual to real labs may not fully be possible. It then became necessary to design a research that will bring out the truth about transfer of skills and especially in the TVET tertiary level of education where much research has not been conducted. But v-labs can be used to explain procedures for doing the actual experiment or executing the skills prior to the actual work environment tasks.

2.5 Virtual Laboratories in Skills Training connection Speed

Elliott et al. (2007) established that fire fighters can gain skills in decision making via v-labs as well as indicating modifications in factors such as accuracy, speed, efficiency and planning. Moreover, it has been found that trainees' connection of electrical circuits using a virtual laboratory transferred their competencies to the real lab (Finkelstein et al., 2005). In pilot training, students' education on a computer have shown transfer of competencies to a real airplane (Ortiz, 1984). In PC networking, there has been some research that has indicated beneficial properties in theoretical understanding but gains in technical skills transfer not been established (Anisetti et al., 2007). By implementing new technologies in the educational process, we supply learners the chance not solely to learn the content in the subject, however,additionally to operate a computer by trial and error they get to better their computer skills (Paluch, 2015). Ericson (1993) explains that in the training of skills, transition from beginner to expert is executed through a deliberate and repetitive practice in quite a number circumstances. Virtual lab offers newcomers the additional opportunity to work on permitting them many times to navigate over a similar area of information.

V-labs save time and space and also allow learners to arrange the apparatus as required (Milo et al., 2011; Reese, 2013; Akpan & Strayer, 2010). In the pragmatic model, this is a looping between the internal and external feedback circles. Routine with regards to issues that opens the trainee to a wide variety of attainable conditions constructs the two repertoire and schema of recognizable arrangements. For this research the investigator was eager on gazing proof beginning of this process. V-lab can be utilized as an intermediary to real apparatus. This is like to train chess on a PC when you don't have an actual opponent.

V-lab can be utilized to motivate one to have immediate transference of information and competencies to real world via contextualization of learning (Dalgarno & Lee, 2010). Students ought to access tools with the objective of practicing the techniques, arrangement and navigation. Toward the commencement of training, these innovative ideas might be hard to recall with the method that can be particularly disappointing. As student rehashes the configurations severally, on a slight variation of system topology, they pick up speed and precision. Anderson and Pearson (1984) tested that such practice administrations follow a negative power rule;

$$T = BN^{-k},$$

where T is the time to accomplish an activity, k is the rate of learning parameter, B is the initial overall performance on undertaking before training, and N is the number of trials that are involved in the learning. Despite the fact that this specific type of power law is expressed related to the pace of execution, comparative relationships hold true for unique parts of performance, for example, accuracy. Electric and electronic circuitry and measurement are adaptive skills. The trainee ought to recognize situations from associated expertise and utilize their know-how schema to determine the best strategy. If the scenario is quickly unmistakable and the right reaction is known, on the spot action is taken. In the event that on the different hand the situation is new, the learner needs to utilize both their internal model of the circuitry and their crucial thinking skills obtained during training to clear up and fix the fault.

From the foregoing review of literature, the researcher felt that there are situations in which the speed of connection of the electrical and electronic circuits may not merely improve by having the trainees training in the virtual laboratory. For example, when complex circuits are involved it may need that the trainees train using the real laboratory because in the long run the trainees will be encountered with real circuits to connect where they be dealing with real components and equipment. However, for simple ones and for testing before trying out the connection v-lab is of great importance to the trainees and practitioners. To this effect there are software that are meant for such test, among them are Spice, Matlab Simulink and Everycircuit, that electronics enthusiasts use to test the workability of circuits before they do the actual connection. If the trainees are not given chance to practise the technical skills, they will feel that they have mastered the skills using v-labs and that they can easily do it, but on actual circuits they may get that they have either not mastered the connections well or they take too long a time to connect or both such situations. It then became necessary to design a research that will bring out the truth about transfer of skills and especially in the tertiary level of education where much research has not been conducted. Again v-labs can be used a physical experiment pre-lab.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the research design, region of study, the study subjects and the methods used for: target population, sample size and techniques for sampling, description of the experimental treatment, the instruments of research, procedures for collecting data, analysis of data and ethical considerations.

3.2 Area of Study

Kisii National Polytechnic is located in Kisii Municipality, South-western Kenya. Kisii is the capital of the Kisii County, a densely populated county with 1,266,860 inhabitants (Kenya National Census of 2019). A vibrant town, the Kisii municipality has a large dependent metropolitan population of about 300,000, according to 2019 estimates. The Municipality sits at an elevation of 1,700 m and covers an area of 10 km^2. The weather is such that the temperature is about 15^0C to 27^0C, with North-Eastern winds flowing at average speeds close but less than 10 kilometers per hour. The place is normally humid (94%) and suitable for agriculture and livestock rearing, but because the lands are small the inhabitants normally practice peasant farming. The population stood at 112,417 as at year 2019. The map of Kisii town is attached (Appendix K).

The TVET institution neighbours the Coffee Research Institute of Kenya, Kisii Branch; the Kenya Agricultural and Livestock Research Organisation (KALRO), the Farmers

Training Centre, Kisii University Kenya Industrial Research and Development (KIRDI), *Jua Kali* (informal) sector and the Kisii Referral and Teaching Hospital. For the high quality of these lives of this large population the knowledge of Physics is important in seizing the opportunities and challenges come with it. The Kisii Municipality is centrally located relative to the counties that neighbour Kisii County, which makes it a very busy town in terms of business and human traffic. Because of the county has got a very high population the number of secondary schools is very high, at more than 430 Public Schools (Kenya National Census of 2019). These numerous schools require qualified Science Laboratory technicians and technologists in the right numbers and with the right knowledge, skills and attitudes.

The Abagusii leaders led farmers, Kisii cooperative union, Gusii County Council, businessmen and the general public to fund-raise to set up the institute 1971. By 1972 it was registered under the Education Act CAP 212 of the laws of Kenya. The first cohort was admitted in 1976 for secretarial studies at the Catholic Church headquarters at St. Vincent. It was then built on current site with the construction activities starting in 1980 on a land measuring 16.95 hectares. In 1983, with these new buildings available, on top of offering secretarial, Woodwork technology, mechanical engineering, there was an addition of more courses the curriculum. Trades in building; Carpentry and Joinery, Plumbing, Masonry and Electrical Installation were the ones added. In 2014 it was uplifted to become a National Polytechnic. The Polytechnic continues to grow due to assistance from donors and other organizations. The government initiatives of partial sponsorship and student loans has made the numbers to increase very fast. The college currently has a population of 10000 trainees, 231 lecturers and 70 non-teaching staff. The Kisii National Polytechnic, formerly Gusii Institute of Technology is a hive of activity where people work together to transform dreams into skills for life.

Presently the polytechnic has nine academic departments, namely; Electrical and Electronics, Engineering, Health Sciences, Applied Sciences, Institutional Studies, Building and Civil Engineering, Mathematics, Business, Mechanical Engineering, Computer Studies. All these require the knowledge of Physics for their study. Physics used to be a non-examinable (support subject) in many of these courses, but now it is examinable and therefore more weight has been given more weight in the curriculum. Science Laboratory Technology falls under the Department of Applied Sciences. The course is loaded with almost all the secondary school Physics plus additional content in some areas. Therefore, a study in bettering the way the acquire these highly desired learning outcomes was very necessary for this region, within which stands the Kisii National Polytechnic.

3.3 Research Design

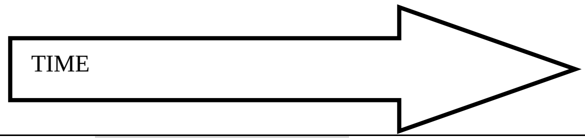
A research design as strategy, configuration, and technique of research to attain solutions to investigation interrogations or problems (Creswell, 2012; Creswell & Guetterman, 2019). Kothari (2004) sees it as the scheme for collecting, measuring and analysing information. The study applied two research designs; a descriptive survey research design and a quasi-experimental research design. The study utilized both of them so that what could not be explained by one type of research design was covered by the other. This was to achieve triangulation so that a more complete conclusion could be created. The descriptive survey design describes people's feelings and the traits which might be rising from a phenomenon or study (Singh, 2012). This design has a purpose of better defining the opinion, attitude or behaviour by a group of individuals in a given subject and also gives an indication of the changes of the respondents' opinions, attitudes and behaviour over time. Cohen et al. (2011) argue that, the great advantage of survey design is that you can gather a big amount of data in a short duration.

Gall, Borg, & Gall (2009), on the other hand, view Non-equivalent Pretest, post-test, experimental-control group Quasi-experimental research design as capable of addressing many of the internal validity issues that can easily plague a research. It additionally permits the researcher to limit the effect of confounding variables such as duration of practice, learner type, including learning styles and that it lets the researcher to check whether or no longer the Pretest itself has an effect on the respondents (Mugenda & Mugenda, 2009). A Pretest and post-test design becomes the most applicable design in bringing out the effect or influence of a treatment on the learning, where one group is treated and the other is not (Kumar, 2005). Here two intact classes were assigned randomly to the control and experimental groups.

The trainees in experimental (v-lab) group were subjected to the virtual laboratory while the control (no-virtual-lab) group were subjected to physical Physics laboratory.

The trainees in both groups were taught the same content and were exposed to identical Pretests, post-test 1, and post-test 2 (retention test) as shown in Table 3.1.

Table 3.1. Experimental design adopted.



	Observation 1	Treatment 1	Observation 2-Theory; Practical	Observation 3-Retention Test
Group 1 Virtual-lab (VPL)	Pretest, PT1; Theory and Practical	Virtual Lab Practice (5 trials)	Post-test 1, PT2; Theory and Practical	Retention Test-theory, PT3
Group 2 Non-virtual-lab (CPL)	Pretest, PT1; Theory and Practical	Real Lab Practice (5 trials)	Post-test 1, PT2; Theory and Practical	Retention Test-theory, PT3

Source: Field, 2020

The Second Year Certificate in Craft Science Laboratory Technology (CCSLT) trainees of the Kisii National Polytechnic in the experimental and control groups were first Pretested and thereafter, taught the Physics using v-lab experiment and physical laboratory respectively. After the six-week treatment, both groups attempted post-test 1 immediately after treatment. Then, another post-test 2 (retention test) was administered to both sets of trainees after four weeks, a time sufficient enough to check how much was recalled. An independent t-test was utilized to decide whether to reject or accept the null hypothesis. This research design is a before and after design that is capable of revealing whether students who were instructed using conventional physical laboratory and virtual laboratory in Physics showed significantly superior learning outcomes than those trainees taught without virtual laboratory. The influence of the treatment was established by comparing the difference in the performance before the treatment (pre-test) after the treatment (post-tests).

In this design, Group 1 = Experimental: Virtual-lab (VPL); Group 2 = Control: Non-virtual-lab (CPL). To check the effect of skills transfer a Practical Assessment tool was applied. This was done by the researcher with the help of the research assistants as the practical test proceeded. Pretest was done before the treatment, treatment was done and thereafter a post-test was carried out and the results analyzed, discussed and interpreted with conclusions coming out of the tests done.

3.4 Target Population

The population that was targeted for this study was all the 1940 Second Year trainees in the Craft Certificate in Science Laboratory Technology (CCSLT) course and 96 trainers, in the 30 TVET institutions out of all the 142 public tertiary TVET institutions in Kenya that were offering the course by the time of conducting this research (MoE Website, 2019). The rest of the 112 TVET institutions do not offer the course because they are relatively new and the costs for mounting it are prohibitively high.

3.5 Sample and the sampling techniques

Two stages of sampling technique were adopted. Firstly, one TVET institution out of the 142 in Kenya was purposively sampled – The Kisii National Polytechnic for the study. This was based on: equivalent (manpower and Physics facilities); exposure (availability and usage of computer); the purposive sampling method is used by a researcher in selecting a few cases that are rich in sought information who will assist him/her to get an in-depth understanding of the problem (Creswell, 2012). The institution was selected because it has been offering CCSLT programme over a long period of time, so that experience of the trainers and availability of learning resources are of minimum requirements for training. To obtain a sample for the trainees, the non-equivalent group design was utilized. In the non-equivalent group design normally utilizes intact groups that are treated as similar before the intervention, as control and experimental groups. Thus, a class rather than individual trainees was used as the unit of sampling so that the normal running of the school was not affected (Gall, Borg, & Gall, 2009). Therefore, each TVET class is considered as one intact group. The sample for the study was made up of 53 Craft Certificate in Science Laboratory Technology Second Year Physics students, in The Kisii National Polytechnic, Kenya; 16 male and 37 female trainees. These classes were randomly assigned to the two groups.

Four trainers were also sampled; two for the control class and two for the experimental class. Equally, a practical observation checklist was used to check the learning of the selected learning outcomes. Second Year class was chosen because by this time in their training they had been taught an appreciable number of topics in Physics, Practicals in Physics and computer applications in Year One. Also, because the Second Year trainees was not purposively being prepared for a national examination as it used to be in Year Three classes of public tertiary TVET institutions, Kenya were purposively sampled.

3.6 Treatment – The Virtual Lab Experiments

Design and development of Virtual Lab Experiments on the topic of current electricity and electronics is a time consuming and expensive venture. There are websites, where virtual lab experiments on various topics of Physics were available for use. An example of such is PhET website (http://phet.colorado.edu/research/index.php), of the University of Colorado, USA, where experiments can be performed in the virtual world (PhET Team, 2015). The other very handy website is the Direct Current-Alternating Current (DCAC) Circuits online virtual laboratory that has alternating current and direct current experiments. Yet another very useful one is the Amrita Virtual laboratory, India (V-Lab.amrita.edu, 2013). The "MIT iLab" is an open-source system that supports mainly experiments in the remote laboratory(Hardison, DeLong, Bailey & Harward, 2008). Although it was started for for batch-mode remote experiments, now it supports interactive experiments with a huge and strong system for data storage and again with high bandwidth communication systems linking the end user and the server. A v-lab for robotics at the School of Electrical Engineering of the University of Belgrade, was created to focus on the notion of dynamics in industrial robots. Using modern user interface, trainees are provided with the opportunity to modify motors, transmission systems and control parameters and receive feedback (Potkonjak, et al., 2016). In Potkonjak, et al (2016), a description of development of state-of-the-art virtual laboratories which include the UK-based Loughborough University, TriLab; the Turkey-based Firat University's Virtual Electric Machine Laboratory and the USA's Stevens Institute of Technology (Virtual Laboratory Environment). The University of Western Australia has remote robotics developed in the Mercury Project and the Telegarden Project (Jara, Candelas, Puente, & Torres, 2011).

The researcher went through these websites and identified virtual lab experiments on the topics current electricity and electronics fitting in to the purpose of the study and therefore, decided to employ the DCAC Circuits Online Virtual Laboratory. This was because in this particular virtual laboratory there was an extra feature that the rest did not have - the Cathode Ray Oscilloscope (CRO). Here the trainee is offered the real feeling and functioning of the CRO at a lower cost and sometimes an experience that would have otherwise been impossible to achieve. The simulations herein allow students to vary quantities such as resistance, current, voltage, and it permits the user to receive real-time feedback on the results due to the changes made with the set-up of the experiment. If students are properly guided, they can form mental models of the experimental procedures within the simulations. These simulations also allow learners to construct graphs of phenomena by interacting with the system as the are depicted in textbooks, such as current versus voltage, current versus resistance, and current versus power. By seeing these graphs created in real time as they manipulate the control tabs in an experiment, the learners are enabled to see the relationship between the graphical displays and the experiment more clearly as compared to viewing static images. The v-labs experiment provide simulated learning environments through the use of internet. The learning environment for v-labs is designed and developed by the application of an instructional design model (Stozhko, Stozhko, & Shilovtsev, 2016) for Analysis, Design, Development, Implementation, and Evaluation (ADDIE) which is considered one of the important models for instructional system design and consists of the following sections: Instructions, and learning objectives, 3D animations interactive activities-Physics experiments via computer simulation. A Physics Practicals Training Module which consists of the experiments to be followed when teaching the topics electricity and electronics were designed, developed for use. The researcher discussed it with the research assistants before starting to use it.

For a period of approximately six weeks, during which treatment is carried out, trainees' activities were monitored by the researcher and trainees were required to take snapshots of their work for inclusion in their laboratory reports. At the start of the research, a two-hour session for orientation on the utilization of virtual lab on the web site, the components therein, the website link was given to students via Physics trainers/tutors. In this session, each trainee was provided with a user name and corresponding password that would allow them to access the web site and login and using online assessment instruments. During the intervention, trainees were required to copy and paste the screenshots of their screens and attach to their reports.

As the experimental trainees were utilizing the virtual labs during the period of the treatment, the control group trainees studied exactly the same content just like their experimental group counterparts. The learning activities for the control group trainees comprised classroom lectures and physical laboratory experiments. The trainees in the control group were synchronously exposed to the textbooks and closely associated sources.

3.7 Data Collection Instruments

The study made use of a number of researcher-made data collection instruments: a trainers' interview schedule, Physics Achievement tests; PAT 1, PAT 2 and PAT 3, a trainees' questionnaire and a practical skills test. A description of each instrument is presented in subsections 3.7.1 to 3.7.4.

3.7.1 Physics Achievement Test (PAT) Instrument

For collecting data for this study, a researcher-made Physics Achievement Test (PAT) instrument was used with modification for the pre-test, post-test 1 and the retention test (post-test 2) (See Appendices E, F and G). The PAT comprised of 50 objective test items modeled on past examinations for CCSLT past papers of Kenya National Examinations Council (KNEC, July, 2003-2019). The PAT covered content learnt by both learners in both groups (the experimental and the control groups). Each of the test items in the PAT had four choices (A - D) as answers that were possible to the question. It was required of the trainees to select their best choice of what they thought was the correct answer by ticking one of the letters corresponding to the correct option in each test item. The PAT was administered before the treatment, after six weeks of the treatment and a last one as a retention of content four weeks after the first pos-test to both groups as after its items had been reshuffled so that they appear to be different to the trainees so that they do not just recall the answers they gave in the past.

3.7.2 Questionnaires

Questionnaires are commonly utilized in collecting information in a survey, providing structured, often numerical data often in numerical form (Cohen et al., 2011). A Likert-scale with four items was utilized in collecting information on participants' perceptions about specific issues; such as their satisfaction with utilizing v-labs in the process of learning (Bickmore & Schulman, 2009). Among the many methods of collecting data, surveys are used as a common method for this task of collection data in researches including those for virtual laboratories.

The trainees' questionnaire (Appendix G) was constructed to have both close-ended and open-ended questions. It was divided into two sections: Section A captured the demographic details: gender and age. Section B had attitude towards specific issues such as the satisfaction drawn by trainees with utilization of v-labs in the process of learning. Again it was to obtain information about the experiences about the teaching and learning in the Physics lessons; ease of v-labs, their influence on; academic achievement, academic achievement by gender, retention of content and transfer of skills –speed and accuracy of connection.

3.7.3 Interview schedule

This is an oral administration of a questionnaire, which involves a face to face interaction. The interview schedule (Physics v-labs Trainers' Interview Schedule-Appendix H) was administered to trainers of Physics. The interview schedule was intended to collect information on v-labs' suitability in use to teach both academic and in training of technical skills. Face to face interview was done in order to confirm the information obtained through PATs and questionnaires in the Physics Techniques subject. This helped to bring out how v-labs influence the acquisition of knowledge, skills and attitudes in Physics at the tertiary level. It also sought information about trainers' and trainees' ICT Skills, trainers' preparedness for instruction using v-labs and the special skills the Physics trainers possesses as far as assessment and evaluation are concerned.

The trainers in Physics are best placed to give correct information as concerns the required information as they not only directly teach but also have the understanding of the subject and the processes involved in the acquisition of the concepts in Physics (Techniques). The trainers' Interview Schedule (trainers' feedback) for the trainers in v-lab Physics (Appendix H) was based on the research questions that the study aimed to answer; it sought the background information on gender, professional qualification, major teaching subjects, teaching experience on the part of the trainer; and on the part of the trainees it sought information on; academic achievement, gender of trainee, time of connection, connection accuracy, transfer of skills and retention of content. The interviews were administered by the researcher in person.

3.7.4 Practical Skills Assessment Tool – Checklist

The research tool utilized here was a researcher designed and adopted Practical Skills Assessment tool. This tool was used to get firsthand information by observing trainees and record as the practical procedures were being carried out by the trainees at site (Creswell, 2012, p.213). The practical skills assessment tool - checklist was designed for making observations for the trainees who practised in both physical and v-labs for checking how the trainees went through the practical skills test so that the researcher documents points of concern in the field. In this study a Practical Skills Assessment Tool– Checklist document was applied to document the training and learning activities in either type of hands-on activities (See Appendix I). Moreover, the observation was used to confirm if what is said by the participant during the questionnaire actually occurs in the practical skills test.

Thomas (2011) suggests that observations permit the researcher to study particular behaviours within the research site as they arise. These are the pace with which the trainee connects the wires, his/her accuracy of connection, taking measurements and recording them, choice of materials and equipment and general workmanship on the final project/experiment. Each practical test lesson lasted for one hundred and twenty minutes. This observation gave the researcher, with the assistance of the research assistants, an opportunity to record activities as they occur during the practical test lesson. These are the pace with which the trainee connects the components and equipment, one's accuracy of connection, taking measurements and recording them, choice of materials and equipment and general workmanship on the test experiment.

3.8 Piloting

Pretesting (piloting) of the research instruments is a pre-requisite of data collection. Piloting involves a small-scale study that focuses on testing the suitability of instruments for data collection, research protocols and other techniques of research as the researcher prepares for a longer study (Hasan, Schattner & Mazza, 2006). Piloting was carried out on the treatment and the research instruments to establish their suitability before the actual study was conducted out. The facilities were also looked at in terms of workability. The results from piloting were be used to determine the level of the reliability of the instruments. Pretesting (piloting) of the research instruments is a pre-requisite of data collection. To ensure the reliability of the research instruments, piloting was done on the Year Three (3) class, a class that was just ahead of the sample class because the students therein had similar characteristics to the sample class. The class was utilized as the trainees in it were to leave the college soon after completion of their classes, therefore minimal contamination could occur on the sample classes. To check reliability the instruments were administered a first round and then after two weeks. The PATs, the questionnaires, interview schedule and Practical Test Assessment tool – checklist were administered to the Physics trainers and trainees on two different occasions within an interval of two weeks as Muijs (2004) advises. The reliability of the instruments was done as explained in section 3.9.2 below.

3.9 Reliability and Validity of the Research Instruments

3.9.1 Validity of the Research Instruments

A research instrument is said to be valid if it has the ability to measure that which it is meant to measure (Creswell, 2012). It does this by logically linking the research questions to the study objectives. The research tools were validated by various experts. There are essentially four types of validity: content validity, construct validity, criterion validity and face validity. Content validity refers to the degree to which the content material of a test or questionnaire covers the quantity and intensity of the topic it is intended to cover. Content material validity of research tool is judged with the useful resource of the usage of the researcher and professionals in the area of specialization (Kumar, 2005). It is based totally on a logical relationship among variables (Babbie, 2001). The measures and techniques of the tools utilized in that research have proven to have criterion-related validity (Akiba et al., 2008).

Face validity is overall impression of a research tool; content validity means the content covered. The researcher consulted with his supervisors, departmental lecturers in Curriculum, Instruction and Educational Media at Kisii University, senior CCSLT KNEC examiners, Physics lecturers/trainers; and the School of Education and Human Resource Development at Kisii University and other science education experts in verifying face and content validity of the Physics Achievement Tests (PATs), study questionnaires, interview schedule and Physics Practical Test Assessment tool - Observation Checklist were established and necessary modifications were made based on their feedback. From the recommendations made by the expert reviews, adjustments were made as regards to meanings, accuracy, clarity of language, and functionality; additionally additions and deletions on some items done. The face and content validity of the research instruments were established through a pilot study in which it came out whether the procedures of data collection and analysis were valid and solicited the required data.

3.9.2 Reliability of the Research Instruments

A research instrument is said to be reliable if it provides consistent results (Kothari, 2004). Unreliable measures exist if all or the least number of items are unreliable (Cohen et al. 2011). The results from piloting were be used to determine the level of the reliability of the instruments. To determine the reliability of the questionnaires the researcher applied the test-retest method. The test-retest reliability is estimated by administering the same test to the same sample on two different occasions. For the PATs and the practical test, the half-split method was used. In the half-split half the items that purport to measure the same construct are divided into randomly into halves and a correlation coefficient between the two halves is determined. The PATs, the questionnaires and Practical Test Assessment tool–checklist were administered to the

Physics trainees and an interview schedule to trainees on two different occasions within an interval of two weeks as Muijs (2004) advises. This is to check whether the instruments produce the same results at different times and therefore that they are reliable. It was assumed that the numbers (opinions) representing the responses during the first testing was X and those ones obtained when the pilot obtained during the second time the numbers representing the responses will be taken to be Y. The amount of linear correlation between two variables is expressed by a coefficient of correlation, given the symbol r. This is defined in terms of the deviations of the co-ordinates of two variables from their mean values and is given by the product-moment formula which states: coefficient of correlation,

$$r = \frac{\sum xy}{\sqrt{\left\{ (\sum x^2)(\sum y^2) \right\}}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; 3.1$$

where the x-values are the values of the deviations of co-ordinates X from $\bar{X}$, their mean value and the y-values are the values of the deviations of co-ordinates Y from $\bar{Y}$, their mean value. That is, $x = (X - \bar{X})$ and $y = (Y - \bar{Y})$.

The questionnaire for trainees and the practical test assessment tool - checklist were administered to participants in the pilot group. The items were tested for reliability using twenty (20) randomly selected CCSLT students of the Year Three (3) class. This group was picked because they were to be out of the college after the completion of their course, therefore the effect of contamination by mixing and sharing could be reduced. Two Physics trainers who were not involved in the actual study responded to the questions in the interview schedule designed for them twice, with the items in the first round reshuffled and presented during round two of the test-retest. The results for items in the research tools from the first administration were compared with those from the second administration to provide reliability coefficients for the two research tools. The coefficient is a number ranging from +1 (a perfect positive correlation) through 0 (no relationship) to -1 (a perfect negative relationship).

According to Cohen et al. (2011), an r of 0.7 is considered suitable to make inferences that are accurate enough. Therefore, for this research a calculated r of 0.79 for the trainees' questionnaire was accepted and therefore the tool was adopted for use, otherwise it was to be improved before application. The value of r for the trainers' interview schedule was calculated as 0.75 and that of the practical test assessment tool was calculated as 0.94 and therefore these three research tools were accepted for use in the study. A Spearman's correlation coefficient of 0.86 of PAT that was obtained was considered adequate for this research study.

To make sure that the PATs and the practical test tool that were employed in the study were equivalent there was need to perform a Pearson's Correlation as an alternative test of reliability. This was done for the Pretest, post-test 1 and post-test 2. The results were as presented in Table 3.2 which shows the cross tabulation of the Pearson's correlations between Academic achievement and Connection of the set circuits.

The high Pearson's coefficient between all Physics Academic Achievement Tests (PATs) with a significance of $**p < 0.05$, implies high degree of reliability of the equivalence of the PATs. The lowest Pearson's coefficient between all PATs was 0.812

with a significance of **p < 0.05. This being the case the instruments were deemed fit for use in the research.

Table 3.2. Pearson's Correletation between Physics Achievement Tests (PATs)

	Pretest (Test before treatment)	Post-test 1 after treatment	Post-test 2 four weeks after Post-test 1 (retention test)
Pretest (Test before treatment)	1	.835**	.812**
Post-test 1 after treatment	.835**	1	.966**
Post-test 2 (retention test)	.812**	.966**	1

**. Correlation is significant at the 0.05 level (2-tailed), (N=53).

The Pearson's coefficient between Practical Tests Assessment Tools between the Pretest and post-test was conducted and the result is as presented in Table 3.3.

Table 3.3. Pearson's Correletation between Practical Tests Assessment Tools

	Skills transfer Pretest	Skills transfer Post-test 1
Skills transfer Pretest	1	.803**
Skills transfer Post-test 1	.803**	1

**. Correlation is significant at the 0.05 level (2-tailed), (N=53).

The Pearson's coefficient between Practical Tests Assessment Tools between the Pretest and post-test was 0.803 with a significance of **p < 0.05, implies high degree of reliability of the equivalence of the Practical Tests Assessment Tool. The research had 53 trainees and 2 v-lab trainees as its sample. Shown in Table 3.4 is the participants on whom research tools were used in the investigation.

Table 3.4. Participants in the research

Item	Trainers' Interview Schedule	Trainees' Questionnaires	Pre - Test	Post - Test 1	Post - Test 2	Practical Test Assessment tool
Total Returned	2	26	53	52	52	52
Total Expected	2	27	53	53	53	53
% Return rate	100%	96.3%	100	98.1	98.1	98.1

As can be seen in Table 3.4 both the trainers who were expected to be interviewed were interviewed which is 100% return rate. Only the participant trainees in the v-lab group and not those ones in the non-v-lab group were to fill the trainees' questionnaire. Out of this 96.3% returned the questionnaires. The percentage was this high because the researcher waited as the trainees responded to the questionnaires. For the PAT which was administered as Pretest, post-test 1 and post-test 2 (retention test) the return rates were 100%, 98.1% and 98.1% in that order. Mugenda and Mugenda (2009), posit that if 70% of research tools are returned then that is a good enough rate of return and can be considered a good representation of the respondents who were sampled. The return rate of the Practical Test Assessment tool was 98.1%. Therefore the return rates were sufficient enough to help the researcher obtain the results needed for analysis and interpretation.

3.10 Data Collection Procedure

The study was carried out at The Kisii National Polytechnic between January 2020 and March 2020. The research employed two designs; survey research design and the quasi-experimental research design approach. The researcher sought a letter of introduction from the Research and Extension Directorate through the School of Education and Human Resource Development, Kisii University to National Commission for Science, Technology and Innovation (NACOSTI) to allow for getting a research permit. After the permit was obtained, the Principal of the sampled institution was requested for permission to conduct the study through a letter seeking permission for use of the science and computer laboratories and for collection of data from the college.

Further request to be allowed to use the Second Year CCSLT students in the study was made. Letters were also sent to the CCSLT trainees, requesting them to participate in the study and explaining to them how they were to be involved in the study. Their trainers alike, were sent letters requesting for their assistance in providing lists of CCSLT Physics students in their classes. Two out of the four sampled trainers were made to be research assistants in the experimental group while the other two were in the control group, therefore they were trained on how to use the research tools. Those in the experimental group were trained by the researcher on the procedures to be followed in data collection and demonstration of how to use virtual laboratories.

The pilot study was particularly useful in training the research assistants since they were later accompanying the researcher in the demonstrations to the trainees in the experimental group. Those trainers in the control group got instructions on how to carry out the physical laboratory experiments. Discussions were held with the research assistants on how to behave professionally and appropriately when performing the virtual laboratories or when administering the tests (PATs). The training of the research assistants helped to standardize the data collection procedure as it strengthened the consistency of the procedure (Muijs, 2004). Data collection was done by the researcher with the help of the trained research assistants. A practical module which consisted of experiments to be followed when teaching the chosen topics was used.

The researcher visited the selected tertiary institution and sought the cooperation of students and staff. Before the teaching began, trainers with the assistance of the research assistants administered the Pretest to the specified groups so as to determine the entry behaviour of the trainers. The Pretest was about the pre-requisites for learning the topics electricity and electronic circuits. After the tests were done, the scripts were collected and forwarded by the research assistants to the researcher for marking and recording of the scores. The researcher scored the Pretest out of 50 marks and changed it to percentage before recording. The post-test examination was done just as the Pretest. The primary information was gathered by means of an empirical study - The PAT test, the trainees' questionnaire, the trainer's interview schedule and practical test assessment tool - observation checklist. Respondents were requested to complete a questionnaire comprising both open-ended and closed questions that were arranged thematically. The questions were formulated according to a model established during the literature study.

At the commencement of the experiment, PAT was administered on students in the sample as Pretest. Thereafter, treatment which lasted for six weeks followed. The Virtual Physics Laboratory (VPL) was not installed on standalone computer systems, but was online. During the experiments, the experimental group were exposed to the use of VPL as a treatment, while students in the control group were exposed to the conventional Physics laboratory, but with identical experiments tried out by each group. Each group was given a pre-lab instruction for ten minutes followed by laboratory activities specifically designed for each group. For the experimental group the Physics practical contents were presented through the computer and the learners interacted and responded to the computer prompts. The VPL presents an experiment in which trainees selected some parameters required and execute the virtual experiment. The participants in the control group did identical experiments in a physical lab using physical equipment and materials as per the laboratory manual designed and developed by the researcher.

After the six weeks of treatment the researcher with the assistance of the research assistants administered post-test 1 to both the control and the experimental groups. The immediate testing after teaching ensured that no new learning experience(s) interfered with the experimental condition and to ensure that learners did not forget what they had learnt. After the post-test was done, the scripts were collected and forwarded by the research assistants to the researcher for marking and recording the scores. The researcher scored the post-test 1 and recorded the scores as done with the Pretest. All the scripts were marked by the researcher only, to ensure equal treatment by the examiner as opposed to a case where several examiners were to mark. The completed questionnaires were collected immediately to ensure a high return rate and were forwarded to the researcher for editing, organization and coding. After another four weeks, the PAT was re-administered as a post-test 2 (retention test) to both groups, but the items therein reshuffled with some slightly modified while leaving the content same. Results were obtained out of it just like in the Pretest and the first post-test.

3.11 Methods of Data Analysis

The study was designed to generate both qualitative and quantitative data. Data analysis involved scrutinizing the acquired information and making inferences. The Physics achievement test (PAT), both the Pretest and the post-tests were marked and marks recorded for each respondent while the data from the questionnaires was sorted, edited and recorded. On the scoring of the multiple-choice items, '1' was awarded for each correct answer and '0' for each wrong answer. Thus, maximum possible score was 50. The trainees' score was expressed as percentage for ease of comparison. The data generated from questionnaires and PATs was ordered, coded, categorized, classified and labeled as per the research objectives and research questions for the study. The Statistical Package for the Social Sciences (SPSS) - version 23.0, a software package exceptionally intended for processing statistics in social science disciplines, was utilized to conduct the statistical analysis. The researcher utilized descriptive statistics such as frequencies, percentages, means and standard deviations and the results presented in tables, charts and descriptive form. The statistical test; the independent student's t-test was applied to investigate the information obtained. These were aimed at establishing the relationship between the independent and dependent variable and so were used to test the null hypotheses. The t-test was used to determine whether there was any difference in learners' performance between the group exposed to virtual Physics laboratories and those who were not. As per Hinton, Brownlow, McMurray & Cozens (2004) the t-test is one of the most acknowledged tests for comparing two samples; the required data has to be interval or ratio from continuous distributions and normally distributed population. The researcher confirmed the condition of choosing t-test (at least interval scale or ratio and assumption of normal distribution in the population from a sample) as a suitable statistical test for the study.

The research sought to find out if there is an effect of the v-labs on the academic achievement, retention of content and the transfer of technical skills. To accomplish this, the Cohen's d for effect size was calculated using the fact that Cohen's *d* for between-subjects designs is directly related to a *t*-test, and can be calculated by:

$$d = t\left({}^{1}/n_1 + {}^{1}/n_2\right)^{½}$$

where n_1 is the population in the experimental group and n_2 is that of the control group.

These were used to address the research objectives and to test the null hypotheses of the study. The data obtained from the trainees' questionnaires were analysed quantitatively using means and standard deviations and so the resulting numbers given a meaning as far as pedagogy is concerned. The results from trainers' interview schedule were analysed, interpreted and presented using descriptive statistics. Their analysis and discussion was done under the study objectives and research questions.

3.12 Ethical Considerations

Creswell (2012) indicates that it is necessary to obtain the consent and cooperation of people who will be assisting in the investigation. The researcher sought permission from The Research and Extension Directorate through The School of Education, Human Resource Development of Kisii University, from where he got a letter of introduction to NACOSTI so as to be granted research permit. After obtaining a research permit from NACOSTI, the Principal of the sampled institution was asked for permission to conduct the study through an official letter seeking permission and assistance for use of the college premise and that of collecting information from the institution. The participants in this research were the CCSLT Physics trainees and their trainers and they had the capacity to give informed consent directly. The researcher provided information about the purpose of the study to them by attaching a covering letter (Appendix C) to the research instruments that states the purpose of the study. They were again informed on how to keep their anonymity by not writing their names, registration numbers, email addresses or any other personal details that can positively be used to identify an individual. In order to address confidentiality, the respondents were assured that data was only to be used for the stated purpose of the study at the Kisii University, Kenya, and no other person would have access to the raw data. Participation was strictly voluntary, with respondents having the freedom to withdraw at any time. No trainer or trainee was forced to take part in the study. Participants had the right to refuse to participate in the study, and this right was respected at all times during the study period. They were also assured that the information they were to provide was to be kept private, confidential and anonymous and were not to be used for any other purpose apart from the study. The researcher tried to reach respondents at their convenient time. The respondents were further assured that any feedback on results can be accessed upon request. In reporting the findings, researcher was honest, accurate and objective.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

The chapter presents and discusses the results of the study that was designed and executed to answer the question of whether or not utilization of v-lab in training contributes to trainees' acquisition of knowledge Physics concepts, retention and transfer of practical skills at the tertiary phase of schooling in Kenya. Specifically, the study sought to examine how v-labs compare to real hands-on labs in terms of; a) academic achievement, b) retention of content, c) the transfer of electronic and electric circuitry competencies - connection accuracy and d) skills transfer - connection speed.

To achieve the objectives of the study, both qualitative and quantitative tests were carried out with the study guided by the four research questions on data from the PATs and the lab test. The analyzed data from the responses from the questionnaire and interview schedules were presented and discussed thematically.

4.2 Demographic Variables of the Respondents

To understand the results from the research tools and therefore give the results of the analysis,it was necessary to understand the demographic variables of the trainees and Physics trainers who were involved in the study are presented here. The researcher gathered the information about the sample as presented hereunder.

4.2.1 Number of Participants

The study involved only Year Two trainees and the Physics trainers in the Kisii National Polytechnic. Table 4.1 shows the details on the number of sampled participants in the study.

Table 4.1. Number of Participants

	Gender					
Respondents	Male	%	Female	%	Total	%
Trainees	16	30.2	37	69.8	53	100
Trainer	4	100	0	0	4	100

As shown in Table 4.1 the number of participants was 57 of which 92.9 % were CCSLT Physics trainees and 8.1 % were Physics trainers. The percentage of male trainees was 30.2% and the female were 69.8%.

The instruments analysed showed that the ages of the trainers who were interviewed were 54 years and 39 years respectively. They had taught physics for 29 years and 16 years respectively. Therefore the responses they gave were quite instructive and could be relied on in making conclusions about utilization of v-labs for teaching physics concepts at the TVET tertiary level.

The trainees were almost of the same age and their average age was computed as 22.4 years which meant that they had almost similar characteristics. However, again it was noted that there was a negligible number of underage (below 18 years) and that there was a single (oldest) trainee was age 35 years.

4.2.2 Respondents' group type

The quasi-experimental approach of the Pretest – Post-test design was applied in the study. The participants were placed in either the experimental group or the control group. The members of the experimental group had trainees taught Physics utilizing virtual laboratory while those in the control group had trainees were under instruction of Physics utilizing conventional laboratory. The data displayed in Table 4.2 is of the type of group of the trainees.

Table 4.2. Distribution of Trainees' Group Type

Respondents' Group Type	Frequency	Percent
Experimental	27	50.9
Control	26	49.1
Total	53	100.0

Table 4.2 shows that 50.9% of the participants were in the experimental group while 49.1% were in the control. The proportions are almost equal up to end of study because the researcher involved the trainers in the research, especially in the explanation why the trainees needed to participate till the end of the study.

An independent t-test was used in testing the hypotheses. All the t-tests were to meet the independence of observation, equivalence of variance, and the normality of the distribution criteria. To assure independence of observation, the researcher with the help of the research assistants ensured the trainees do not share information. The Levene's F-test was used to check on homogeneity of the two samples. Whenever this criterion was not met readjusted degrees of freedom were used to calculate the p-value in SPSS. To check whether distributions were normal graphical methods were applied on each independent variable.

4.3 Virtual laboratories and Trainees' Academic Achievement

Objective number one of the study was to establish whether there was a difference in the academic achievement between trainees who were taught physics using the virtual laboratory and those who were taught using the conventional laboratory. In an attempt to achieve this objective, the study sought details on the performance of the Pretest and post-test administered to all trainees involved in the study. An independent sample T-test was applied to analyze the data obtained. To achieve triangulation, interview was carried out on the trainers and a survey on trainees and the results are as presented below.

4.3.1 Descriptive Statistics on Academic Achievement of Trainees by Group

Table 4.3 gives summary of the analysis of descriptive statistics of results obtained in the Pretest and post-test 1.

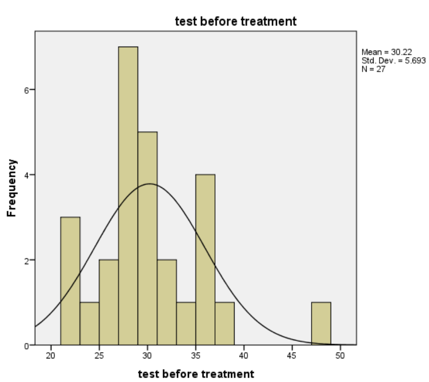
Table 4.3. Pretest Scores and Post-test 1 Scores Analysis

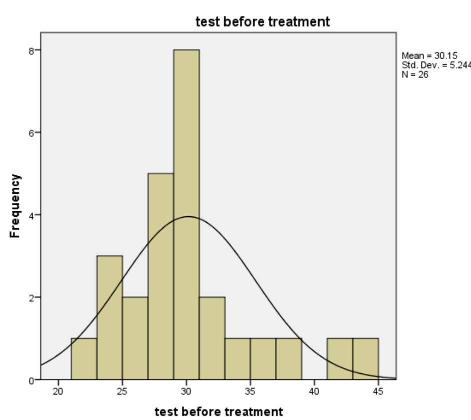
	N	Minimum score	Maximum score	Mean	Std. Deviation
Pretest	53	22	48	30.19	5.354
Post-test 1	52	24	54	35.94	6.082

As can be seen in Table 4.3 there was an increase in the minimum scores from the Pretest scores to the Post-test 1. There was also an increase in the maximum score from the Pretest and post-test 1. The mean score for the Pretest was 30.35 and the mean for post-test 1 was 35.94. This implies an improvement in the mean score of 5.59 points on the post-test 1 compared to the mean score of the Pretest. This means that whichever the mode of experimentation, Physics practicals have a significant positive effect on trainees' academic achievement.

4.3.2 Academic Achievement of Trainees in Experimental and Control Groups

The study was set out answer the question whether there is any significant difference between the post-test 1 mean score in Physics of trainees exposed to Virtual Physics laboratory and those exposed to the physical laboratory. The distribution of the academic achievement (score) for both the experimental and the control group in the Pretest (before treatment was done) are as presented in Figure 4.1. This score attained was out of a maximum of 100. The two distributions are almost similar which means that the participants of either group had almost similar chances of performing similarly if exposed to the same laboratory.





Group 1 = Experimental Group

Group 2 = Control Group

Figure 4.1. Distribution of the Pretest academic achievement score by group.

In an attempt to establish if treatment had any effect on the overall results, the data for the Pretest and the post-test experimental and the control groups were analyzed and presented in Tables 4.4, 4.5 and 4.6.

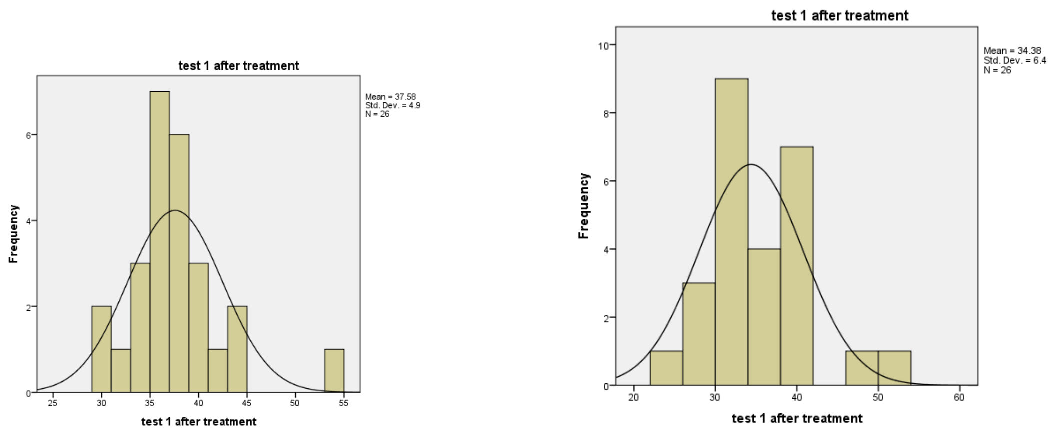
Table 4.4 shows the descriptive statistics for both the experimental group and the control group for the pre-treatment scores.

Table 4.4. Descriptive Statistics on Pretest Scores of Experimental and Control Groups

	Group Type	N	Mean	Std. deviation	Std. Error Mean
Test before treatment	Experimental	27	30.22	5.693	1.096
	Control	26	30.15	5.244	1.028

The trainees in the experimental group scored a mean of 30.22 with a standard deviation of 5.693. This was as the trainees in the control group had a mean score of 30.15, with a standard deviation of 5.244 from the mean.

On closer examination the two scores are more or less the same in terms of both the mean score and the standard deviations. The small difference between the means (of 0.07) implies that the trainees in the two groups were similar in achievement in the Physics subject before the treatment was carried out. This means that the two groups are almost same at the start of the treatment. The distributions of the post-test 1 results are as displayed in Figure 4.2.



Group 1 = Experimental Group   Group 2 = Control Group

Figure 4.2. Distribution of the post-test 1 academic achievement score by group.

The two distributions show a general improvement in the mean score, with the experimental group having a higher mean score than that of the control group. Table 4.5 shows descriptive statistics on post-test 1 of the academic achievement for both the experimental and control groups.

Table 4.5. Descriptive Statistics on Post-Test 1 test scores of Experimental and control groups

	Group Type	N	Mean	Std.	Std. Error Mean
Post-test 1	Experimental	26	37.58	4.900	0.961
	Control	26	34.38	6.400	1.225

The descriptive statistics presented in Table 4.5 depict the scores of the post-test 1 scored by the participants in both experimental and control groups. The twenty-six (N = 26) trainees in the experimental group scored a mean of 37.58 with a standard deviation of 4.900. A similar number (N = 26) of trainees in the control group who attempted the post-test 1 had a mean score of 34.38, with a standard deviation of 6.400. Therefore, the mean score by the participants of the experimental group was higher than their counterparts in the control group, which implies that the virtual laboratory treatment had a greater positive effect than that of the physical laboratory on the score in PAT, which is an indicator of academic achievement. Again the gain in score for the experimental group was 7.36 (that is 37.58 - 30.22) while that of the trainees in the control group was 4.23 (that is 34.38 – 30.15). By this inspection, it could be interpreted that virtual Physics laboratory gives a trainee a greater chance of improvement in academic achievement than the conventional Physics laboratory.

Further analysis using and independent t-test was performed to help in checking whether the means scores, 37.58 for the experimental group and 34.38 were statistically significantly different from one another. The test was utilized in deciding whether to accept or reject the H_{01}. That is, to determine whether there is a statistically significant difference between the mean in post-test 1 scores in Physics for the trainees exposed to the virtual Physics laboratory and those exposed to the physical Physics laboratory. This is because the independent-samples t-test (or independent t-test, for short) compares the means between two unrelated groups on the same continuous, dependent variable.

4.3.3 T-test on Academic Achievement of Trainees in Experimental and Control Group

Null Hypothesis 1. There is no significant difference between the post-test 1 mean score in Physics of trainees exposed to Virtual Physics laboratory and those exposed to the physical laboratory. The independent variable for this null hypothesis is the type of laboratory the two groups are exposed to and the dependent variable is the score in Post-test 1. The study tested first null hypothesis, H_{01}, that there is no significant difference between the post-test 1 mean score in Physics of trainees exposed to Virtual Physics laboratory and those exposed to the physical laboratory.

In order to randomize the experimental and control groups, an independent T-test was done on the Pretest scores for the groups so as to see if the groups were comparable before the treatment. The Levene test and the significance level for a two-tailed test (Sig. 2-tailed) was used as a guide as to which row of the two to use ('equal variances assumed' and 'equal variances not assumed'). Looking at the column 'Sig.' in the Levene test, the value obtained was 0.606. If the probability value is not statistically significant ($p > 0.05$) as in this case (0.606), then variances are *equal* and the researcher used the first row of data ('Equal variances assumed'). Once the research had decided which row to use then the Levene test has served its purpose and he moved on. The T-test was utilized to either accept or reject the H_{01}. That is, to determine whether there is a statistically significant difference between the mean scores of the Pretest scores of the experimental and control groups.

The means and standard deviations were 30.22 and 5.69 for experimental and 30.15 and

5.24 for control group respectively for the pretest. Table 4.6 shows the results of two independent sample t-test carried on the two sample means (experimental and control groups) and t = 0.045 with a p - value = 0.964 > α = 0.05 with degrees of freedom of 51.

Table 4.6. T-Test Results on Pretest Scores of Experimental and control groups

Independent T test		T	DF	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Pre-Test	Equal variances assumed	.045	51	.964	.068	1.505

Based on the rule: If $p \leq \alpha$, then reject H_0, then in this analysis, 0.964 is greater than 0.05, so we fail to reject the hypothesis and therefore we accept H_0. This implies that there is no a statistically significant difference between experimental group and control group before the treatment (pretest). This implies that there is no significant difference between the Pretest mean scores in Physics of trainees exposed to virtual Physics laboratory and those not exposed. Therefore, the groups were similar before the treatment. That a participant in control group has the same chances to learn the same way as that from the experimental group. If there are any differences in the participants' scores in PAT 1, then it would be attributed to the instruction/treatment they receive.

The t-test was then performed on the mean scores of the experimental and control groups to study the effect of the treatment (post-test 1). Because the probability value is not statistically significant ($p = 0.105 > 0.05$), then the research used 'Equal variances assumed'. Table 4.7 shows the results of the independent T-test on the scores of post-test 1 between experimental and the control groups.

Table 4.7. T-Test results on post-test 1 scores of experimental and control groups

Independent T test		T	DF	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Post-Test 1	Equal variances assumed	2.019	50	.049	3.192	1.581

From Table 4.7, assuming equal variances, the findings show that the t-test for the two groups in post-test 1 yielded a $t = 2.019$ with p - value $= 0.049 < \alpha = 0.05$, with 50 degrees of freedom, implying that there was a significant difference in scores between the control and the experimental groups with the experimental scoring higher than control.

Based on the rule: If $p \leq \alpha$, then reject H_0, then in this analysis $p = 0.049 < .05$, so we reject H_{01}, that there is no significant difference between the Post-test mean score in Physics of trainees exposed to virtual Physics laboratory and those exposed to the physical Physics laboratory. This means the alternative hypothesis, that there is a statistically significant between 37.58 for the experimental group and the score of 34.38 attained by the trainees in the control group was accepted.

The research sought to find out if there is an effect of the v-labs on the academic achievement. To accomplish this, the Cohen's d for effect size was calculated using the fact that Cohen's *d* for between-subjects designs is directly related to a *t*-test, and can be calculated by:

$$d = t\left(\frac{1}{n_1} + \frac{1}{n_2}\right)^{½}$$

where n_1 is the population in the experimental group and n_2 is that of the control group.

In interpreting the Cohen's d, a commonly used interpretation is to refer to effect sizes as small (*d* = .2), medium (*d* = .5), and large (*d* = .8) based on benchmarks suggested by Cohen *et al*. (2011).

The virtual-lab group scored higher in academic achievement test than the no-virtual-lab group with an effect size tending to medium (Cohen's d = 0.56). The Cohen's d obtained here means that the result obtained in the post-test 1 mean score of the experimental group is 0.56 standard deviations higher than the mean score of the control group.

This is in agreement with the findings of Tatli and Ayas (2012) who realized significant improvements in the performance students presented to virtual lab than their partners in the physical laboratory. This again agrees with the experiment by Zacharia and Olympiou (2013) which suggests that v-labs can be of great effectiveness in promoting of learning concepts. However, it contradicts those of several studies that hold that inconsistencies between the goals of the teachers, expectations by the learners and outcomes out of the learning across the domains of meaningful learning: affective, psychomotor and cognitive have been revealed by numerous researches (Brandriet et al., 2013; Galloway & Bretz 2015a, 2015b). This result contradicts the findings of

Bayrak et al. (2007) who did not discover any statistically significant difference between the execution of students educated with virtual lab and those instructed with conventional lab.

4.3.4 Descriptive Statistics on Academic Achievement by gender

Children are born alike but they are socialized differently with males having specific roles to perform which makes children to engage in activities that are gendered. This brings about gendered schooling. The study sought details on all the participants' scores across the tests during the period of study. The results for the whole sample (both experimental and control groups) are shown in the Table 4.8.

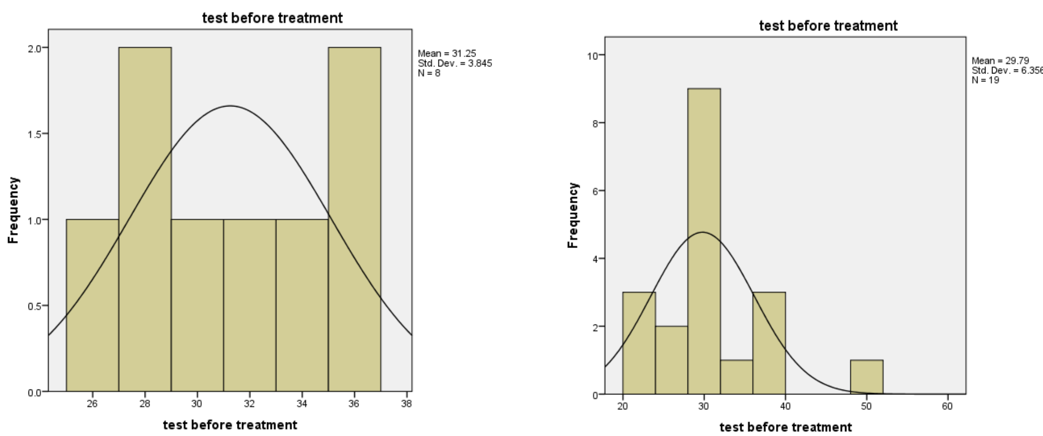
Table 4.8. Descriptive Statistics on Pretest and Post-test 1 Scores by gender

	Group Type	N	Mean	Std.	Std. Error Mean
Pretest	Male	16	31.50	4.033	1.008
	Female	37	29.62	5.885	0.967
Post-Test 1	Male	16	36.94	5.507	1.471
	Female	36	35.56	6.050	1.061

From Table 4.8 the results for the Pretest show that the performance of the female trainees were slightly higher than those of the male trainees. The scores for each gender rose, which means either type of laboratory had a positive effect on the academic achievement. The male trainees across both groups had an increment of 5.44 marks from the Pretest to the post-test. This was as the female trainees across the experimental group and the control group had an increment of 5.94.

To find out if the increments were statistically significant, a t-test was carried out.

Pretest. To test the effect the treatment of the v-lab had on the academic achievement the scores in the Pretest of the experimental group by gender, analysis was performed basing on gender as the independent variable. Figure 4.3 displays the distribution of the scores by gender of the trainee. The two distributions are almost similar which means that the participants of either group had almost similar chances of performing similarly if exposed to the same laboratory.



Group 1 = Male trainees Group 2 = Female trainees

Figure 4.3. Distribution of the Pretest academic achievement score by Gender.

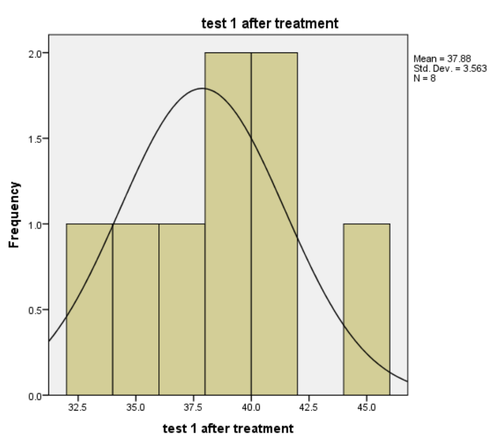
The results for descriptive statistics for how v-labs influence academic achievement by gender are shown in the Table 4.9.

Table 4.9. Descriptive Statistics on Pretest Scores for Male and Female trainees within the Experimental Group

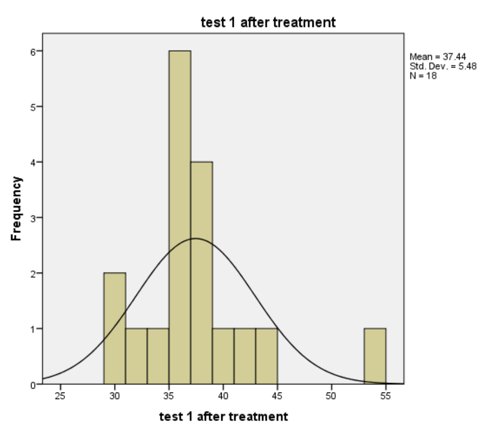
	Gender	N	Mean	Std.	Std. Error Mean
Test before treatment	Male	8	31.25	3.845	1.359
	Female	19	29.79	6.356	1.458

Table 4.9 shows the descriptive statistics for both gender in the experimental group for the pre-treatment scores. The male trainees in the experimental group scored a mean of 31.25 with a standard deviation of 3.845. This was as the female trainees in the experimental group had a mean score of 29.79, with a standard deviation of 6.356 from the mean. On closer examination the two scores are more or less the same in terms of both the mean score and the standard deviations. The small difference between the means (of 1.46) implies that the trainees of either gender were similar in achievement in the Physics subject before the treatment was carried out. This means that the participants of either gender are almost same in academic achievement at the start of the treatment.

The distributions for the scores of the post-test 1 of male trainees and those for female trainees were carried out and they are as presented in Figure 4.4 below.



Group 1 = Male trainees



Group 2 = Female trainees

Figure 4.4. Distribution for post-test 1 academic achievement score by Gender.

The two distributions are not similar which means that the participants of either gender performed differently though they were exposed to the same laboratory. However, both distributions met all the requisite criteria for carrying out an independent t-test.

The descriptive statistics presented in Table 4.10 depict the scores of the post-test 1 scored by the participants of experimental group of both gender.

Table 4.10. Descriptive Statistics on Post-test 1 Scores for Male and Female trainees within the Experimental Group

	Gender	N	Mean	Std.	Std. Error Mean
Post-Test 1	Male	8	37.88	3.563	1.260
	Female	18	37.44	5.480	1.292

The eight (8) male trainees in the experimental group scored a mean of 37.88 with a standard deviation of 3.563. The eighteen (18) female trainees in the experimental group who attempted the Post-test had a mean score of 37.44, with a standard deviation of 5.480. The small difference between the score between male and female of 0.44 (that is 37.88 - 37.44) shows that the difference across gender is negligible. This could be interpreted as virtual Physics laboratory giving female trainees an almost equal chance of improvement in academic achievement as the male trainees.

Although there was no stand-alone hypothesis concerning how v-labs influence performance across the gender of the trainees, the study evaluated the effect of v-labs on performance across the gender of the trainees. It started by stating that there is no statistically significant difference between the mean academic achievement scores of male and female trainees taught using virtual Physics laboratory. The independent variable is the training of the two groups and the dependent variable is the academic achievement as measured by the score in Post-test 1.

A t-test of equivalence of means at Pretest was carried out and the yielding as follows. For the reason that the probability value is not statistically significant (p = 0.485 > 0.05), then the researcher assumed equal variances. The means and standard deviations were 31.25 and 3.85 for male trainees and 29.79 and 6.36 for female trainees respectively for the pretest.

Table 4.11 shows the results of two independent sample t-test was carried on the two sample means (male trainees and female trainees).

Table 4.11. T-Test Results on Pretest Scores for Male and Female trainees within the Experimental Group

Independent T test		T	DF	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Pretest	Equal variances assumed	.601	25	.553	1.461	2.429

Table 4.11 shows that the t = 0.601 with a p - value = 0.553 > α = 0.05 with degrees of freedom of 25 for the scores of pretest male and female trainees of experimental group only. Based on the rule: If $p \leq \alpha$, then reject H_0, then in this analysis, 0.553 is greater than 0.05, so we fail to reject and therefore accept H_{02}. This implies that there is no significant difference between the Pretest mean scores in Physics of male trainees and

female trainees who were both exposed to virtual Physics laboratory are practically similar before the treatment. This implies that female trainees had an equal chance to perform well just like their male counterparts if both are exposed to the same learning experiences. In this particular case the learning experiences are all those that are contained in the virtual Physics laboratory, VPL.

To establish how much the VPL influenced the academic achievement across the gender, a t-test on equivalence of means for the post-test 1 was carried out. For the very reason that the probability value is not statistically significant (p = 0.540 > 0.05), then the row 'Equal variances assumed' is applied in the research. Table 4.12 shows the results of the independent T-test on the scores of post-test 1 between male and female trainees within the experimental group.

Table 4.12. T-Test Results on Post-Test 1 Scores for Male and Female trainees within the Experimental Group

Independent T-test		T	DF	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Post-test 1	Equal variances not assumed	.203	24	.841	.431	2.123

From Table 4.12, assuming equal variances, the findings show that the t-test for the two groups in post-test 1 yielded a t = 0.203 with p - value = 0.841 >.05 and at 24 degrees of freedom. Based on the rule: If $p \leq \alpha$, then reject H_0, then in this analysis p = 0.841 >.05, so we fail to reject hypothesis that there is no significant difference between the post-test 1 mean score in Physics of male trainees and female trainees exposed to virtual Physics laboratory. This means we accept the null hypothesis. This implies that there is no significant difference between the post-test 1 mean score in Physics of male trainees and female trainees exposed to virtual Physics laboratory. The research sought to establish if there is an effect of the v-labs on the academic achievement based on gender. To accomplish this, the Cohen's d for effect size was calculated. The male trainees scored higher than the female trainees both of whom were instructed in the virtual-lab group, with a small effect size (Cohen's d = 0.09). The Cohen's d obtained here means that the result obtained in the post-test 1 score of the experimental group is 0.09 standard deviations higher than that of the control group. This result agrees well with that of Kara (2008) who did not find out any sexual orientation distinction in achievement of students trained with virtual laboratory methodology and computer-assisted instructional bundle with microbiology and science. This again agrees with several studies which hold that the student's gender has little effect, in the learning of a subject, which is based on creativity (Abubakar & Dogubo, 2011; Gambari, 2010). Gender is a psychological and social dimension of boys and girls. However, this result is contrary to the findings of some studies have shown that when female students utilize virtual laboratory the outperform their male counterparts (Koksal, 2014). Again, Keter et al. (2016) obtained similar results in a study by that found computer assisted experiments motivate girls as well change their attitudes of learning chemistry.

The results here are in line with those of Abubakar and Dogubo (2011), who found insignificant difference between performance of male and students. Anagbogu and Ezeliora (2007) found that young ladies do better than young men when utilizing science skill technique for instruction. Gambari (2010) announced that sex has no impact in academic achievement of learners. Again Gunawan et al., (2017) on their research in high schools also found that the application of virtual laboratory in the learning of Physics improves figurative creativity and enhances verbal ability of the students, of which the female trainees are affected more. The results found here negate those obtained by Odagboy (2015) observes that if girls come to school with an attitude and image that boys are superior it might affect their interest to learn. It also goes in the opposite direction of Akeyo & Achieng (2012), who found that there are serious disparities in gender as far as enrollment, retention, performance and transition in STEM fields is concerned with the girl child being disadvantaged. These led the research to conclude that the virtual Physics laboratory had the same effect on the trainees, irrespective of their gender. If asked to prefer a gender on which the v-labs are to be used so that learning can take place better, we cannot prefer one gender over another. They produce the same learning effect on trainees of either gender.

4.3.4 Trainees' perceptions on Influence of v-labs and Academic Achievement

The study sought the trainees' perceptions about the influence of the virtual laboratory on academic achievement. The responses were rated on a four point Likert scale where 1 = Agree; 2 = Tend to Agree; 3 = Tend to Disagree and 4 Disagree. Table 4.13 gives the summary of the findings.

A mean score of 1.0 to 1.49 means strongly agree, that of 1.5 to 2.49 means tends to agree, that between 2.50 and 3.49 means tend to disagree and therefore will be treated as not agreeing while lastly 3.50 to 4.0 will be treated strongly disagreeing.

Table 4.13. Trainees' Perspectives on Virtual Lab and Academic Achievement

Statement	Minimum	Maximum	Mean	Std. Dev.
My score improves because I understand the content of the experiment properly by performing it in virtual lab	1	4	1.19	.491
Virtual lab can improve my score because it decreases my anxiety with experimentation while helping me learn new concepts	1	4	1.04	.196
Experiments in virtual lab make physics concepts easy to understand, thus improving my score	1	4	1.35	.797
Experiments in virtual lab is fun, but I need the trainer is around to direct me. This may not lead me to score better	1	4	1.31	.788
Virtual labs make my score to be better because they assist me make sense of unfamiliar phenomena	1	4	1.12	.326

The trainees felt that through performing experiments via virtual labs they are enabled to improve in their score because they understand the content of the experiment properly.

The mean of 1.19 and standard deviation of 0.491, show that the trainees agree strongly to the statement that virtual labs make them understand the content well, thus can be enabled to perform. This is in agreement with the findings of earlier studies that students can gain knowledge and skills by using v-labs when discovering about their real environment, as they gain content and create science process skills (Jaakkola et al., 2011; Lampi, 2013).

Virtual lab do improve the trainees' score because it decreases the trainees' anxiety with experimentation while helping them to learn new concepts. The trainees agree (mean of 1.04, standard deviation of 0.196) that v-labs lower their anxiety as the perform experiments and learning new concepts. This makes them score a higher mark in the Physics academic achievement test. This is in agreement with the earlier findings that virtual labs are student-centered, enable students to get prompt feedback and correct their misconception of an idea (Smetana & Bell, 2012).

To whether experiments in virtual lab make physics concepts easy to understand, thus improving score in PAT, the trainees rated this item at a mean = 1.35 and with a standard deviation = 0.797). This means that the trainees perceive that by doing experiments in v-lab the score in PAT will be enhanced unlike when done in the conventional lab. This is in agreement with other studies by Kollöffel and de Jong (2013) and Tsihouridis et al. (2014) that students increment their insight with respect to imperceptible molecular-level phenomena and obtain better theoretical comprehension therefore making the learners to score highly.

The mean of 1.31 and a standard deviation of 0.788 for the statement for v-labs being fun, but not being that fun, unless trainer is there to direct the trainees implies that the trainee needs to be there for the trainees to benefit optimally from these labs. Otherwise they may digress and get to non-beneficial activities as far as academic achievement is concerned. They therefore feel that v-labs may not lead me to score better, unless the trainer guides them and help them with the labs.

Finally, they agree that virtual labs make their score to become better because the labs assist them make sense of unfamiliar phenomena. The mean of 1.12 and standard deviation of 0.326 means that the respondents agree strongly to the statement that v-labs make it easy for learners to visualize what is not easy to visualize. This is in agreement with other studies that students increment their insight with respect to imperceptible molecular-level phenomena and obtain better theoretical comprehension (Kollöffel & de Jong, 2013; Tsihouridis et al., 2014). This could be linked to the fact that v-labs helps the learner to access places or situations that are not normally attainable. For example, the inside of a nuclear reactor, the nucleus of an atom, very hot furnaces, microscopic scale phenomena can also be accessed by the learner through the simulations. This increases imagination and improves memory of the learner as far as some given content is concerned.

The study also explored the trainees' perceptions about the influence of the virtual laboratory on academic achievement by gender. The rating involved the following trainees' Academic achievement by gender. The responses were rated on a four point

Likert scale where 1 = Agree; 2 = Tend to Agree; 3 = Tend to Disagree and 4 = Disagree.

For the interpretation of Table 4.14; A mean score of 1.0 to 1.49 means strongly agree, that of 1.5 to 2.49 means tends to agree, that between 2.50 and 3.49 means tend to disagree and therefore will be treated as not agreeing while lastly 3.50 to 4.0 will be treated strongly disagreeing. The mean of 3.15 and standard deviation of 0.675 to the statement that v-labs favour male trainees in terms of score was rejected by a great percentage of trainees.

Table 4.14. Trainees' Perspectives of V-Lab and Achievement by Gender

Statement	Minimum	Maximum	Mean	Std. Dev.
By using virtual labs to learn, male trainees will score a higher mark than female trainees	1	4	3.15	.675
Virtual lab can help female trainees to achieve higher grades because it allows them in engaging in play activities that are male dominated	1	4	1.12	.558
Female trainees who use virtual labs to learn will score better than when they carry out experiments not within women's usual roles	1	4	1.15	.464
Virtual labs make trainees of both gender to improve in examination score alike because they do not do not treat trainers preferentially based on gender	1	4	1.14	.368
Male score better than female trainees in exams because the Virtual labs are more appealing to male trainees-are like ICT games they play	1	4	1.08	.272

This implies male and female trainees are likely to be affected the same way by virtual labs in terms of academic achievement as indicated by theory tests, in this particular case the Post-test 1. The result is in conformity with that of Koksal (2014), assert that when female students utilize virtual laboratory the outperform their male counterparts.

To the statement that virtual lab can help female trainees to achieve higher grades because it allows them in engaging in play activities that are male dominated, the low mean of 1.12 and standard deviation of 0.558 means that female trainees are likely to gain more by using v-labs than the traditional labs as v-labs afford them the opportunity of practicing what is considered as ‘male activities’. This tries to break the ‘gendered education’ problem where girls and women are treated as a ‘weaker gender’, not for specific roles and activities. Once this is weakened, girls and women and in this particular case, female trainees are likely to do better utilizing v-labs than the conventional ones. This fits well to the findings by Keter et al. (2016) who found computer assisted experiments motivate girls as well change their attitudes of learning chemistry. The trainees see it as a plus when female trainees use virtual labs to learn Physics as they will score better than when they carry out experiments not within women’s usual roles in the conventional labs.

The low mean score of 1.15 and standard deviation = 0.464 shows that there is strong agreement to the statement that v-labs will make the female trainees score better while utilizing v-labs. The respondents again agree strongly that virtual labs make trainees of both gender to improve in examination score alike because they do not do not treat trainers preferentially based on gender (mean = 1.14, standard deviation = 0.368). This means that unlike in the conventional laboratory, where the teacher may have preferential treatment, the virtual laboratory does not have such. This fits well to the findings by Keter et al. (2016) who found computer assisted experiments motivate girls as well change their attitudes of learning chemistry. Thus it will allow male and female trainees explore to their best of ability and knowledge. This makes it more friendly to both gender in terms of acquisition of knowledge, practice and conceptualization. However, to whether male scoring better in examinations than female trainees who practiced in the v-labs, most respondents felt that because the virtual labs are more appealing to male trainees, because the v-labs are like ICT games male trainees normally play. A low mean of 1.08 with a standard deviation of 0.272 means that respondents feel that male trainees have an advantage over the female trainees in that the male trainees from time to time keep playing computer games that are related to the virtual laboratories that both gender are now exposed to. This could mean that although we assumed that both gender had been introduced to ICT in year one of their training, male trainees may be having superior skills of manipulation as compared with their female counterparts. This could affect the practice and eventually the academic achievement as could be evidenced in a score in the Post-test 1.

4.3.5 Trainers' perceptions on Influence of V-labs and Academic Achievement

Trainers in Physics identified the challenges that they face with the real laboratory as: Shortage of apparatus or in some case totally lacking; it is difficult to handle a large group of students – especially now that the government of Kenya is highly subsidizing the fees for TVET trainees; time constraints affect the use of labwork in teaching as the National examinations are mainly theoretical. Therefore the trainers brush over the content because of the pressure due the examinations and again being that even the time that is allocated by the Kenya Institute of Curriculum Development (KICD) per topic does not tally to the actual time that is available. They also cited unmotivated trainees – some trainees joined the course without the full knowledge of what the course entailed. It happens that most of them had dropped the Physics Subject in Form Two during their secondary school, means they did not have interest in the Physics Techniques subject. Apparatus used in real laboratory are prone to errors, which the virtual lab offers a solution. Again the trainers indicated that there are some experiments which they themselves either never had a chance of conduction or new content that they did not meet during their school days. Marking the trainees' reports and supervision becomes very taxing, especially with the ever enlarging classes. This is in agreement with Tuyuz (2010). These statements point to the reasons that other researches have established earlier, that v-lab is an alternative answer for expensive labs, empowering students to advance at their own pace, giving students quick feedback with the goal that they can check their learning (Ajogbeje & Akeju, 2012; Fiscarelli et al., 2013; Rutten et al., 2012; Smetana & Bell, 2012; Tatlı & Ayas, 2011; Trundle & Bell, 2010; Zabunov, 2013). On how v-labs assist trainees to understand content better, the trainers said; V-labs give learners an opportunity to perform experiments that are not possible to carry out because of the dangers involved hence understand the content better. This makes them to conceptualize content better and therefore making them score higher grades. But some trainees may not see the v-labs as a learning activity but just fun, play and waste of their valuable time. This view is agrees with Zacharia and Olympiou (2011) who posit that v-labs can be of great use in promoting learning of science concepts. This is agrees with the findings of Tsihouridis et al. (2016) who maintain that virtual labs kept students' enthusiasm by upgrading their basic reasoning and enhancing the process of learning. Computer simulations makes the learners become motivated towards the subject and also change their attitude towards the subject (Gambari et al., 2016).

Again v-lab can allow the trainees to perform experiments that are dangerous or the equipment is quite costly. This is so because with v-lab no fragile or costly items are involved. The environment is safe, hence the trainees can repeat the experiment a number of times, thus failing in a safe to fail environment. This finding conforms to the results of earlier findings that with the use virtual laboratory, students can repeat many times any inaccurate trial or to extend their proposed encounters as it offers almost perfect and non-boring learning environment (Mejías & Andújar, 2012). That some experiments in the physical lab which may pose dangers or can easily cause accidents can now be done in the v-lab, experiments such as those involving high voltage, radioactivity and the like can be carried in a safe to fail environment. This is in conformity to the earlier establishments that virtual environment is a safe way of doing experiments that may pose health and environmental challenges, hence the gaps that exist in the traditional labs can be bridged (Achuthan & Murali, 2015).

By slowing down the speed or hastening it, a learner is allowed to work at his or her own pace, thus it could bring more comfort in learning than the usually timed synchronous classes. This is in line with Rutten et al. (2012), that v-labs can assist in executing time-consuming experiments in a shorter time-frame, completing dangerous experiments in a safe environment, reproducing events that would be difficult to be observed in physical laboratory virtually.

The trainers observed that virtual lab decreases trainees' anxiety, learn new concepts thus scoring more in tests. By performing the experiments in v-lab and seeing how physical phenomena and processes occur the learner not only gets firsthand information but feels like he has constructed information by himself or herself. This reduces anxiety and makes the learner to grasp more content and is likely to do better in academic achievement. This agrees with the findings of Borrás et al. (2011) who established that the virtual lab provides a chance for learners to work freely, at their own particular pace on the web, figure out how to utilize instruments and other materials and do a pre-lab experiment prior to doing it in the lab. Again that virtual laboratories in Physics education expands student interest and gives a fun learning condition (Gambari et al., 2016).

It was perceived by the trainers in the v-lab group that by performing the experiment in virtual lab decrease your trainees' conceptual load. That virtual labs offer the trainees with an opportunity to figure the experimental procedures or structures of items in more detail. For example, the inside of an atom, the flow of electrons or the internal structure of a nuclear reactor can be simulated and the trainees can access what is not possible with the conventional laboratories. Virtual labs have also been found to foster attention in the learners, which will in turn make the learners to get interested in the content. This is in agreement with the work of Rutten et al. (2012), that v-labs can assist in executing time-consuming experiments in a shorter time-frame, completing dangerous experiments in a safe environment, reproducing events that would be difficult to be observed in physical laboratory virtually.

As for the ease with which trainees understand the experimental procedure in virtual lab, the trainees find it easy to perform experiments in the virtual lab as compared to performing the same experiments in the conventional laboratory. Although at the start of the time of introduction some of the trainees had a challenge. This could be attributed to the differential computer knowledge and skills. To reduce the effect, the trainees were taken through basics of the v-lab, especially on how to maneuver with the experiments' components and equipment. Teacher A said "the inconsistencies involved in the results in the conventional labs are eliminated by utilization of the v-labs". This is in agreement with the findings of Gambari et al. (2016), Pyatt and Sims (2012), Tatli and Ayas (2012).

Trainers said that virtual labs help your trainees to understand physics concepts more easily therefore making them to have a better score in the theory examinations. On how the v-labs assist trainees to understand Physics concepts the teachers had this to say: v-labs offer the trainees the chance to perform experiments in an environment that is like that of the conventional laboratories. The can manipulate materials and equipment which will develop their psychomotor skills just like in the real laboratory. This makes them follow the scientific method and the allied skills that the method comes with; thus the basic skills in the scientific method – problem identification, hypothesizing, setting experiment, observation and measurement, data analysis, reporting and communication can be fostered. The trainees are again offered the opportunity to repeat the experiment any number of times because the supplies in the v-lab are boundless and not like in the real lab where the supplies are either inadequate or lacking, but also deplete altogether. This makes the trainees to conceptualize the content better, hence making the trainees to achieve better grades. This is in agreement with the results of Dalgarno et al. (2009) and those of Tatli Ayas (2013).

On how female trainees compared with male trainees in using the v-lab better their results in academic achievement, the trainers had these to say; although at the start, male trainees were getting it more easy to maneuver through the virtual lab than their female counterparts, there was a significant improvement with the ease and speed with which the female trainees connected the virtual laboratory electrical circuits to a level that at the end they were almost at bar. This is in agreement with the findings of several studies that have found virtual lab can therefore be treated as an equalizer not only in the connection of the circuit, but also in the acquisition of theoretical knowledge. The result is in conformity with that of Koksal (2014), assert that when female students utilize virtual laboratory the outperform their male counterparts. It offers the female trainees an opportunity of practicing roles that are not normally performed by female, such as electrical wiring. This makes them to construct knowledge and therefore make them to score better thus lessening the gap between the genders. This can be evidenced by similar scores by the male and female trainees in the post-test 1 of PAT.

The results contrast the works of Salta and Tzougraki (2004) who found that that girls have negative attitudes as far as the cognitive load of these courses are concerned. They have been socialized to believe that men are born scientists and technologists. Various studies have shown that men have not only traditionally outnumbered women in fields STEM but outperformed the women because of 'gendered' education, with all the societal and environmental factors (Hill et al., 2010; Miyake et al., 2010).

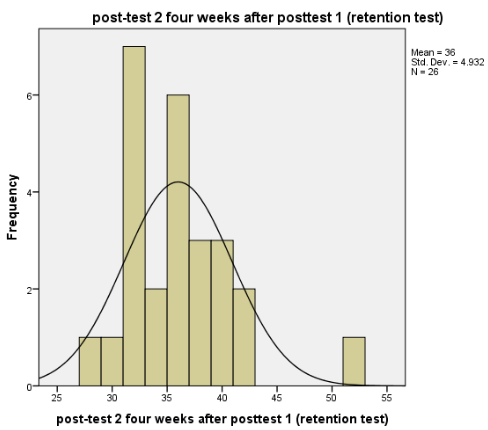
4.4 Virtual Laboratories and Trainees' Retention of Content

The third objective of the study was to investigate if there is any statistically significant difference in the mean retention scores of trainees exposed to virtual Physics laboratory and those exposed to physical laboratory as measured in second post-test. To answer the question of whether trainees who studied using the virtual Physics laboratories retained the content that they have learnt longer than their physical Physics laboratory the data from the study was analyzed and interpreted.

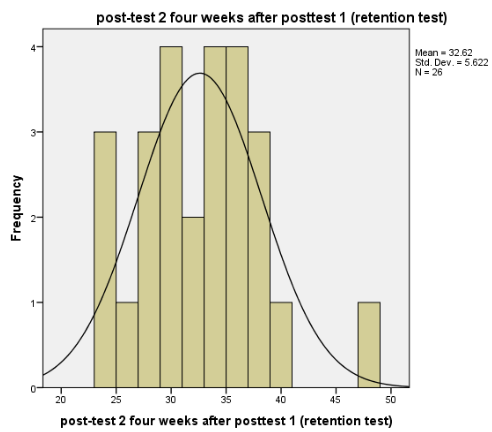
4.4.1 Descriptive Statistics on Retention of content for Experimental and Control Group

Pretest. As was displayed in Table 4.4 and Table 4.6, again in Figure 4.1, the scores in the Pretest were practically same for either the Experimental group or the Control group. Therefore, any difference in the scores in the retention test can be attributed to the lab through which instruction was applied in the instruction of Physics; of either the v-labs or the physical Physics laboratory.

Figure 4.5 shows the distributions of both the experimental group and the control group in the post-test 2 Physics Achievement Test (PAT) that was carried four weeks after the first post-test (Post-test 1).



Group 1 = Experimental Group



Group 2 = Control Group

Figure 4.5. Distribution of the post-test 2 academic achievement score by Group.

From Figure 4.5, it can be seen that the distribution for the Experimental group is has a lower peak than that of the Control Group, meaning that at some mark far from the mean there is a high frequency there. Again the scores are not as spread as those of the control group. Pedagogically, this means that the scores in the retention come close together and towards the mean score. Meaning that the gap in score by the participants tends to close up. Table 4.15 shows the results for descriptive statistics in the retention test (Post-test 2)

Table 4.15. Descriptive Statistics on Post-Test 2 by Experimental and Control Group

	Group Type	N	Mean	Std.	Std. Error Mean
Post-test 2	Experimental	26	36.00	4.932	.967
	Control	26	32.62	5.622	1.103

The twenty-six (N = 26) trainees in the experimental group scored a mean of 36.00 with a standard deviation of 4.932. A similar number (N = 26) of trainees in the control group who attempted the post-test 2 had a mean score of 32.62, with a standard deviation of 5.622. Therefore, the mean score in the retention test (Post-test 2) of the participants of the experimental group was higher than their counterparts in the control group, which implies that the virtual laboratory treatment had a greater positive effect than that of the physical laboratory on the retention score in Physics examination, which is an indicator of how much is retained (learnt). This could be interpreted as virtual Physics laboratory giving a trainee a greater chance of retaining more content than if the trainee did the experiments in the conventional Physics laboratory. This can be supported by the findings that learning science from, a constructivist point of view, happens when learners construct their ideas about how the world works (Skamp, 2007). Kara (2008) posits that utilizing computer assisted instruction led to better in content retention of students in science education.

4.4.2 T-test on Retention of content of Trainees in Experimental and Control Group

Null Hypothesis 3: There is no statistically significant difference in the mean retention scores of the v-lab and the non-v-lab trainees. The score in the post-test 2 (retention test) is the dependent variable which is dependent upon the group in which the trainee was instructed in; either the experimental or the control group.

A t-test for the pretest scores between the groups was carried as shown in Table 4.6 and it was confirmed that the groups (experimental and control) were found to be almost similar before the treatment. Now a t-test was carried on the scores of post-test 2 between experimental and the control groups. The test was utilized in deciding whether to accept or reject the H_{03}. That is, to determine whether there is a statistically significant difference between the mean in post-test 2 scores in Physics of the trainees exposed to the virtual Physics laboratory and those exposed to the physical Physics laboratory. This is because the independent-samples t-test (or independent t-test, for short) compares the means between two unrelated groups on the same continuous, dependent variable.

The probability value obtained was not statistically significant ($p = 0.323 > 0.05$), so the research used the ‘Equal variances assumed’ row. Table 4.16 shows the results of the independent T-test on the scores of post-test 2 between experimental and the control groups.

Table 4.16. T-Test Results on Post-Test 2 Scores by Experimental and Control Group

Independent T test		T	DF	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Post- Test 2 (Retention Test)	Equal variances assumed	2.308	50	.025	3.385	1.467

From Table 4.16, the findings show that the t-test for the two groups in post-test 1 yielded a t = 2.308 with p - value = 0.025 < α = 0.05. This is as the degrees of freedom were at 50. Based on the rule: If p ≤ α, then reject H_0, then in this analysis p <.05, so we reject H_{03}. This means we reject the null hypothesis, that there is no significant difference between the mean scores in the retention test between the trainees who were instructed in the virtual Physics laboratory and those instructed in the conventional Physics laboratory. So we opt for the alternative hypothesis; that v-lab positively affects the way trainees retain the learnt content. This implies that there is statistically significant difference between the Post-test 2 mean score in Physics of the Experimental Group mean score (36.00) and the Control Group (32.62). In other words a trainee who practices in the virtual Physics laboratory is likely to remember (retain) more than the non-virtual laboratory trainee.

The research sought to investigate if there is an effect of the v-labs on the retention of content by the trainees in either the virtual lab group and the non-virtual lab. To accomplish this, the Cohen's d for effect size was calculated. The virtual-lab group scored higher in academic achievement test than the no-virtual-lab group with an effect size tending to medium (Cohen's d = 0.64). The Cohen's d obtained here means that the result obtained in the post-test 1 mean score of the experimental group is 0.64 standard deviations higher than the mean score of the control group. This favours the virtual lab as a better laboratory to engage the trainees in if we as educators would wish content to be remembered (retain) for long. This will not only assist the trainees to score higher in the theory examinations but also help them learn theoretical content. This could be because the trainee can easily remember how he or she did the experiments.

By doing the trainee constructs his/her own knowledge, skills and attitude. This could be explained by the fact that normally the trainees share physical laboratory equipment and components, working in groups and therefore individual interaction with the materials is limited. Again the trainee gets to practice with the content on the digital platform without the exhaustion experienced with the conventional classroom where the teacher or trainer needs to be there physically to do instruction. This is supported by the results of Cobb et al. (2009) posit that v-labs can be used in student cognition which may make the learners to retain the experiences for longer than when the experiments are performed in the conventional laboratory. Olalekan and Oludipe (2016) found that learners using computer simulations are afforded the opportunity to visualize, comprehend and develop a high knowledge retention rate.

4.4.3 Virtual laboratories and Trainees' Retention of content by Gender

Although there was no stand-alone hypothesis of testing whether there was any statistically significant difference in the mean retention scores of male and female trainees exposed to virtual Physics laboratory as measured in second post-test, this was tested to see the influence of v-labs across the gender of the trainees. In the reviewed literature, Kara (2008) did not find out any sexual orientation distinction in retention of students trained with virtual laboratory methodology and computer-assisted instructional bundle with microbiology and science.

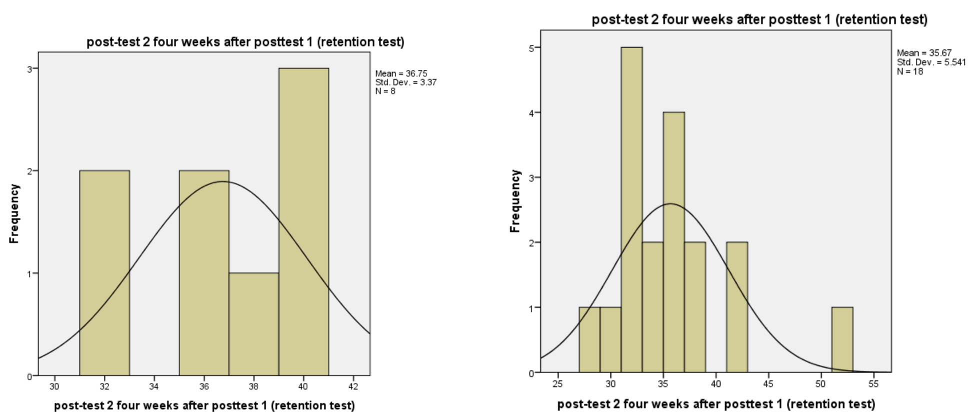
Pretest. As was displayed in distributions in Figure 4.3 and Table 4.10, the scores in the Pretest were practically similar for the male and female trainees within the Experimental Group. Therefore, any difference in the scores in the retention test (post-test 2) can be attributed to the gender of trainee, either male or female. To study the relative retention rates by the different gender, an analysis on how male trainees and female trainees retain the acquired content the analysis of the retention scores was done. The descriptive statistics presented in Table 4.17 presents the scores of the post-test 2 (retention test) scored by the v-labs male and female participants.

From Table 4.17 The eight male (N = 8) trainees in the experimental group scored a mean of 36.75 with a standard deviation of 3.370. The female trainees within the Experimental Group (N = 18) who attempted the post-test 2 had a mean score of 35.67, with a standard deviation of 5.541.

Table 4.17. Descriptive Statistics on Post-Test 2 Scores in VPL by gender

	Whether male or female	N	Mean	Std. Deviation	Std. Error Mean
Post-test 2 four weeks after Post-test 1 (Retention Test)	Male Trainee	8	36.75	3.370	1.191
	Female Trainee	18	35.67	5.541	1.306

Therefore, the mean of the male participants of the experimental group was higher than their female counterparts, with the spread of the scores not as distributed as those of female trainees. This implies that the virtual laboratory treatment had a greater positive effect on male trainees than their female counterparts on the score in Physics examination, which is an indicator of retention of content. More sensitive tests were required to show whether this difference in the mean scores were statistically significant. Figure 4.6 shows the distributions of both the male and female gender within the Experimental Group in the post-test 2 Physics Achievement Test (PAT) that was carried four weeks after post-test 1 (Retention test).



Group 1 = Male trainees Group 2 = Female trainees

Figure 4.6. Distribution of the Retention Score in post-test 2 by Gender.

The distributions in Figure 4.6 show that they meet criteria for a t-test for carrying out a t-test.

4.4.4 T-test on Retention of content based on trainees' gender

Although there was a stand-alone hypothesis testing whether or not there was a statistically significant difference in the mean retention scores of the male trainees and female trainees who were instructed using the v-labs, this was carried out to see the influence of v-labs on the retention of content by the different genders of trainees. The score in the post-test 2 (retention test) is the dependent variable which is dependent upon the gender of the trainee within the experimental group.

The t-test was utilized in deciding whether to accept or reject the statement that there was no statistically significant difference in the mean retention scores of the male trainees and female trainees who were instructed using the v-labs. That is, to determine whether there is a statistically significant difference between the mean in post-test 2 scores in Physics Achievement Test (Retention Test) of the male and female trainees exposed to the virtual Physics laboratory. This is because the independent-samples t-test compares the means between two unrelated groups on the same continuous, dependent variable.

A t-test for pretest the mean scores and standard deviations were 31.25 and 3.85 for male trainees and 29.79 and 6.36 for female trainees respectively had been carried out and presented in Table 4.12 and it was confirmed that the mean scores of male trainees and females were found to be almost similar before the treatment. Now, the t-test was performed on the scores in post-test 2 for male trainees and female trainees within the experimental group. The t-test for the results in the post-test 2 were analyzed and tabulated. Because the probability value is not statistically significant ($p = 0.431 > 0.05$), then the row 'Equal variances assumed' was utilized. Table 4.18 shows the results of the independent T-test on the scores of post-test 2 between male and female trainees within the experimental (VPL) group.

From Table 4.18, assuming equal variances, the findings show that with 24 degrees of freedom, t = 0.509 with p - value = 0.615.

Table 4.18. T-Test Results on Post - Test 2 Scores by gender

Independent T-Test		T	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
post-test 2 four weeks after posttest 1 (retention test)	Equal variances assumed	.509	24	.615	1.083	2.127

Based on the rule: If $p \leq \alpha$, then reject H_0, then in this analysis $p = 0.615 > .05$, so we fail to reject the null hypothesis, that there is no significant difference between the mean retention scores between male and female trainees who were both exposed to the v-lab. This means we accept the null hypothesis, that there is no significant difference between the mean retention scores between male and female trainees within the experimental group. This implies that there is no significant difference between the Post-test 2 (retention test) mean scores in Physics of male and female trainees exposed to virtual Physics laboratory. This in plain language means that male and female trainees retain content the same way when they are instructed using virtual Physics laboratories.

The research sought to find out if there is an influence of the v-labs on the retention of content by the male and female trainees within the virtual lab. To accomplish this, the Cohen's d for effect size was calculated. The male trainees within the virtual-lab group scored a higher mean score than their female counterparts within the same group with a small effect size (Cohen's d = 0.22). The Cohen's d obtained here means that the effect obtained in the post-test 2 score for the male trainees within the experimental group was 0.22 standard deviations from the mean of their female counterparts.

The result is in perfect agreement with that of Kara (2008) who did not find out any sexual orientation distinction in retention of students trained with virtual laboratory methodology and computer-assisted instructional bundle with microbiology and science. However, the findings contradict those of Udo and Ubana (2013) who reported that there was no statistically significant difference in physics retention ability between male and female students. Similarly, a study on gender differences in achievement and retention in Mathematics in the topic of algebra utilizing Problem-Based Learning (PBL) method shows that the results do not differ significantly across the gender (Ajai & Imoko, 2015). The result contradicts those of Nwankwo and Madu (2014) who hold that gender was found to influence retention of content in their study utilizing the delayed Physics achievement test (PAT) in which they reported that female students outperformed their male counterparts. Akpoghol et al. (2016) hold a similar stance by reporting that when lecture method was supplemented with either music or computer animations, the female learners had higher retention scores than their male counterparts. The result is in conformity with the results of several studies which did not find out any sexual orientation distinction in retention of students trained with virtual laboratory methodology and computer-assisted instruction (Ajai &Imoko, 2015; Kara, 2008; Udo & Ubana, 2013) who reported that there was no statistically significant difference in retention ability between male and female students. However, this result is in the opposite direction to what Nwankwo and Madu (2014) who hold who found female retaining better than their male counterparts in Physics PAT. Similary, Akpoghol et al. (2016) hold a similar stance when lecture was supplemented with music and computer animations.

4.4.5 Results from trainees' perception on Retention of content

The study sought the trainees' perceptions about the influence of the virtual laboratory on retention of content. The rating involved the following trainees' retention of content. The responses were rated on a four point Likert scale where 1 = Agree; 2 = Tend to Agree; 3 = Tend to Disagree and 4 = Disagree. A mean score of 1.0 to 1.49 = strongly agree, that of 1.5 to 2.49 = tends to agree, that between 2.50 and 3.49 = tend to disagree and therefore will be treated as not agreeing while lastly 3.50 to 4.0 = strongly disagreeing. Table 4.19 gives the summary of the findings.

From Table 4.19 and as far as retention of content that has been learnt is concerned, the trainees felt that Virtual laboratory makes them score more for they remember more of what was taught than if they learnt it without using the v-labs. The mean for this statement was 1.04 with a standard deviation of 0.196. This means the trainees cherish v-labs if they are to remember more of what they were taught. This could be attributed to the fact that in v-labs much of the content acquisition is by constructivism, where the learner constructs information by himself or herself thereby making meaning of the information gathered.

They also felt that the organization of the content in virtual lab assists them have a better score as they remember what they have learnt. The low mean of 1.02 and the low standard deviation of 0.198 mean very strong agreement to the statement. That information that is normally presented in the v-labs is well researched and its arrangement evaluated well before it is presented. This makes it to be easily followed. These results are in line with what was established by Connell et al. (2016) that inquiry-based mastering pedagogies are meant to shift from teacher-centeredness to learner-centeredness so that trainees are involved more in information construction, which will in turn lead to more content retention. This agrees Lux (2002) who found that there was an 80% increase in the rate of retention when learners have been exposed to virtual laboratory throughout microbiology class.

Table 4.19. Trainees' Perspectives on Virtual Lab and Content Retention

Statement	Minimum	Maximum	Mean	Std. Dev.
Virtual laboratory makes me score more as I remember more of what I was taught than if I learnt it otherwise	1	4	1.04	.196
The organization of the content in virtual lab assists me have a better score as I remember what I have learnt	1	4	1.02	.198
I score better for my learning skills have been improved by v-labs-I remember more content taught	1	4	1.23	.514
I score more because I remember more content obtained through v-labs by forming mental maps	1	4	1.08	.272
My score in Physics has improved because I easily recall how I practised through the content using v-labs	1	4	1.27	.452

Kara (2008) posits that utilizing computer assisted instruction led to better the academic achievement and retention of students in science education. Milo et al. (2011) argued that the capacity for students in seeing the internal working of the system and have the capacity of changing or modifying conditions, makes the v-labs capable instruments for students to form internal schema. The trainees feel that they are able to score better because v-labs improve their learning skills and thus they are able to remember more of content taught (1.23, standard deviation 0.514). The values in the bracket indicate a very strong agreement to the statement of v-labs improving the (retention) score by improving how the trainees learn.

The trainees agreed strongly (Mean = 1.08, standard deviation = 0.272) that they score more because they are able to remember more content obtained through v-labs by forming mental (concept) maps of what they have already been taught via v-labs. It is important that learners are able to form concept maps of the content that they have acquired, if they are to achieve more academically. The also strongly agree (mean = 1.27, standard deviation = 0.452) that their scores in Physics have improved because they easily recall how they practised through the content using v-labs. By recalling how they practised in v-lab the trainees can easily recall key concepts and as a result this could lead them to remembering more. The results obtained here are in agreement with those of Lux (2002) found that there was an 80% increase in the rate of retention when learners have been exposed to virtual laboratory throughout microbiology class. This could be explained as v-labs allow the learner to experience situations that are not in real life attainable. For instance, seeing an electron flow through wires or seeing the depletion layer in the p-n junction increase when the p-n junction is reverse biased and narrowing when it is forward biased can be easily shown in v-labs.

4.4.6 Trainers' perceptions on Influence of V-labs on Retention of content

For the question of how trainers rate the organization of the contents in virtual lab in aiding your trainees' learning and retention, the response was; A well thought and well-designed v-labs enhance the learning by the learners. V-labs have a configuration that is interactive which can attract and maintain the interest. The v-lab allowed the trainee to adjust conditions and variables and was able to learn. By repeating the experiments, the trainees gain better understanding not only of the procedure of performing the experiments but the content in the labs. By the fact that the v-lab has a non-depletable supply of components and equipment, the trainee can do and redo experiments without a limit that exists with the conventional laboratory. These results are in line with what was established by Connell et al. (2016) that inquiry-based mastering pedagogies are meant to shift from teacher-centeredness to learner-centeredness so that trainees are involved more in information construction, which will in turn lead to more content retention. The experiments can be done anywhere, any time and not necessarily requiring the teacher or trainer to be present like in the physical lab where the trainer/teacher must be there, arrange the materials early enough and be there to see that accidents or misuse of materials do not occur. By such a repetition the trainee can be more proficient and again can retain more content that is learnt.

Trainers felt that v-labs make trainees to easily remember content that has been taught in class because they were part of the acquisition of the information. That because of the visual and audio effects of the v-labs the trainee is engaged, creates and maintains interest in the content being learnt and subsequently remembers more of the content hence a higher retention of content is expected. This can lead to the trainees retaining more content and for longer period as compared to by using the conventional laboratory.

To how using v-labs improves trainees' learning skills, the trainees felt: By utilizing v-labs a trainee has a chance of interacting with a near real environment, from which to acquire information. By constructing information by himself or herself, the trainee learns better. They are made by trial and error to learn the system and how to gain information.

They also fail in a safe environment and they can repeat within a short time if they get results that are far off what they expect. There may be situations a trainee will wish to ask a question concerning what of if we try this and that, but has a fear of asking the trainer. The trainee can try out such activity on the v-lab by self and thus can get the answer(s) and satisfaction needed. This will improve the knowledge base of the trainee as well make one improve on how to acquire knowledge. This improves the learning skills of one. Hence a better score in the second post-test than their control group counterparts. These results agree with Lux (2002) who found that there was an 80% increase in the rate of retention when learners have been exposed to virtual laboratory throughout microbiology class. Kara (2008) posits that utilizing computer assisted instruction led to better the academic achievement and retention of students in science education. Again the setup of the virtual experiments is made to be pleasant. This makes the trainee to grasp more and retain more content compared to when the content is delivered using the conventional labs.

The v-labs are again in such a way that they reinforce the learner/trainee appropriately because the system does not get tired saying “well done”, “sorry try again”, “check again”. This is unlike the human teacher/trainer who may have emotions and the emotions may affect the reinforcement and therefore learning. They can again go to extents that they cannot attain with the real laboratories. This in agreement with what Dalgarno et al. (2009), found out in their study that the students can inquire about uninhibitedly inside a to a great extent within a given structure. However, to the question of whether trainees find in the v-lab experiments and on the trainees working on assignments off the class, the trainers reported that a number of trainees find the v-labs fun but if they are not well supervised they start doing their own searches in the internet. Thus they are derailed from the core business intended of the internet and the v-labs. Therefore, it may work better if the trainees do the lab while the trainer is present and supervising the lab work. Thus if not checked it can work negatively on the acquisition of content and the retention of content.

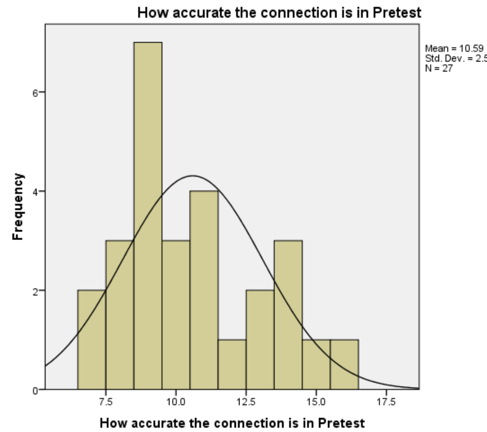
To how female trainees compared with male counterparts in retaining content as result of having used v-labs the trainers have a feeling that trainees of both gender have equal chances of retaining content although male may get it easier doing slightly better because the virtual environment is almost similar to the games they normally play. They further feel that for male trainees who sometimes play games in their mobile phones will do well equally as their male counterparts. By practising in the v-lab the trainees who play games on their mobile phones on other electronic gadgets are likely to do better. This could be the reason there is a slight difference between male and female trainees who were in the experimental group. The results matched with those of Kara (2008) who did not find out any sexual orientation distinction in retention of students trained with virtual laboratory methodology and computer-assisted instructional bundle with microbiology and science.

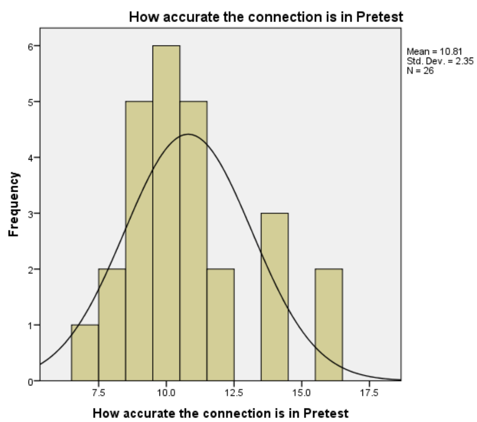
4.5 Virtual laboratories in Skills Training-Accuracy of Connection

Virtual laboratories normally use idealized data, the learners are not afforded the opportunity of collaborating and lack of tactile skills with the physical equipment (Hofstein & Lunetta, 2004). The third objective was to establish if there is a statistically significant difference in the accuracy of connecting physical circuit components and equipment between trainees who practiced in a virtual lab.

4.5.1 Descriptive Statistics on Connection Accuracy for Experimental and Control Group

Pretest. To check on the effect of type of laboratory in which a trainee practices on the accuracy of a trainee, a Pretest on similar circuit to the set circuit was carried out and the accuracy of the connection for trainees were obtained and a mean for these was calculated. To test whether the groups were different before the treatment a Pretest was carried out on the connection accuracy. Figure 4.7 displays the distributions for the pretest for experimental and control groups. The two distributions are almost similar which means that the participants of either the Experimental Group and the Control Group had almost similar chances of performing similarly if exposed to the same laboratory.





Experimental Group Control Group

Figure 4.7. Distributions of Connection Accuracy in Pretest across the Groups.

The scores for accuracies for the two groups in the Pretest is given in Table 4.20.

Table 4.20. Descriptive Statistics on Pretest Scores for Connection Accuracy

	Group	N	Minimum	Maximum	Mean	Std. Deviation	Std. Error Mean
Pretest - connection Accuracy	Experimental Group	27	7	16	10.59	2.500	.481
	Control Group	26	8	16	10.81	2.350	.461

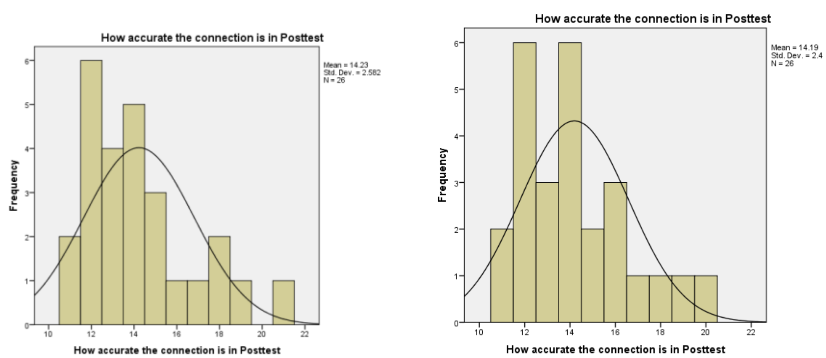
From Table 4.20 the trainees in the experimental group scored a mean of 10.59 with a standard deviation of 2.500. This was as the trainees in the control group had a mean score of 10.81, with a standard deviation of 2.350 from the mean score. The difference between the two scores is negligible and therefore implies that the trainees in the two groups were similar in circuit connection accuracy before the treatment was carried out. This means that the two groups are almost same at the start of the treatment.

The scores obtained after the treatment were processed. Table 4.21 shows the descriptive statistics of the post-test scores for accuracy of connection of a set circuit.

Table 4.21. Descriptive Statistics on Post-Test 1 Connection Accuracy by group

	Whether in experimental group or control group	N	Mean	Std. Deviation	Std. Error Mean
How accurate the connection is (Post-test)	Experimental Group	26	14.23	2.582	.506
	Control Group	26	14.19	2.400	.471

From Table 4.21 the twenty-six (N = 26) trainees in the experimental group scored a mean of 14.23 marks out of a possible 25 with a standard deviation of 2.582. A similar number (N = 26) of trainees in the control group who attempted the post-test 1 had a mean score of 14.19, with a standard deviation of 2.400. Therefore, the mean of the participants of the experimental group was slightly higher than their counterparts in the control group, which implies that the virtual laboratory treatment had a greater positive effect than that of the physical laboratory on the score in practical Physics examination, which is an indicator of attainment in accuracy of connection. Again the gain in score for the experimental group was 3.64 (that is 14.23 – 10.59) while that of the trainees in the control group was 3.38 (that is 14.19 – 10.81). This could be interpreted as virtual Physics laboratory giving a trainee a greater chance of improvement in connection accuracy than would the conventional Physics laboratory. After treatment the data gathered was use to plot the distributions of the marks. Figure 4.8 shows the distributions of Accuracy of Connection in Post-test across the Experimental and Control Groups.



Group 1 = Experimental Group   Group 2 = Control Group

Figure 4.8   Distributions Connection Accuracy in Post-test across the Groups.

The distributions seem to be almost similar. More statistical measures were used to test significance of any differences that there may have been.

4.5.2 T-test on Connection Accuracy for Experimental and Control Group

Null Hypothesis 3: There is no statistically significant difference in the mean score in accuracy of connecting physical circuit components and equipment between the v-lab and the non-v-lab trainees. The independent variable is the type of laboratory of the two groups and the dependent variable is the score out of 25 marks that a trainee attains in the practical test set circuit connection.

An independent T-test on the scores of post-test for accuracy of connection between experimental and the control groups was calculated. The test was utilized in deciding whether to accept or reject the fifth null hypothesis, H_{05}. That is, to determine whether there is a statistically significant difference between the mean score in post-test scores in accuracy of connection of circuit by Physics of the trainees exposed to the virtual Physics laboratory and those exposed to the physical Physics laboratory. Here the independent variable is the type of laboratory of the two groups and dependent variable is the score out of 25 marks that a trainee attains in the practical test set circuit connection.

Randomization was done by performing a t-test on the mean scores for pre-test to establish whether the trainees were similar in connection accuracy before treatment was conducted using a t-test on the Pretest results. The probability value is not statistically significant ($p = 0.105 > 0.05$), making the research to use 'Equal variances assumed' row. Table 4.22 shows the results of the independent T-test on the scores of pretest accuracy of connection between experimental and the control groups.

Table 4.22. T-Test Results on Accuracy of connection Pretest Scores by group

Independent T-Test		T	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Post-test Accuracy of Connection	Equal variances assumed	-.322	51	.748	-.215	.667

The result in table 4.22 shows the t-test value for the mean scores of 27 and 26 trainees assigned to experiment and control group. Their means and standard deviations were 10.59 and 2.50 for experimental and 10.81 and 2.35 for control group respectively. A two independent sample t-test was carried on the two sample means (experimental and control groups) and $t = -0.322$ with a p - value $= 0.748 > \alpha = 0.05$ with 51 degrees of freedom implying that there is not a statistically significant difference between experimental groups and control before the test (pretest). Based on the rule: If $p \leq \alpha$, then reject H_0, then in this analysis $p > .05$, so we fail to reject the null hypothesis, that there is no statistically significant difference between the mean score in pre-test scores in accuracy of connection of circuit by Physics of the v-lab trainees and the non-v-lab trainees. This means we accept the null hypothesis, that there is no statistically significant difference between the mean score in pre-test scores in accuracy of connection of circuit by Physics of the trainees exposed to the virtual Physics laboratory and those exposed to the physical Physics laboratory. This implies that there is no significant difference between the Pretest (accuracy of connection test) mean scores in Physics of the VPL and the CPL trainees. The trainees in the two groups can be treated to be practically the similar before the treatment occurs.

The probability value for the Levenes test is not statistically significant ($p = 0.765 > 0.05$), then the 'Equal variances assumed' row was utilized. Table 4.23 shows the results of the independent T-test on the scores of post-test 1 between experimental and the control groups.

From Table 4.23, assuming equal variances, the findings show that with 50 degrees of freedom t-test for the two groups in post-test 1 yielded a t = 0.056 with p - value = 0.956 > α = 0.05.

Table 4.23. T-Test Results on Connection Accuracy Post–Test 1 by group

Independent T-Test		T	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Post-test Accuracy of Connection	Equal variances assumed	.056	50	.956	.038	.691

Based on the rule: If $p \leq \alpha$, then reject H_0, then in this analysis $p > .05$, so we fail to reject H_{03}. This means we accept the null hypothesis, that there is no statistically significant difference between the mean score in post-test scores in accuracy of connection of circuit by Physics of the trainees exposed to the virtual Physics laboratory (14.23) and those exposed to the physical Physics laboratory (14.19). This implies that there is no significant difference between the Post-test (accuracy of connection test) mean scores in Physics of the VPL and the CPL trainees. This in plain language means that virtual lab trainees gain the same accuracy in connection of the physical circuits just as the non-virtual lab trainees gain the connection skills.

The research sought to establish if there is an effect of the v-labs on the accuracy of connection on the accuracy of connection brought by the utilization of the v-lab. To accomplish this, the Cohen's d for effect size was calculated. The trainees in the virtual-lab group scored a higher mean score in accuracy of connection than their non-virtual lab counterparts with a very small (negligible) effect size (Cohen's d = 0.02). The Cohen's d obtained here means that the result obtained in the post-test score in accuracy for the experimental group is 0.02 standard deviations from the mean of the control group. The results are supported by earlier works that while a number of studies highlight only their beneficial outcomes, research regarding the effectiveness of simulations for science learning is inconclusive (Sabah, 2011). Again to the findings that v-labs normally use idealized data, the learners are not afforded the opportunity of collaborating and lack of tactile skills with the physical equipment (Hofstein & Lunetta, 2004).

This led the research to conclude that the two laboratories have the same effect, so we cannot prefer one over another in terms of usage. They produce almost exactly the same learning effect, so we conclude that both are preferable to the same extent. An educational practitioner in Physics can use either to do instruction in the practicals. This is in agreement that there are worries about students getting tied up in figuring out how to associate with the PC simulator as opposed to investigating the topic (Frezzo, 2009). Again it has been pointed out by the critics that when external stimuli are oversimplified it may lead to students to developing an incorrect view of reality (Barnard, 1985). However, the findings are in contrast to the fact that now it has become a regulation, such as in Federal Aviation Administration, for pilot to adapt flight simulator in their training (Haslbeck et al., 2014). Additionally, Dalgarno et al.

(2009) affirm the fact that the real lab was more viable than the v-lab; real lab learners are seen to be scoring better than v-lab students. The results of the study propose that the learning that results from experimenting in the real lab is more effective than investigating the virtual lab, yet the distinction was somewhat little.

4.5.3 Trainees' perceptions on Trainees' connection Accuracy

The study sought the trainees' perceptions about the influence of the virtual laboratory on accuracy of connection of set circuit. The rating involved the following trainees' connection accuracy of a set electronic circuit. The responses were rated on a four point Likert scale where 1 = Agree; 2 = Tend to Agree; 3 = Tend to Disagree and 4 = Disagree. A mean score of 1.0 to 1.49 means strongly agree, that of 1.5 to 2.49 means tends to agree, that between 2.50 and 3.49 means tend to disagree and therefore will be treated as not agreeing while lastly 3.50 to 4.0 will be treated strongly disagreeing. Table 4.24 gives the summary of the findings.

To reduce a response set in the questions in the questionnaire the researcher had both positive and negative statements in the questionnaire. To the negative statement that V-lab has not helped to improve the trainees' accuracy in connecting physical circuits, the mean of 3.48, and standard deviation of .706 means that the trainees are strongly disagreeing with the statement and therefore they are saying that v-labs increase their accuracy of connection of the physical circuits.

They again feel that performing the experiments in virtual lab increases their confidence level (accuracy) in connecting actual circuits, with a mean of 1.31, and standard deviation of 0.736, it means that they perceive VPL as making them increase their confidence level in real life circuit connection after having practised similar ones in the virtual world.

Table 4.24. Trainees' perspectives on virtual lab and connection accuracy

Statement	Minimum	Maximum	Mean	Std. Dev.
Virtual Lab has not helped to improve my accuracy in connecting physical circuits	1	4	3.48	.706
Performing the experiment in virtual lab increases my confidence level (accuracy) in connecting actual circuits	1	4	1.31	.736
Using virtual lab in my learning enables me to accomplish physical lab tasks accurately	1	4	1.15	.368
Virtual lab makes me lazy so that whenever readings are required I get it a problem getting the accuracy needed with ease	1	4	1.23	.430
Sometimes it becomes challenging to connect real circuits as the virtual lab makes me lazy thus lowering my accuracy of connection	1	4	1.27	.452

'Using virtual lab in my learning enables trainees to accomplish physical lab tasks accurately', the trainees said. The average score of 1.15, on a scale of 1 to 4 and a standard deviation of 0.368 means that the trainees perceive VPL as an enabler in increasing their accuracy of connection. This agrees with the results from several studies; The virtual laboratory enhancements the theory with the aid of giving a dynamic feel of the idealized system (Strayer & Akpan, 2010). Phenomena besides the confusion and effects of noise can be evidently demonstrated by the simplification of the conceivable results (Gagne, 1962). Virtual laboratories have been touted for bearing novices the fail-safe module capacity errors (Duarte et al., 2008). Amateurs in skills training are more likely to make errors in their execution of assignments. In sensitive systems, for instance, PC networks, students are not given a real system to exercise and fail as it is being utilized by clients on the other end (Duarte et al., 2008).

However, the trainees have a strong feeling that virtual lab makes them lazy as they believe computer will give them whatever readings are required. This makes the trainees not to do well whenever readings are required I get it a problem getting the accuracy needed with ease. The mean of 1.23 and standard deviation of 0.430 means that the trainees strongly agree to the fact that whenever readings are required they find it an issue. The mean score of 1.27 with a standard deviation of 0.452 for the statement that sometimes it becomes challenging to connect real circuits as the virtual lab makes me lazy thus lowering my accuracy of connection implies that the trainees are made to become lazier in doing the actual hands-on by virtual labs as they find it more friendly doing the connections in v-labs. This could be explained by earlier studies such as Wolf (2010), who says some researchers have attested that students who get trained in virtual laboratories do not experience the commotion and obstruction that goes with actual measurement. Subsequently, they may incorrectly build up a mapping or model of the system that is unrealistic and their response to the real system might be inaccurate. Again, the dissections of a virtual frog have been previously compared with real life specimen in real laboratories; with these studies having mixed results; with some showing that real dissections are superior (Cross & Cross, 2004), while others (Akpan & Strayer, 2010) suggest otherwise.

4.5.4 Trainers' perceptions on Accuracy of Connection of Trainees

To the question how performing the experiments in virtual lab increase the trainees' confidence level (accuracy) for performing the same in real laboratory environment, the trainees had this to say: As for how performing experiments in the v-lab increase confidence (and therefore accuracy) of connecting the same circuits in the real laboratory the trainers said that it boosted the trainees' confidence, though because they are not doing it in real they may become lazy and not easily figure out the actual connections in the real. Transferring what has been learnt using the v-labs is not easily transferred to the real connection as the trainee has not been doing the real connection. This is so because in the trainees do it on computer system that tells them when the connection is not right or even blows out components indicating that there is an issue with the connection or the values of the components picked are not the right ones.

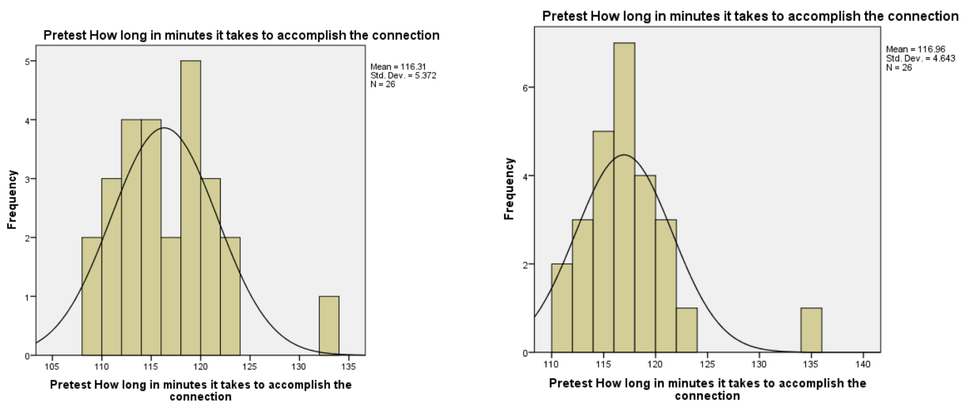
The trainers suggest that it is important that whatever has been done in the virtual laboratory be repeated by way of class experiment or a demonstration with the real equipment, unless the experiment in practically undoable or is associated with possible dangers to the users or is fragile or very toxic or very expensive and breakages may cause great losses. Again where they seem to agree is that the v-labs can be used when trainees are being introduced to a complex process or once a topic is over, the v-labs can be used for revision. This seems to be in agreement that more worries about students getting tied up in figuring out how to associate with the PC simulator as opposed to investigating the topic (Frezzo, 2009). Additionally, Dalgarno et al (2009) affirm the fact that the real lab was more viable than the v-lab; real lab learners are seen to be scoring better than v-lab students.

However, the results in contradiction with several other researches that look at it as to make the learning meaningful, there is need for a blend of both real and v-labs in science classes so as to enable learners acquire knowledge and the necessary practical skills required in real life tasks; this will help to easily transfer knowledge and skills from the v-lab simulations an idealized (virtual) environment into physical reality (Yu, Brown, & Billet, 2005). A number of studies propose that in engaging learners in which both labs are integrated, it will be beneficial to expose the learners to the v-labs before the real hands-on activities (Akpan & Strayer, 2010; Cobb et al., 2009).

4.6 Virtual laboratories in Skills Training-Speed of Connection

4.6.1 Descriptive Statistics on Connection speed Scores for Experimental and Control Group

The fourth objective of the study was to find out if there is a statistically significant difference in the mean time taken to connect physical circuit components and equipment between trainees who practiced in a virtual lab and trainees who did not practice in a virtual lab. Pretest. To check on the effect of type of laboratory in which a trainee practices a Pretest on similar circuits to the set circuit was carried out and the times for connection were obtained and a mean for these was calculated. The distributions of the times for the two groups in the Pretest is given in Figure 4.9. The two distributions are almost similar which means that the participants of either group had almost similar chances of performing similarly if exposed to the same laboratory.



Experimental Group Control Group

Figure 4.9. Distributions of Speed of Connection in Pretest across the Groups.

Table 4.25 shows the descriptive statistics for both the experimental group and the control group for the pre-treatment test scores for time taken (in minutes) to complete connecting a set electrical circuit.

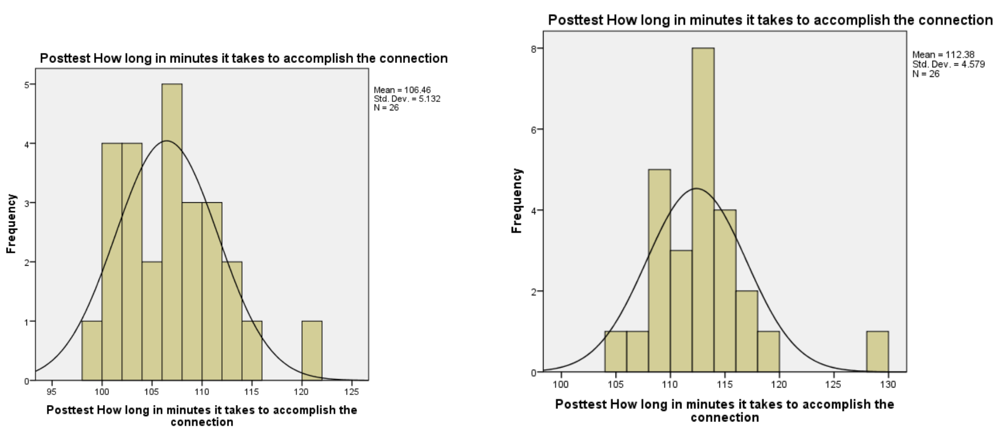
Table 4.25. Group Statistics for connection time Pretest Scores by group

	Whether in Experimental or Control Group	N	Mean	Std. Deviation	Std. Error Mean
How long in minutes it takes to accomplish the connection	Experimental Group	27	116.56	5.423	1.044
	Control Group	26	116.96	4.643	.911

The trainees in the experimental group a mean of 116.56 minutes as the time taken for connection of set circuit. This was accompanied with a standard deviation of 5.423. This was as the trainees in the control group had a mean score of 116.96, with a standard deviation of 4.643 from the mean time. On inspection the two times (scores) are more or less the same in terms of both the mean score and the standard deviations. The small difference between the means (of 0.40) implies that the trainees in the two groups were similar in terms of speed of connection (time taken to complete) a set electrical circuit before the treatment was carried out. This means that the two groups are almost same at the start of the treatment.

To get to see the effect the treatment had on the trainees, several statistics were involved and their results are presented in the following discussion.

Figure 4.10. shows the distributions of time of Connection in Post-test 1 across the Experimental and Control Groups.



Group 1 = Experimental Group Group 2 = Control Group

Figure 4.10. Distributions of time of Connection in Post-test across the Groups.

The distributions appear almost similar and they meet all the criteria for a t-test.

Table 4.26 shows the descriptive statistics for both the experimental group and the control group for the post-test 1 test scores that were obtained in the Post-test for time taken (in minutes) to complete connecting a set electrical circuit. The trainees in the experimental group a mean of 106.46 minutes as the time taken for connection of a set circuit. This was accompanied with a standard deviation of 5.132. This is a reduction of the time taken by 10.01 minutes. The mean time required by the participants in the Control Group reduced from 116.88 to 112.38, which translated to 4.5 minutes reduction in the mean time required for completing the connection of a set circuit.

Table 4.26. Group Statistics for connection time Post-test 1 Scores by group

	Whether in Experimental or Control Group	N	Mean	Std. Deviation	Std. Error Mean
How long in minutes it takes to accomplish the connection (Post-test 1)	Experimental Group	26	106.46	5.132	1.006
	Control Group	26	112.38	4.579	.898

From Table 4.26 there is a large difference between the two times for connection, between the post-test and the Pretest. This means that practice of connection skills improves the speed of connection. This is irrespective of whether the trainee is practicing on the virtual laboratory or the conventional Physics laboratory. Again there exist a notable difference (5.51 minutes) between the time of completing connection between the Experimental Group and the Control Group, with the drop in the times required to accomplish a set circuit favouring the participants in the Experimental

Group. The difference between the means implies that the trainees in the Experimental Group had a better chance of reducing the time of connection of a set circuit as compared to the Control Group at the post-test.

This means the Experimental Group trainees will develop a higher speed of connection. This could be attributed that as they keep practicing they can be able to practice severally without any fear of loss or damage of materials and equipment whereas the participants in the Control Group keep being careful so as not to cause damage to the components, equipment and the laboratory rooms and self for the participants themselves. Again once the circuit is well connected the computer software indicates whether the trainee is on the right track in the connection and sometimes suggests which way to go with the connection. This makes the trainees' work checked easily unlike in a case where one trainer has to move from one trainee to the next guiding him or her on how to go about given tasks.

4.6.2 T-test on Connection speed Scores for Experimental and Control Group

Null Hypothesis 4: There is no statistically significant difference in the mean times taken to connect physical circuit components and equipment between trainees who practiced in a virtual lab and trainees who did not practice in a virtual lab. Here the independent variable is the type of practice of either being in the experimental group or the control group while the dependent variable is the time in minutes taken by the trainee to accomplish the connection of the set circuit.

Randomization was done by conducting a t-test on pre-test on the mean times taken to connect real circuits for the 27 and 26 trainees assigned to experiment and control group respectively. Their means and standard deviations were 116.56 and 5.42 for experimental and 116.96 and 4.64 for control group respectively. To find out if the difference in the times required to accomplish the connection of set electrical circuits were statistically significant, there was need to perform a more accurate tests – the independent t – test. The probability value is not statistically significant ($p = 0.229 > 0.05$), then the 'Equal variances assumed' was utilized. Table 4.27 shows the results of the independent T-test on the scores of pretest for time required to accomplish connection of real circuits between experimental and the control groups.

A two independent sample t-test was carried on the two sample means (experimental and control groups) and $t = -0.470$ with a p - value $= 0.641 > \alpha = 0.05$, with degrees of freedom of 50 implying that there is not a statistically significant difference between experimental groups and control before the test (pretest).

Table 4.27. T - test for Time of Connection Pretest Scores by group

Independent T – test		T	DF	Sig. (2-tailed)	Mean Difference	Std. Error Difference
How long in minutes it takes to accomplish the connection (Pretest)	Equal variances not assumed	-.470	50	.641	-.654	1.393

Based on the rule: If $p \leq \alpha$, then reject H_0, then in this analysis $p > .05$, so we fail to reject H_{04}. This means we accept the null hypothesis, that there is no significant difference between the mean scores in the pretest speed (time taken in minutes) of connection of set electrical circuit between the trainees who were instructed in the virtual Physics laboratory and those instructed in the conventional Physics laboratory. This implies that there is no significant difference between the Pretest mean scores in accuracy in the connection of set circuit between the Experimental Group and the Control Group. In other words all the trainees can be assumed to be almost same at the time of the pretest, irrespective of the lab they practiced in.

The effect of the treatment was evaluated by utilizing a t-test for the post-test 1 scores. The probability value is not statistically significant ($p = 0.278 > 0.05$), then variances are 'Equal variances assumed' row. Table 4.28 shows the results of the independent T-test on the scores of post-test 1 time required to complete connection of real electrical circuits between experimental and the control groups.

Table 4.28. T - test for Time of Connection Post-test 1 Scores by group

Independent T - test		T	DF	Sig. (2-tailed)	Mean Difference	Std. Error Difference
How long in minutes it takes to accomplish the connection (Post-test)	Equal variances assumed	-4.391	50	.000	-5.923	1.349

From Table 4.28, assuming equal variances, the findings show that at 50 degrees of freedom, a t-test for the two groups in post-test 1 yielded a t = - 4.391 with p - value =

0.000. Based on the rule: If $p \leq \alpha$, then reject H_0, then in this analysis $p = 0.000 < .05$, so we reject H_{04}, there is no statistically significant difference between the mean score speed of connection (time needed for connection of circuit) between the trainees in the experimental group (106.46 minutes) and those in the control group (112.38 minutes). So we accept the alternative hypothesis, meaning that there was a significant difference between the mean scores in the post-test speed (time taken) of connection of set electrical circuit between the trainees who were instructed in the virtual Physics laboratory and those instructed in the conventional Physics laboratory, with the results favouring the virtual Physics laboratory group over the conventional Physics laboratory trainees. This implies that there is significant difference between the Post-test mean score in speed of connection of set circuit between the Experimental Group and the Control Group. In other words the v-lab trainees took a remarkably shorter time to complete the connection of a set electrical circuit than their counterparts in the conventional Physics laboratory.

To establish how strong the effect of the v-lab was on the speed of connect of the set circuit, the Cohen's d for effect size was calculated. It can be summarized as, the virtual-lab group scored higher in connection speed (shorter time taken) than the no-virtual-lab group and the difference was statistically significant. The calculated Cohen's $d = -1.22$. The Cohen's d obtained here is high means that the result obtained in the post-test 1 score of the experimental group is -1.22 standard deviations from the mean of the control group's score. The d here is having a negative value because the higher the speed of connection means that the time taken is lower than the time at the start of the experiment. Again all along the difference has been considered by taking the score of the control group from that of that experimental group, which in this is negative.

This result agrees with that of Lampi (2013) who established that the student who practiced in the virtual laboratory did reduced their troubleshooting time of the computer networks. Additionally, Pilot training, military equipment training, medical training and nuclear power plant training have relied on these simulators or v-labs as suggested in research (Gredler, 2004). This means that the speed of the participants of the experimental group increased a great deal, because they were able to connect the set circuit within a shorter time as compared to the participants who practiced in the real Physics laboratory. This led the study to conclude that the virtual Physics laboratory enhance the speed of connection of actual electrical and electronic components with the allied equipment in real hands-on. In other words it assists in transfer of skills. If asked to choose between the two laboratories, in which to engage learners if we wish to increase the speed of connection, the virtual lab will be preferred over the physical Physics laboratory. The results are supported by the fact that psychomotor skills, training medical and surgery training have already been accomplished in a few fields like medicine (Issenberg & Scalese, 2008). This is in agreement with the findings of Elliott et al. (2007) established that fire fighters can gain skills in decision making via v-labs as well as indicating modifications in factors such as accuracy, speed, efficiency and planning.

Virtual laboratories have been touted for bearing novices the fail-safe module capacity errors (Duarte et al., 2008). The potential to rapidly arrange, disconnect and reconfigure circuits supposedly is a component in improving mistakes made by the trainees and aiming towards perfection in skills gaining according to Mayer and Johnson, (2010). Simulators are applied for instance flight simulators, with some even making part of curricula, in for example, a flight school (United States Department of Transportation, Federal Aviation Administration, 2016).

4.6.3 Trainees' perceptions on Connection speed of trainees

The study sought the trainees' perceptions about the influence of the virtual laboratory on connection speed. The rating involved the following trainees' speed of connection of a set electronic circuit. Table 4.29 shows the trainees' perspectives on virtual lab and connection speed. The responses were rated on a four point Likert scale where 1 = Agree; 2 = Tend to Agree; 3 = Tend to Disagree and 4 = Disagree.

A mean score of 1.0 to 1.49 means strongly agree, that of 1.5 to 2.49 means tends to agree, that between 2.50 and 3.49 means tend to disagree and therefore will be treated as not agreeing while lastly 3.50 to 4.0 will be treated strongly disagreeing. Table 4.32 gives the summary of the findings.

The trainees felt that practising in the virtual lab helped them to figure out the physical circuit faster. This is as the mean of 3.58, with a standard deviation of 0.578 for the negative statement that v-labs did not help them become faster in figuring out how to connect physical circuits. This means that the trainees consider v-labs as assisting them become faster in figuring out and connecting the physical components and equipment due to the training they obtained through the VPL. This is in agreement with the findings of Lampi (2013) that v-labs improve speed of trainees in troubleshooting speed.

Table 4.29. Trainees' Perspectives on Virtual Lab and Connection Speed

Statement	Minimum	Maximum	Mean	Std. Dev.
Practising in the virtual lab does not help me become faster in figuring out how to connect physical circuits	1	4	3.58	.578
I get circuits in real life situations easy to interpret and connect after using the virtual lab- this increases my speed of connection	1	4	1.27	.452
I like the fact that I can try and practice several times using virtual labs, thereby increasing my speed of connection of real life circuits	1	4	1.23	.430
I get circuits easy to connect as I first try their workability before connecting actual components, increasing speed of connection	1	4	1.27	.453
Practising in the virtual lab does not help me become faster in figuring out how to connect physical circuits	1	4	3.27	.724

To the statement to whether the trainees get circuits in real life situations easy to interpret and connect after using the virtual lab and to whether this increases their speed of connection, the respondents affirmed it at a mean score of 1.27 with a standard deviation of 0.452. This means that they strongly agree that v-labs make them find the circuits easier to connect and this boosts their speed of connection. By doing and redoing – practicing several times using virtual labs, the speed of connection of real life circuits increases, the trainees reported. The mean was 1.23 with a standard deviation of

0.430, which implies strong agreement to the feeling that v-labs help them practice without any fear of loss of material, thereby making them feel more ready for the connections.

The trainees further felt that physical circuits become easy to connect as they first try the workability of the circuits before connecting actual components, increasing speed of connection. This is because they become confident that the connections would work out. The mean was 1.27, with a standard deviation of 0.453, which is strong agreement to the statement that v-labs makes trainees feel confident. Again the trainees disagree strongly (mean = 3.27, standard deviation, $\sigma = 0.724$) that practising in the virtual lab does not help trainees to become faster in figuring out how to connect physical circuits, means they strongly hold that v-labs assist them a lot in increasing the speed of connection. Again these many sentiments can be supported by the fact that in vocation and specialized instruction, learning is estimated by the achievement of key capabilities essential for the execution of work related assignments (Akpan & Strayer, 2010).

4.6.4 Trainers' perceptions on Connection speed of Trainees

To the question of what the trainers feel about the influence of the v-lab utilization on the rate at which your trainees accomplish the physical lab after having practiced in virtual lab, the trainers hold that the trainees improve their speed of connection greatly as a result of having practised in the virtual laboratory. This is in agreement to the statement it has now become a regulation, such as in Federal Aviation Administration, for pilot to adapt flight simulator in their training (Haslbeck et al., 2014). This could be because they figure it out how the connection should be like in the virtual lab situation and try it in their mind-map before they start connecting. Again they are encouraged to move fast as most virtual labs have a possibility of a timer to help the experimenter time himself or herself. This finding is in line with those of Mayer and Johnson, (2010) who argue that the potential to rapidly arrange, disconnect and reconfigure circuits supposedly is a component in improving mistakes made by the trainees and aiming towards perfection in skills gaining.

To the question of what the difficulties that trainees faced in the virtual laboratory, the trainers said: Some of the trainees were not good at the computer manipulations. To reduce this bringing about a negative effect, the trainers and the researcher were there hand offering help on how to maneuver, only and not doing the connection for the trainees. Some trainees, especially female were just seeing the virtual lab as a computer game and did not have full interest at the start but they adjusted very quickly and the experimentation went on well as planned. Sometimes differentiating the components was an issue to some trainees; especially the pin diode and Zener diode could not be differentiated by some trainees. The researcher and the research assistants (the trainers) were there handy to offer help to those trainees who needed it. Having all the required components fit the window space was an issue at the beginning but as time went on the trainees knew how to shrink the window so that all their work fits on the screen. This is in agreement with the earlier establishments that gaining skills to operate actual equipment depends on how accurate the feedback the virtual laboratory provides through fidelity of function (Jacobs, 1975). Taking readings on multi-scale instruments was also a great problem at the start. But it should also be noted here that this was also the case with the control group participants. Most likely this issue must have emanated from the fact that the trainers do not take enough time for the introduction of the functioning of digital multimeter (DMM), which they ought to do and do sufficiently. They ought to show their trainees the different functions of the DMM and how to change from one function to the other and how to read the multi-scale electrical instruments whether they are analogue or digital. Again there are times when serious misconceptions were caused, for instance in the half-wave rectification or the full-wave rectification, the peak is drastically lowered in the display as compared to real-life, one of the trainers observed that the fact was brought up by one of the trainees during one of the practical sessions. On the overall evaluation the trainees in the experimental group praised the v-lab intervention as a way of mitigating the issues of lack or inadequacy of equipment and materials for practical work in the Physics subject, safety in the laboratory for those experiments that require use of toxic substances or high voltage. That these experiments can be carried without any worry of money involved as they are cheap and for safety, they do not involve any physical harm. That as far as the virtual labs are concerned there is very little that the trainer does during the practical session unlike in the physical laboratory where the trainer needs to be there for the trainees in order that they either do not cause accidents or cause breakages or even sometimes do not go astray as far as the experimental procedure is concerned. To quote trainer M verbatim;

> *" in the v-lab the trainer is relieved of some duty, you do not need to prepare so much for laboratory work, so long as the computers are there and in working*

conditions and internet for those that are online there you are. Give the work to your trainees and things will work out themselves. You do not need to worry of preparing the materials and equipment, they are in the simulations. The v-labs are also good for revisions and sometimes they can be used when introducing a practical to be done as a class experiment, instead of demonstrating with real materials. They again reduce not only the load on the trainer, but the time taken for performing the experiments and that for grasping a concept. The time for cleaning up like in the conventional lab is not there, instead this can be used to learn more content or even practising the experiments. The virtual labs or simulations can again check a trainees work and reinforce, giving a more readily available feedback as compared with the conventional labs''.

That being the case, However, there is need for the trainers to prepare well in time, try out the simulations by themselves before they leave the trainees to try them out on their PCs. Again, some trainees stray off the core business of the v-lab experiments. They sometimes get surfing the net for social media connections. The trainers need to be around to see that the time that is dedicated to the practicals is well utilized if meaningful learning is to take place.

4.7 Percentage Transfer of Training

To gauge the amount of transfer of training, the difference between the mean score of the experimental group and that of the control group is obtained; divided by mean of control group and multiplied by 100%. Transfer of training is a measure of the extent to which training on the virtual equipment was transferred to the real equipment. The transfer of training measures the percentage improvement between the virtual-lab and the no-virtual-lab group. The transfer in accuracy of connection was calculated as 0.28% while that of connection speed came to 5.27%. These means that for purposes of practical skills training, the v-labs should be used just as an additional or complementary activity to the physical laboratory experiments. This was calculated by the difference in the post-test 1 score of the practical skills test between the virtual-lab and the no-virtual-lab group, divided by the no-virtual-lab group score, and all multiplied by 100. Table 4.30 gives the calculated transfer percentages. The transfer in accuracy of connection was calculated as 0.28% while that of connection speed came to 5.27%.

Table 4.30. Calculated Transfer Percentages

Variable	Virtual lab Group	Non-virtual Group	Percentage Transfer
Connection Accuracy	14.23	14.19	0.28
Connection Speed (Time in minutes)	106.46	112.38	5.27

The implication here is that virtual labs had a small or practically no impact on both the speed of connection and accuracy of connection on the practical skills test. So for purposes of practical skills training, the v-labs should be used just as an additional or complementary activity to the physical laboratory experiments.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents a summary of the findings, conclusions and recommendations.

5.2 Summary of Findings

The study aimed at establishing the influence of virtual Physics laboratory on TVET trainees' learning outcomes. These learning outcomes included; academic achievement, retention of content learnt, accuracy of connection of physical circuit components and equipment and lastly the speed of connection of real life equipment and components. The last two of the outcomes were looking at the transfer of electrical and electronic circuitry skills to real hands-on labs while the earlier ones were geared towards the acquisition of knowledge. The research aimed at determining whether utilization of v-labs in Physics made trainees at the TVET level of education in Kenya grasp the concepts more easily and retain more content. Again what the contribution of v-labs to the to the acquisition of practical skills needed in electrical and electronic circuitry were looked at. To measure skill transfer, the accuracy and speed with which the trainees were able to complete set electrical and electronic circuitry tasks were measured.

There is little literature on the influence of use of v-labs in TVET on learning outcomes at the tertiary level of education. Much literature that is available is in either the secondary segment of education or the university. Before any technology can be utilized, it is imperative to establish that it will obtain that which it claims to obtain. This is as far as issues of the use of v-labs for learning Physics influences; academic achievement by type of lab, retention of content and transfer of skills and its potential as a replacement or a complement for physical laboratory activities at the tertiary segment of education in Kenya. To do these, four null research hypotheses were formulated and tested in this study at significance alpha level of 0.05. The data from the trainees' questionnaire and the trainers' interview schedule were analyzed qualitatively under themes based on the objectives of the study.

The following is a summary of the findings, conclusions, recommendations from the study and recommendations for further study. It was found that there was no significant difference in connection accuracy across the experimental and control groups. On the other hand, the research established a significant difference in the in the academic achievement between the experimental and control group participants, retention between the experimental and control groups and again in the speed of connection of set electrical circuits between the experimental and control group. The group who utilized virtual labs had a higher academic achievement (score), and a higher retention rate than the control group. Again the experimental group took a significantly short time to accomplish connection of a set electrical circuit. There was no significant difference in the way male trainees who used v-labs to train learned Physics Physics Techniques.

For the first objective, the t-value was 2.019 at $p = 0.049$. The first null hypothesis was rejected since $p < .05$. Therefore, the mean score of 37.58 in the post-test 1 for the experimental group was statistically significantly higher than 34.38 by the control group trainees. The medium effect size medium (Cohen's $d = 0.56$) in the score of the experimental group is 0.56 standard deviations higher than that of the control group. Again the insights from the trainees' questionnaire and the trainers' interview confirms that virtual laboratories make trainees to understand the concepts better, assist them visualize abstract concepts, give immediate feedback, allow one to access situations that are not attainable and a safe to fail lab. The $t = 0.203$ at $p = 0.841$ implies that, for trainees in the virtual lab group, the mean score of 37.88 in the post-test 1 for the male trainees was not statistically significantly higher than 37.44 by the female trainees. The calculated Cohen's $d = 0.09$, implies that there is no difference between the mean scores by male trainees and female trainees. These led the research to conclude that the virtual Physics laboratory had the same effect on the trainees, irrespective of their gender. From trainees and trainers' insights v-labs do not favour either male or female trainees; v-labs afford female trainees the opportunity of practicing what is considered as 'male activities'. These results show no sexual orientation distinction in achievement of trainees.

For the second objective, $t = 2.308$, $p = 0.025$. The second null hypothesis was rejected since $p < .05$. Therefore, the mean score of 36.00 in the post-test 2 for the experimental group was statistically significantly higher than 32.62 by the control group trainees. The medium Cohen's $d = 0.64$, indicates that post-test 2 mean score of the experimental group is 0.64 standard deviations higher than the mean score of the control group. The virtual lab trainees' score is statistically significantly higher than the non-virtual lab trainees' mean score, meaning the v-lab trainees retain physics content better. From the trainees' and trainers' insights virtual labs allow the user to get experiences that are not attainable in the actual world; allow for experiments to be done without any fear of depletion and time for laboratories; reinforcement that does not favour any learner and 'non-tiring teacher' and that v-labs are good for revision.

The calculated $t = 0.509$ at $p = 0.615$ means that the mean score of 36.75 in the post-test 2 for the male trainees was not statistically significantly higher than the 35.67 by the female trainees both of whom were exposed to virtual Physics laboratory. A low Cohen's $d = 0.22$ means a small difference exists between the mean scores for male and female trainees. The mean score of male trainees and that of female trainees in post-test 2 do not differ significantly from one another. Insights by the trainees and the trainers indicated that v-labs do not favour either male or female trainees. These led the research to conclude that the virtual Physics laboratory had the same effect on the trainees' retention test score, irrespective of their gender.

For the third objective, $t = 0.056$; $p = 0.956$. The third null hypothesis was retained since $p > .05$. Therefore, the mean score of 14.23 out of a possible 25 in the post-test 1 for the trainees of the experimental group was not statistically significantly higher than 14.19 by the control group's trainees. The negligible Cohen's $d = 0.02$, so meaning there is no significant difference between the mean score of the virtual group and that of the non-virtual group in accuracy of connection test. The trainees' and trainers' insight bring out a perception that v-labs increase trainees' accuracy of connection of the physical circuits by making them confident because they practice enough and create mind maps. However, they make them lazy as they find it easy working with v-labs instead of real labs. These led the research to conclude that the virtual Physics laboratory had the same effect on the trainees' connection accuracy score, irrespective of their group of instruction.

For the fourth and final objective, $t = -4.391$ at $p = 0.000$. Since $p < .05$, so the fourth null hypothesis was rejected. Therefore there is a statistically significant difference between the mean score speed of connection (time needed for connection of circuit) between the trainees in the experimental group (106.46 minutes) and those in the control group (112.38 minutes). The high Cohen's $d = -1.22$, indicates that post-test mean time by the experimental group is -1.22 standard deviations lower than the mean time of connection for the control group. The virtual-lab group scored higher in connection speed (shorter time taken) than the no-virtual-lab group and the difference was statistically significant. The trainees and their trainers gave the research insight that the transfer of skills tool could not have obtained. The v-labs assist trainee in becoming faster because they can repeat experiment severally; workability of circuit can be tried virtually before real connection, thus increases the speed of connection. These results are in line with what was established by earlier researchers that v-labs improve speed of trainees in connection and troubleshooting because they possess the potential to rapidly arrange, disconnect and reconfigure circuits supposedly which is a component in improving mistakes made by the trainees and aiming towards perfection in skills gaining.

Additionally, trainers advise that for meaningful learning to take place, trainees need to be introduced to computer use well. The teacher/facilitator/trainer, need to look at each of the experiments or experiences that S/he needs to use before applying them in class and whenever there are any precautions arising from misconceptions that need to be taken, plan them in advance and explain them to the learners. A serious misconception sighted by the trainers was in the half-wave rectification or the full-wave rectification, where the peak is drastically lowered in the display as compared to real-life. There is need for enough working computers and sometimes with internet supply and a reliable supply of electricity which is a tall order for developing countries, especially in the Sub-Saharan Africa. Again, the v-labs should be applied by teachers as tools and not have them replace the teacher. They should also be applied in blended learning and not in isolation if meaningful learning is to take place. There were significant differences in the mean academic achievement score, mean retention score and connection speed favouring the virtual-lab group over the non-virtual group. These differences resulted in percent transfer gains of 0.28% and 5.27% respectively for accuracy of connection and speed of connection of set electrical circuit.

5.3 Conclusions

Based on the findings of the study the following conclusions can be made:

Use of virtual Physics laboratory produced superior results than those of conventional Physics laboratory in two learning outcomes while two learning outcomes were not positively influenced by the v-lab. From the various data analysis techniques, there was sufficient evidence to reject the null hypothesis, the v-lab trainees gained a great deal as far as academic achievement is concerned by the utilization of the virtual Physics labs in learning content in TVET Physics. This can again be obtained by the insight the trainees themselves shared through the questionnaire and the results from the trainers' interview. By comparison of the post-test 1 mean scores, the v-lab trainees scored higher than their non-v-lab trainees. However, the gender of a trainee using virtual Physics laboratory does not have a great influence on academic achievement in Physics. This means therefore that male trainees and female trainees acquire information to the same extent by using the virtual Physics laboratory. That given the same conditions female and male learn the same way.

Virtual Physics laboratory improved trainees' retention of content. The second null hypothesis was rejected and therefore the alternative hypothesis was adopted. This means therefore that the v-lab trainees had a significantly higher mean in the post-test 2 (retention test) than their counterparts in the control group. This implies that the v-lab trainees retained physics content better than their conventional Physics laboratory trainees who were taught the same content. This means therefore that male trainees and female trainees both of whom were treated with the v-lab retained the physics content learnt the same way. This implies that both male and female trainees retain physics content the same way.

Practicing connection of electrical circuit in virtual Physics laboratory did not increase connection accuracy in the real lab. The third null hypothesis was retained for the lack of sufficient evidence to make the research reject it. This means therefore that v-lab trainees and the non-v-lab trainees both had gained the same accuracy of connection of electrical circuits in the real laboratory. Hence, use of either the virtual lab or the real lab were found to bring about the same effect in as far as the accuracy of connection of electrical circuits is concerned. A small positive transfer ratio was recorded for transfer of accuracy for the v-lab trainees.

Practicing connection of electrical circuit in virtual Physics laboratory appreciably reduced time of connection of circuits in the real lab. The fourth and final null hypothesis was rejected and therefore the alternative hypothesis was adopted. This means therefore that the v-lab trainees took a significantly shorter time to accomplish the set electrical circuit as compared with their non-v-lab counterparts (in the control group). This implies that the v-lab trainees were able to interpret the set circuit faster and connect it.

Basing on these findings the utilization of virtual labs as a teaching tool in electrical and electronic circuitry is justified. The use of the v-labs is seen to have some contribution in the learning and practising skills, knowledge and attitudes. However, it is important for the trainers to know that the v-lab is a tool on whose wheels to have the content of Physics is to be delivered. How replicable the findings of this study are, using the methods used here is of very great importance. Virtual labs can be utilized to have the trainees practice before the real equipment are used. V-labs can be used in the developing countries, such as Kenya, to experience more experiments in electrical and electronic circuitry. This could make learners feel like they have constructed information by themselves. Since it is possible that the experiments can be done asynchronously, not requiring the teachers and the students be there physically and at the same time for the experiments to take place, the v-labs can be very useful in distance and open learning. Here the distance education students can be exposed to the virtual laboratory and later they can perform the real experiments at learning centres or the schools during face to face sessions, thus reducing the time and cost for onsite training. Again in situations like when it is not possible from the face to face instruction to take place, like the period when learners of all levels; pre-school to university were made to stay at home due to the Corona Virus Disease (COVID-19), the v-labs can become handy.

To reduce the lengths of trainings, especially for the on-job training or in crush programmes, v-labs can be used before introduction to the physical equipment can be handled. This will assist in transfer of training from the virtual to the real lab. In conclusion, the investment in the development and usage of virtual labs in the training of trainees in electrical and electronic circuitry or related areas is worthwhile provided it meets the pedagogical threshold of authenticity of learning.

5.4 Recommendations from the Study

In countries that are still developing such as the ones in the Sub-Saharan Africa, Kenya included, the shortage of equipment and materials for teaching and learning of electrical and electronic circuitry skills is acute. V-labs are touted as a possible solution to these issues. The recommendations that follow are made basing on the results, discussions and conclusions emanating from this study:

(i) TVET trainers should afford their trainees opportunities to engage in meaningful learning activities through the use of virtual Physics laboratory so as to promote constructivism in the trainees where learners are involved in coming up with conclusions based on information that they have gathered themselves, either as individuals or small groups.

(ii) There is need by the Ministry of Education, Science, Technology and Innovation through its Semi-Autonomous Government Agencies such as TIVETA, KICD, SEPU, CEMASTEA, KNEC, KISE, KESI, Universities and other stakeholders to organize workshops on the use of ICT, especially the virtual laboratories to enhance better learning by TVET trainees.

(iii) Teacher education programmes in Kenyan teacher training either pre-service or in-service training should be improved so as to prepare teachers who can infuse virtual laboratories, which in turn lead to effective training and learning.

(iv) The instructional designers, computer programmers, material developers should develop relevant virtual laboratories for use within the Kenyan TVET institutions. It is worthwhile to invest in the development and utilization of virtual labs in the education of trainees in the TVET segment in as far as the learning of electricity and electronics is concerned so long as they meet a given level of minimum levels of pedagogical fidelity. However, if care is not taken while the trainees are using them, negative transfer may occur because these labs may bring about erroneous habits in the trainees, leading to the labs bringing more harm than good.

(v) Given the fact that learners can work from any place and their own time, v-labs can be very helpful to trainees enrolled in Open and Distance Education and Learning (ODEL) to practice technical skills virtually and later during the face to face meetings with their lecturers they can do the same hands-on activities with real equipment, thus transferring the skills. This transfer will drastically reduce the on-site duration of training. This could assist the trainees in reducing cost of staying on-site or travelling and for those who are already working, time of being away from the workplace.

(vi) Because with v-labs there is no fear of depleting the learning materials such as electronic components, they can be utilized in promoting self-paced and self-directed learning by affording trainees the opportunity to explore electrical and electronic circuitry scenarios and possibilities in a safe to fail environment with no fear of spoiling equipment and components. Again they can fail in a safe environment where they cannot be involved in accidents that could be either electrical shock or even incidences of fire. Again it is possible for the trainees to try out different possibilities and designs of the experiments.

(vii) By practicing in virtual lab the time required in connecting the real circuits thereafter reduces. This agrees with the theory that v-labs gives trainees extra practice opportunities. This avails the trainees opportunities to try out different possibilities not possible with real labs. For example, a trainee can be able to see the direction and speed of flow of electrons which is not possible in the real lab setup. Other possibilities include; ‘touring’ the inside of a nuclear reactor, getting to a hot furnace or even getting a feel of deep space.

(viii) In TVET training and education the main objective is the acquisition of practical skills but often the equipment is either lacking or inadequate due to raising enrollment and financial limitations. Virtual labs have been proposed so as the narrow this gap. In the use of v-labs to train and assess proficiency of technical skills, it is a requirement that the v-labs are reliable and validly represent the real laboratory. A virtual lab can be used to gauge practical proficiency - transfer of skills between the virtual lab and the real lab if the virtual lab is well designed. Virtual labs can be used for practical skills assessment as long as they reliably and validly represent the real lab.

5.5 Recommendations for Further Research

Based on are based on the results, findings and conclusions of this study and limitations therein, the research puts forward the following recommendations for further study:

1. Researchers and educators should develop standardized pedagogical measurement instruments for use in evaluating the influence of particular virtual labs
2. Similar studies should be carried out in other topics in Physics TVET Physics. If this is done trainers and educators in TVET would have improved confidence in the instructional effectiveness of using virtual labs for teaching and training.
3. Longitudinal studies should be carried out to check the effectiveness of v-lab training on performance in the actual work.
4. A critical analysis needs to be done to look at which aspects of the v-lab that may lead the trainees or learners to conceptualization of ideas because of misrepresentation of ideas and how they may affect the physical job at hand.

5. More specific studies should be conducted in areas relating:

(a) negative effects of v-labs on academic achievement and retention of content

(b) effect of v-labs on trainees attitude towards a subject at the tertiary level of education

(c) effect of virtual labs on High, medium and low achievers in a subject

(d) a regressional study of the factors that affect academic achievement of TVET trainees when using virtual labs.

(e) models of design of virtual labs that may work best for TVET training.

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APPENDICIES

APPENDIX A: LETTER TO THE PRINCIPAL - KISII NATIONAL POLYTECHNIC

Omosa Elijah Mochama,

P.O. BOX 408-40200,

KISII.

2nd January 2020

THE PRINCIPAL,

THE KISII NATIONAL POLYTECHNIC

P.O.BOX 222-40200

KISII

Dear Sir/ Madam

REF: DATA COLLECTION FROM YOUR INSTITUTION

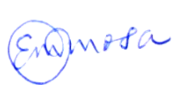
I am a Doctor of Philosophy in Education candidate at Kisii University. As part of my studies, I am required to carry out a research on the Influence of Virtual Laboratory on Selected Trainees' Learning Outcomes in Physics in Tertiary Education Kenya".

The purpose of this letter is to request you to allow me collect the required information from your institution between 4th January 2020 and 8th April 2020. In the process of collecting the data I will be required to work with lecturers from your institution who will do actual teaching and testing of trainees in the Science laboratories and the Computer Science laboratories. So I further request to be allowed to use the said laboratories. Consumables will be supplied by me, but equipment to be used will be your colleges. If allowed, I promise to abide by your rules. Attached are copies of my research abstract, questionnaires and a letter of authorization from the university.

All information collected will strictly be used for the purpose of this study. All the information will be kept confidential.

Thank you.

Yours faithfully,



Omosa Elijah Mochama

(Email: omosae@gmail.com, Tel. +254722346953)

APPENDIX B: LETTER TO PHYSICS TRAINER - THE KISII NATIONAL POLYTECHNIC

Omosa Elijah Mochama,

P.O. BOX 408-40200,

KISII.

2nd January 2020

THE SLT PHYSICS TRAINER,

THE KISII NATIONAL POLYTECHNIC

P.O.BOX 222-40200

KISII

Dear Sir/ Madam

REF: DATA COLLECTION FROM YOUR INSTITUTION

I am a Doctor of Philosophy in Education candidate at Kisii University. As part of my studies, I am required to carry out a research on the Influence of Virtual Laboratory on Selected Trainees' Learning Outcomes in Physics in Tertiary Education Kenya".

The purpose of this letter is to request you to allow me collect the required information from your institution between 4th January 2020 and 8th April 2020. In the process of collecting the data I will be required to work with lecturers from your institution who will do actual teaching and testing of trainees in the Science laboratories and the Computer Science laboratories. So I further request to be allowed to use the said laboratories. Consumables will be supplied by me, but equipment to be used will be your college's. If allowed, I promise to abide by your rules. Attached are copies of my research abstract, questionnaires and a letter of authorization from the university.

All information collected will strictly be used for the purpose of this study. All the information will be kept confidential.

Thank you.

Yours faithfully,

Omosa Elijah Mochama

(Email: omosae@gmail.com, Tel. +254722346953)

APPENDIX C: RESEARCHER'S LETTER TO RESPONDENTS

Omosa Elijah Mochama,

P.O. BOX 408-40200,

KISII.

2nd January 2020

Dear Participant,

I am a Doctor of Philosophy in Education candidate at Kisii University. As part of my studies, I am required to carry out a research on the "Influence of Virtual Laboratory on Selected Trainees' Learning Outcomes in Physics in Tertiary Education Kenya" between 4th January 2020 and 8th April 2020.

You are among the people that have been selected to participate in this study. You will be required sit an objective type of a test, then you will learn the topics electricity and electronics that are in your syllabus for six (6) weeks after which you will sit for an examination at the end of the two topics and another one four (4) weeks later. Your co-operation will again be sought in completing a questionnaire and will be highly appreciated.

All information collected will strictly be used for the purpose of this study. All the information will be kept confidential.

In advance, I thank you most sincerely for accepting to participate in this study.

Yours sincerely,

Omosa Elijah Mochama.

(Email: omosae@gmail.com, Tel. +254722346953)

APPENDIX D: PHYSICS ACHIEVEMENT TEST 1 (PAT 1)

SECTION A

1. Instructions

(i) Choose the most appropriate alternative from the options A to D given for each item.

(iii) Shade **only one** answer for each question.

(iv) Attempt all the questions

Time allowed: 80 minutes

2. Bio-Data

Male ☐ **Female** ☐

CLASS: …………… **DATE:** ………………

SECTION B

1. What is the rate of flow of electric charges called?
(A) Electric potential
(B) electric conductance
(C) Electric current
(D) none of these

2. Which of the following is the SI Unit of Electric Current?
(A) ohm (B) ampere
(C) volt (D) faraday

3. Which instrument is used for measuring electric potential?
(A) Ammeter (B) galvanometer
(C) voltmeter (D) potentiometer

4. When one unit electric charge moves from one point to another point in an electric circuit, then the amount of work done in joules is known as?
(A) Electric current (B) electric resistance
(C) electric conductance (D) potential difference

5. The hindrance presented by material of conductor to the smooth passing of electric current is known as:
(A) Resistance (B) Conductance
(C) Inductance (D) None of these

6. The resistance of a conductor is directly proportional to:
(A) Its area of cross-section (B) density
(C) melting point (D) length

7. The purpose of a rheostat is:
(A) Increase the magnitude of current only
(B) Decrease the magnitude of current only
(C) Increase or decrease the magnitude of current
(D) None of these

8. Point to be kept in mind for verification of Ohm's Law is:
(A) Ammeter and voltmeter should be connected in series
(B) Ammeter should be connected in series and voltmeter in parallel
(C) Ammeter should be connected in parallel and voltmeter in series
(D) Ammeter and voltmeter should be connected in parallel

9. When a 40V battery is connected across an unknown resistor there is a current of 100 mA in the circuit. Find the value of the resistance of the resister:
(A) 5000 Ω (B) 800 Ω
(C) 0.8 Ω (D) none of these

10. A battery of 6V is connected in series with resisters of 0.1 ohm, 0.15 ohm,0.2 ohm,0.25 ohm and 6 ohm. How much current would flow through the 0.3-ohm resistor?
(A) 0.895A (B) 2.22A
(C) 1A (D) none of these

11. A fuse wire is inserted in a?
(A) Live wire
(B) In the neutral wire
(C) In the earth wire
(D) May be connected in any line.

12. Under normal conditions a diode conducts current when it is ……………
(A) reverse biased (B) forward biased
(C) avalanched (D) saturated

13. The term bias in electronics usually means…
(A) the value of ac voltage in the signal.
(B) the condition of current through a p-n junction.
(C) the value of dc voltages for the device to operate properly.
(D) the status of the diode.

14. A good conductor material:
(A) may be made of copper
(B) may be made of plastic
(C) has no free electrons
(D) has lots of free electrons.

15. In a parallel circuit
(A) $R_T = R_1 + R_2$
(B) the current is ' common ' to all resistors
(C) the voltage is ' common ' to all resistors
(D) $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$.

16. In a series circuit
(A) $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$.
(B) the current is ' common ' to all resistors
(C) the voltage is ' common ' to all resistors
(D) $R_T = R_1 + R_2$.

17. The current taken by a 10Ω resistor when connected to a 220 V supply will be:
(A) 2.2A (B) 10A
(C) 22A (D) 220A.

18. The resistance of a kettle element which takes 24A from a 230V main supply is:
(A) 1.44 Ω (B) 2.500 Ω
(C) 6.12 Ω (D) 9.595 Ω.

19. A 24 ohm filament lamp was found to be taking a current of 2 A at full brilliance. The voltage across the lamp under these conditions is:
(A) 12 V (B) 24 V
(C) 48 V (D) 96 V.

20. Resistors of 20 Ω, 40 Ω and 60 Ω are connected in series. The total resistance value will be:
(A) 10.9 Ω (B) 20.0 Ω
(C) 60.6 Ω (D) 120 Ω.

21. Resistors of 20 Ω, 40 Ω and 60 Ω are connected in parallel. The total resistance value will be:
(A) 10.9 Ω (B) 20.0 Ω
(C) 60.0 Ω (D) 120 Ω.

22. Two identical resistors are connected in series across a 24 V battery. The voltage drop across each resistor will be:
(A) 2 V (B) 6 V
(C) 12 V (D) 24 V.

23. The most commonly used semiconductor is……
(A) germanium (B) silicon
(C) carbon (D) sulphur

24. A semiconductor has generally .... valence electrons.
(A) 2 (B) 3
(C) 6 (D) 4

25. The resistivity of pure silicon is about ...
(A) 100 Ω cm (B) 6000 Ω cm
(C) 3 × 105 Ω cm (D) 1.6×10^{-8} Ω cm

26. When a pure semiconductor is heated, its resistance…
(A) goes up (B) goes down
(C) remains the same (D) cannot say

27. Figure 1 shows three resistors connected to a battery.

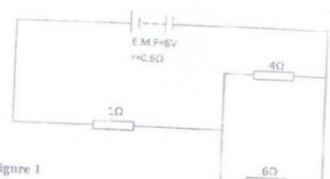


Figure 1

What current flows though the 4 Ω resistor?

(A) 1.2 A (B) 0.83A
(C) 6.0A (D) 2.5A

28. When a pure semiconductor is doped with trivalent element, it becomes ....
(A) p-type semiconductor
(B) an insulator
(C) n-type semiconductor
(D) an intrinsic semiconductor

29. An electric heater operated from the 240V a.c. main supply is rated at 1200 watts. The current through it is…
(A) 0.2A (B) 5.0 A
(C) 0.5A (D) 2.0A

30. A cell of an e.m.f 1.5V and an internal resistance of 0.5Ω is connected three resistors of 2Ω, 3Ω and 4Ω in series. The current flowing through the cell is........
(A) 0.16A (B) 1.6A
(C) 6.6A (D) none of the above

31. The reason for the difference between the total external potential difference and the e.m.f of the cell is....
(A) the cell is a poor conductor
(B) internal resistance
(C) no proper connection
(D) none of the above

32. All the following are advantages of solid state transistor over the triode EXCEPT one. Which one is not?........
(A) 3.5 V (B) 3V
(C) zero (D) 0.3 V

33. When a p-n junction is in forward bias it has ....
(A) minimal resistance (B) almost no current
(C) large current flow (D) very narrow depletion layer

Figure 2 Shows three resistors connected to a 12 V battery. Use it to answer questions 34, 35 and 36.

Fig. 2

34. Calculate the voltmeter reading in the circuit diagram shown in figure 2........
(A) 0.5A (B) 72.0A
(C) 2.0A (D) 0.2A

35. What is the value through the 3 ohm resistor?......

(A) 0.67A (B) 1.33A

(C) 1.0A (D) 2.0A

36. What is the effective resistance in the circuit?.....

(A) 13.0 Ω (B) 1.33 Ω

(C) 10.0 Ω (D) 9.23 Ω

37. What is the combined capacitance of two capacitors in parallel each of capacitance 4μF in series with single 0.5μF capacitor.

(A) 2.0μF (B) 0.34μF

(C) 0.44μF (D) 8.0μF

38. What value of a single capacitor can be connected in place two capacitors in parallel each of capacitance 4μF in series with single 0.5μF capacitor?

(A) 8.0μF (B) 2.0μF

(C) 0.34μF (D) 0.44μF

40. Which one of the following factors DOES NOT affect the resistance of a resistance wire?

(A) colour (B) length

(C) diameter (D) material it is made of

40. Which one of the following is NOT an advantages of an alkaline cell over a lead acid cell?

(A) Alkaline cell last longer than lead acid cell

(B) Alkaline cell is more rugged than lead acid cell

(C) Alkaline cell is readily available than lead acid cell

(C) Alkaline cell is lighter than lead acid cell

41. What quantity of charge passes a given point when a current of 0.5A flows in a circuit for 4 minutes?

(A) 2 C (B) 20 C

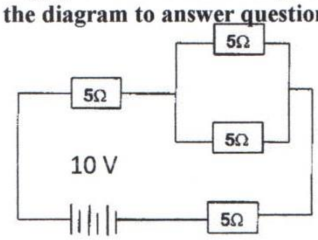
(C) 120 C (D) 8 C

42. A charge of 2 C passes in circuit for 25 minutes. How much current flows through a point in the circuit?

(A) 0.8 A (B) 8.0 A

(C) 0.008A (D) 0.08A

Four 5Ω resistors are connected to a 10V d. c. supply as shown in the diagram in Figure 3. Use the diagram to answer questions 43 and 44.



43. What current flows through the 10 V battery?

(A) 0.08A (B) 0.8A

(C) 8.0A (D) 0.08A

44. What is the effective resistance in the circuit?

(A) 1.25Ω (B) 12.5Ω

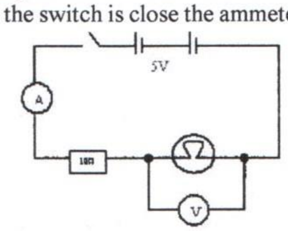
(C) 0.125Ω (D) 125Ω

45. A 6Ω resistor has a length of 1m and cross-sectional area of $5.0 \times 10^{-5} m^2$. What is the resistivity of the material?

(A) $3.0 \times 10^{-6}\Omega m$ (B) $3.0 \times 10^{-4}\Omega m$

(C) $3.0 \times 10^{-3}\Omega m$ (D) $3.0 \times 10^{-7}\Omega m$

46. The diagram below shows an electric circuit. When the switch is close the ammeter reading is 0.3A



What will the voltmeter reading be?

(A) 0.2 V (B) 2.0 V

(C) 0.02 V (D) 0.12 V

47. Which one of the following is not a factor that Ohms law depends on?

(A) Temperature (B) Pressure

(C) Colour (D) Kinks

48. In our electronic gadgets there is a need of transformer for ......

(A) stepping up voltage

(B) stepping down voltage

(C) maintaining voltage at a constant value

(D) none of the above

49. For the same secondary voltage, the output voltage from a centre-tap rectifier is .... than that of bridge rectifier.

(A) twice (B) thrice

(C) four times (D) one-half

50. A half-wave rectifier has an input voltage of 240 $V_{r.m.s.}$ If the step-down transformer has a turns ratio of 20:1, what is the peak load voltage? **(Ignore diode drop).**

(A) 27.5 V (B) 86.5 V

(C) 12 V (D) 42.5 V

APPENDIX E: PHYSICS ACHIEVEMENT TEST 2 (PAT 2)

SECTION A

1. Introduction

The purpose of this question paper is to collect information which will be used in a research study to improve the teaching and learning of Physics at tertiary level. Any information you give is, therefore, strictly for academic purpose and will be treated confidentially. Your name is **NOT** required.

2. Instructions

(i) Please read the questions or statements very carefully and respond appropriately.
(ii) Choose the most appropriate alternative from the options A to D given for each item.
(iii) Shade only one answer for each question.
(iv) Attempt all the questions
(v) Respondents are free to ask questions on any of the items that need clarification.
(vi) Erase any incorrect answer properly before choosing another option
(viii) Use pencil only.
(ix) **Time allowed:** 80 minutes

3. Bio-Data

Male ☐ **Female** ☐

CLASS: ……………………………………..

DATE: ……………………………………….

SECTION B

MULTIPLE CHOICE OBJECTIVE TEST

1. A good insulator material:

(A) has lots of free electrons
(B) has no free electrons
(C) may be made of copper
(D) may be made of plastic.

2. In a series circuit

(A) the current is ‘ common ’ to all resistors
(B) the voltage is ‘ common ’ to all resistors
(C) $R_T = R_1 + R_2$
(D) $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$.

3. In a parallel circuit
(A) the current is ‘ common ’ to all resistors
(B) the voltage is ‘ common ’ to all resistors
(C) $R_T = R_1 + R_2$
(D) $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$.

4. The current taken by a 10Ω resistor when connected to a 230 V supply will be:
(A) 2.3A
(B) 10A
(C) 23A
(D) 230A.

5. The resistance of a kettle element which takes 12A from a 230V main supply is:
(A) 2.88 Ω
(B) 5.00 Ω
(C) 12.24 Ω
(D) 19.16 Ω.

6. A 12 ohm filament lamp was found to be taking a current of 2 A at full brilliance. The voltage across the lamp under these conditions is:
(A) 6 V
(B) 12 V
(C) 24 V
(D) 48 V.

7. Resistors of 6 Ω and 3 Ω are connected in parallel. The combined resistance value will be:
(A) 2.0 Ω
(B) 3.6 Ω
(C) 6.3 Ω
(D) 9.0 Ω.

8. Resistors of 20 Ω, 40 Ω and 60 Ω are connected in series. The total resistance value will be:
(A) 10.9 Ω
(B) 20.0 Ω
(C) 60.6 Ω
(D) 120 Ω.

9. Resistors of 20 Ω, 40 Ω and 60 Ω are connected in parallel. The total resistance value will be:
(A) 10.9 Ω
(B) 20.0 Ω
(C) 60.0 Ω
(D) 120 Ω.

10. Two identical resistors are connected in series across a 24 V battery. The voltage drop across each resistor will be:
(A) 2 V
(B) 6 V
(C) 12 V
(D) 24 V.

11. The most commonly used semiconductor is…………………………
(A) germanium
(B) silicon
(C) carbon
(D) sulphur

12. A semiconductor has generally .... valence electrons.
(A) 2
(B) 3
(C) 6
(D) 4

13. The resistivity of pure silicon is about ...
(A) 100 Ω cm
(B) 6000 Ω cm
(C) 3 × 105 Ω cm
(D) 1.6×10^{-8} Ω cm

14. When a pure semiconductor is heated, its resistance ....
(A) goes up
(B) goes down
(C) remains the same
(D) cannot say

15. When a pentavalent impurity is added to a pure semiconductor, it becomes ....
(A) an insulator
(B) an intrinsic semiconductor
(C) p-type semiconductor
(D) n-type semiconductor

16. As the doping to a pure semiconductor increases, the bulk resistance of the semiconductor ....
(A) remains the same
(B) increases
(C) decreases
(D) none of the above

17. In a semiconductor, current conduction is due ....
(A) only to holes
(B) only to free electrons
(C) to holes and free electrons
(D) none of the above

18. The battery connections required to forward bias a p-n junction are ....
(A) +ve terminal to p and −ve terminal to n
(B) −ve terminal to p and +ve terminal to n
(C) −ve terminal to p and −ve terminal to n
(D) none of the above

19. The barrier voltage at a p-n junction for germanium is about ....
(A) 3.5 V
(B) 3V
(C) zero
(D) 0.3 V

20. A reverse biased p-n junction has ....
(A) very narrow depletion layer
(B) almost no current
(C) very low resistance
(D) large current flow

21. A reverse biased p-n junction has resistance of the........
(A) order of Ω
(B) order of kΩ
(C) order of MΩ
(D) none of the above

22. The leakage current across a p-n junction is due to ....
(A) minority carriers
(B) majority carriers
(C) junction capacitance
(D) none of the above

23. When the temperature of an extrinsic semiconductor is increased, the pronounced effect is on ....
(A) junction capacitance
(B) minority carriers
(C) majority carriers
(D) none of the above

24. The leakage current in a p-n junction is of the order of ....
(A) A
(B) mA
(C) kA
(D) μA

25. A zener diode is used as ....
(A) an amplifier
(B) a voltage regulator
(C) a rectifier
(D) a multivibrator

26. A zener diode utilises .... characteristic for its operation.
(A) forward
(B) reverse
(C) both forward and reverse
(D) none of the above

27. In the breakdown region, a zener diode behaves like A......... source.
(A) constant voltage
(B) constant current
(C) constant resistance
(D) none of the above

28. A zener diode is destroyed if it ....
(A) is forward biased
(B) is reverse biased
(C) carries more than rated current
(D) none of the above

29. A zener diode is .... device.
(A) a non-linear
(B) a linear
(C) an amplifying
(D) none of the above

30. Mains a.c. power is converted into d.c. power for ....
(A) lighting purposes
(B) heaters
(C) using in electronic equipment
(D) none of the above

31. The function of a capacitor in the rectifier circuit is........
(A) act as a current limiting device
(B) smoothing
(C) lighting a circuit
(D) none of the above

32. The disadvantage of a half-wave rectifier is that the ....
(A) components are expensive
(B) diodes must have a higher power rating
(C) output is difficult to filter
(D) none of the above

33. There is a need of transformer for ....
(A) half-wave rectifier
(B) centre-tap full-wave rectifier
(C) bridge full-wave rectifier
(D) none of the above

34. For the same secondary voltage, the output voltage from a centre-tap rectifier is .... than that of bridge rectifier.
(A) twice
(B) thrice
(C) four times
(D) one-half

35. A half-wave rectifier has an input voltage of 240 $V_{r.m.s.}$ If the step-down transformer has a turns ratio of 8:1, what is the peak load voltage ? **(Ignore diode drop).**
(A) 27.5 V
(B) 86.5 V
(C) 30 V
(D) 42.5 V

36. The most widely used rectifier is ....
(A) half-wave rectifier
(B) centre-tap full-wave rectifier
(C) bridge full-wave rectifier
(D) none of the above

37. In a properly-biased NPN transistor, most of the electrons from the emitter
(A) recombine with holes in the base
(B) recombine in the emitter itself
(C) pass through the base to the collector
(D) are stopped by the junction barrier.

38. The following relationships between α and β are correct EXCEPT

(A) $\beta = \frac{\alpha}{1-\alpha}$ (B) $\alpha = \frac{\beta}{1-\beta}$

(C) $\alpha = \frac{\beta}{1+\beta}$ (D) $1-\alpha = \frac{\alpha}{1+\beta}$

39. The value of total collector current in a circuit is
(A) $I_C = \alpha I_E$
(B) $I_C = \alpha I_E + I_{CO}$
(C) $I_C = \alpha I_E - I_{CO}$
(D) $I_C = \alpha I_E$.

40. The EBJ of a given transistor is forward-biased and its CBJ reverse-biased. If the base current is increased, then its
(A) I_C will decrease
(B) V_{CE} will increase
(C) I_C will increase
(D) V_{CC} will increase.

41. The collector characteristics of a CE connected transistor may be used to find its
(A) input resistance
(B) base current
(C) output resistance
(D) voltage gain.

42. Which of the following approximations is often used in electronic circuits?
(A) $I_C \approx I_E$ (B) $I_B \approx I_C$
(C) $I_B \approx I_E$ (D) $I_E \approx I_B + I_C$

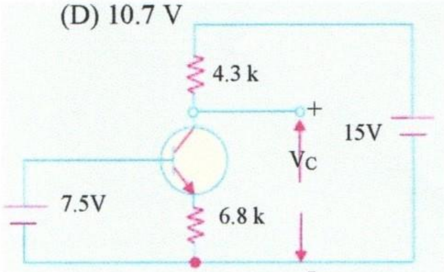
43. If, in a bipolar junction transistor, I_B = 100 μA and I_C = 10 mA, in what range does the value of its beta lie?
(A) 0.1 to 1.0
(B) 1.01 to 10
(C) 10.1 to 100
(D) 100.1 to 1000.

44. In a properly-connected BJT, an increase in base current causes increase in
(A) I_C only (B) I_E only
(C) both I_C and I_E (D) leakage current.

45. When a BJT operates in cut-off
(A) $V_{CE} = 0$
(B) $V_{CE} = V_{CC}$
(C) V_{CE} has negative value
(D) I_C is maximum.

46. When a BJT is in saturation
(A) $I_C = 0$
(B) I_B controls I_C
(C) $V_{CE} = 0$
(D) V_{CE} has positive value.

47. The best approximation for V_C in the circuit shown in Fig. 1 will be (assume β to be high)
(A) 4 V
(B) 6.8 V
(C) 8.7 V
(D) 10.7 V



48. Assume V_{BE} = 0.7 V and β = 50 for the transistor in the circuit shown in Fig. 2. For V_{CE} = 2V, the value of R_B is

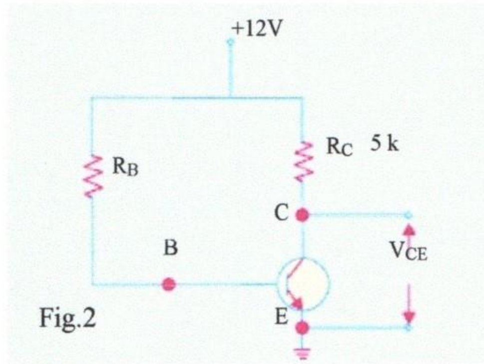


Fig.2

(A) 200 Ω
(C) 283 Ω
(B) 242 Ω
(D) 300 Ω

49. In the circuit shown in Fig. 3, if $R_L = R_C$ = 5KΩ, then the value of V_0 will be

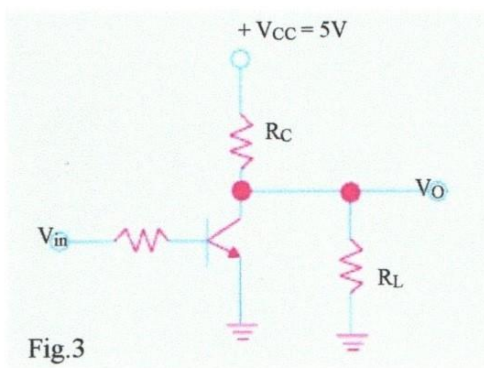


Fig.3

(A) 4.55 V
(B) 2.5 V
(C) 1 V
(D) zero

50. A silicon transistor is biased with base resistor method. If β = 100, V_{BE} = 0.7 V, zero signal collector current I_C = 1 mA and V_{CC} = 6 V, what is the value of base resistor R_B?
(A) 105 kΩ
(B) 530 kΩ
(C) 315 kΩ
(D) none of the above

APPENDIX F: PHYSICS ACHIEVEMENT TEST 3 (PAT 3)

SECTION A

1. Introduction

The purpose of this question paper is to collect information which will be used in a research study to improve the teaching and learning of Physics at tertiary level. Any information you give is, therefore, strictly for academic purpose and will be treated confidentially. Your name is **NOT** required.

2. Instructions

(i) Please read the questions or statements very carefully and respond appropriately.
(ii) Choose the most appropriate alternative from the options A to D given for each item.
(iii) Shade only one answer for each question.
(iv) Attempt all the questions
(v) Respondents are free to ask questions on any of the items that need clarification.
(vi) Erase any incorrect answer properly before choosing another option
(viii) Use pencil only.
(ix) **Time allowed:** 80 minutes

3. Bio-Data

Male ☐ **Female** ☐

CLASS: ....

DATE: ....

SECTION B

MULTIPLE CHOICE OBJECTIVE TEST

1. What is the rate of flow of electric charges called?
(A) Electric potential
(B) electric conductance
(C) Electric current
(D) none of these

2. Which of the following is the SI Unit of Electric Current?
(A) ohm
(B) ampere
(C) volt
(D) faraday

3. Which instrument is used for measuring electric potential?
(A) Ammeter
(B) galvanometer
(C) voltmeter
(D) potentiometer

4. When one unit electric charge moves from one point to another point in an electric circuit, then the amount of work done in joules is known as?
(A) Electric current
(B) electric resistance
(C) electric conductance
(D) potential difference

5. The hindrance presented by material of conductor to the smooth passing of electric current is known as:
(A) Resistance
(B) Conductance
(C) Inductance
(D) None of these

6. The resistance of a conductor is directly proportional to:
(A) Its area of cross-section
(B) density
(C) melting point
(D) length

7. The purpose of a rheostat is:
(A) Increase the magnitude of current only
(B) Decrease the magnitude of current only
(C) Increase or decrease the magnitude of current
(D) None of these

8. Point to be kept in mind for verification of Ohm's Law is:
(A) Ammeter and voltmeter should be connected in series
(B) Ammeter should be connected in series and voltmeter in parallel
(C) Ammeter should be connected in parallel and voltmeter in series
(D) Ammeter and voltmeter should be connected in parallel

9. When a 40V battery is connected across an unknown resistor there is a current of 100 mA in the circuit. Find the value of the resistance of the resister:
(A) 5000 Ω
(B) 800 Ω
(C) 0.8 Ω
(D) none of these

10. A battery of 6V is connected in series with resisters of 0.1 ohm, 0.15 ohm,0.2 ohm,0.25 ohm and 6 ohm. How much current would flow through the 0.3-ohm resistor?
(A) 0.895A
(B) 2.22A
(C) 1A
(D) none of these

11. A length is of 240m and cross-sectional area of 5.0 x $10^{-5}m^2$. What is the its resistance if its resistivity is 3.0 x $10^{-6}\Omega m$?

(A) 1.44Ω

(B) 144.0Ω

(C) 14.4Ω

(D) 0.144Ω

12. Under normal conditions a diode conducts current when it is ……………

(A) reverse biased
(B) forward biased
(C) avalanched
(D) saturated

13. The term bias in electronics usually means ……….

(A) the value of ac voltage in the signal.
(B) the condition of current through a p-n junction.
(C) the value of dc voltages for the device to operate properly.
(D) the status of the diode.

14. A good conductor material:

(A) may be made of copper
(B) may be made of plastic
(C) has no free electrons
(D) has lots of free electrons.

15. In a parallel circuit

(A) $R_T = R_1 + R_2$
(B) the current is ' common ' to all resistors
(C) the voltage is ' common ' to all resistors
(D) $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$.

16. In a series circuit

(A) $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$.
(B) the current is ' common ' to all resistors
(C) the voltage is ' common ' to all resistors
(D) $R_T = R_1 + R_2$.

17. The current taken by a 10Ω resistor when connected to a 220 V supply will be:

(A) 2.2A
(B) 10A
(C) 22A
(D) 220A.

18. The resistance of a kettle element which takes 24A from a 230V main supply is:

(A) 1.44 Ω
(B) 2.500 Ω
(C) 6.12 Ω
(D) 9.595 Ω.

19. A 24 ohm filament lamp was found to be taking a current of 2 A at full brilliance. The voltage across the lamp under these conditions is:

(A) 12 V
(B) 24 V
(C) 48 V
(D) 96 V.

Four 5Ω resistors are connected to a 10V d. c. supply as shown in the diagram in Figure 1. Use the diagram to answer questions 20 and 21.

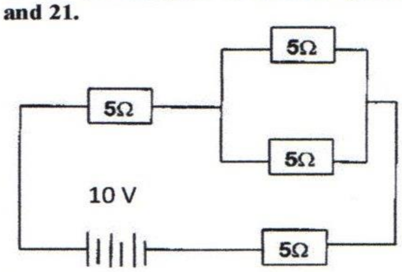


Figure 1

20. What current flows through the 10 V battery?

(A) 0.08A

(B) 0.8A

(C) 8.0A

(D) 0.08A

21. What is the effective resistance in the circuit?

(A) 1.25Ω

(B) 12.5Ω

(C) 0.125Ω

(D) 125Ω

22. The most commonly used semiconductor is……………………………

(A) germanium
(B) silicon
(C) carbon
(D) sulphur

23. A semiconductor has generally .... valence electrons.
(A) 2
(B) 3
(C) 6
(D) 4

24. The resistivity of pure silicon is about ...
(A) 100 Ω cm
(B) 6000 Ω cm
(C) 3 × 105 Ω cm
(D) 1.6×10^{-8} Ω cm

25. When a pure semiconductor is heated, its resistance ....
(A) goes up
(B) goes down
(C) remains the same
(D) cannot say

26. Figure 2 shows three resistors connected to a battery.

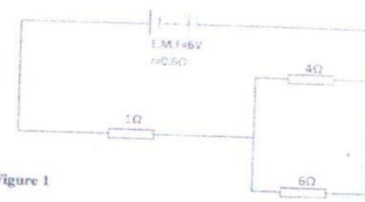


Figure 1

What current flows though the 4 Ω resistor?

(A) 1.2 A
(B) 0.83A
(C) 6.0A
(D) 2.5A

27. When a pure semiconductor is doped with trivalent element, it becomes ....
(A) p-type semiconductor
(B) an insulator
(C) n-type semiconductor
(D) an intrinsic semiconductor

28. The barrier voltage at a p-n junction for germanium is about ....
(A) 3.5 V
(B) 3V
(C) zero
(D) 0.3 V

29. A cell of an e.m.f 1.5V and an internal resistance of 0.5Ω is connected three resistors of 2Ω, 3Ω and 4Ω in series. The current flowing through the cell is........
(A) 0.16A
(B) 1.6A
(C) 6.6A
(D) none of the above

30. A zener diode utilises .... characteristic for its operation.
(A) forward
(B) reverse
(C) both forward and reverse
(D) none of the above

31. All the following are advantages of solid state transistor over the triode EXCEPT one. Which one is not?........
(A) 3.5 V
(B) 3V
(C) zero
(D) 0.3 V

32. When a p-n junction is in forward bias it has ....
(A) minimal resistance
(B) almost no current
(C) large current flow
(D) very narrow depletion layer

34. Mains a.c. power is converted into d.c. power for ....
(A) lighting purposes
(B) heaters
(C) using in electronic equipment
(D) none of the above

35. The most widely used rectifier is ....
(A) half-wave rectifier
(B) centre-tap full-wave rectifier
(C) bridge full-wave rectifier
(D) none of the above

36. The battery connections required to forward bias a p-n junction are ....
(A) +ve terminal to p and −ve terminal to n
(B) −ve terminal to p and +ve terminal to n
(C) −ve terminal to p and −ve terminal to n
(D) none of the above

37. Which of the following approximations is often used in electronic circuits?
(A) $I_C \approx I_E$ (B) $I_B \approx I_C$
(C) $I_B \approx I_E$ (D) $I_E \approx I_B + I_C$

38. In the breakdown region, a zener diode behaves like A......... source.

(A) constant voltage
(B) constant current
(C) constant resistance
(D) none of the above

39. In a properly-biased NPN transistor, most of the electrons from the emitter
(A) recombine with holes in the base
(B) recombine in the emitter itself
(C) pass through the base to the collector
(D) are stopped by the junction barrier.

40. The EBJ of a given transistor is forward-biased and its CBJ reverse-biased. If the base current is increased, then its
(A) I_C will decrease
(B) V_{CE} will increase
(C) I_C will increase
(D) V_{CC} will increase.

41. The value of total collector current in a CB circuit is
(A) $I_C = \alpha I_E$
(B) $I_C = \alpha I_E + I_{CO}$
(C) $I_C = \alpha I_E - I_{CO}$
(D) $I_C = \alpha I_E$.

42. If, in a bipolar junction transistor, I_B = 100 μA and I_C = 10 mA, in what range does the value of its beta lie?
(A) 0.1 to 1.0
(B) 1.01 to 10
(C) 10.1 to 100
(D) 100.1 to 1000.

43. In a properly-connected BJT, an increase in base current causes increase in
(A) I_C only
(B) I_E only
(C) both I_C and I_E
(D) leakage current.

44. When a BJT operates in cut-off
(A) $V_{CE} = 0$
(B) $V_{CE} = V_{CC}$
(C) V_{CE} has negative value
(D) I_C is maximum.

45. When a BJT is in saturation
(A) $I_C = 0$
(B) I_B controls I_C
(C) $V_{CE} = 0$
(D) V_{CE} has positive value.

46. When a BJT operates in cut-off
(A) $V_{CE} = 0$
(B) $V_{CE} = V_{CC}$
(C) V_{CE} has negative value
(D) I_C is maximum.

47. A silicon transistor is biased with base resistor method. If β = 100, V_{BE} = 0.7 V, zero signal collector current I_C = 1 mA and V_{CC} = 6 V, what is the value of base resistor R_B?
(A) 105 kΩ
(B) 530 kΩ
(C) 315 kΩ
(D) none of the above

The diagram in Figure 4 shows a transistor that is correctly biased and whose gain of this transistor is 100, while V_{cc} = 9V, and base current is 2.5 μA. Use it to answer questions 48 to 50.

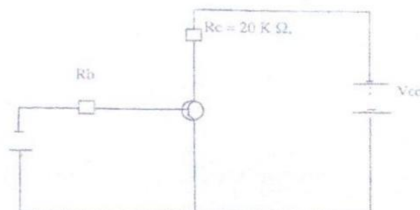


Figure 4

48. Collector current in the circuit equals;
(A) 0.025 μA
(B) 250A
(C) 250μA
(D) 2500mA

49. The potential difference across R_e is;
(A) 0.5V
(B) 250000V
(C) 5.0V
(D) 0.05V.

50. The value of the collector-emitter voltage is equal to……
(A) 0.4V
(B) 4.0V
(C) 40.0V
(D) 400.0V

APPENDIX G: TRAINEES' FEEDBACK – PHYSICS VIRTUAL LAB

SECTION A:

Gender: ◯ Male ◯ Female

Your Age ----------------------

SECTION B:

This study seeks to investigate, virtual laboratory and how it affects Trainees' learning in Physics. Kindly study the various statements specifically in reference to the virtual lab and respond by ticking the choice that best describes your honest opinion.

S. No.	Statement	Agree	Tend to Agree	Tend to Disagree	Disagree
	V-Labs and Academic Achievement				
1	My score improves because I understand the content of the experiment properly by performing it in virtual lab				
2	Virtual lab can improve my score because it decreases my anxiety with experiments while helping me learn new concepts				
3	Experiments in virtual lab make physics concepts easy to understand, thus improving my score				
4	Experiments in virtual lab is fun, but that not that fun, unless trainer is around to direct me. This may not lead me to score better				
5	Virtual labs make my score to be better because they assist me make sense of unfamiliar phenomena				
6	By using virtual labs to learn, male trainees will score a higher mark than female trainees				

7	Virtual lab can help female trainees to achieve higher grades because it allows them in engaging in male dominated play activities				
8	Female trainees who use virtual labs to learn will score better than when they carry out experiments not within women's usual roles				
9	Virtual labs make trainees of both gender to improve in examination score alike because they do not do not treat trainers preferentially based on gender				
10	Male score better than female trainees in exams because the Virtual labs are more appealing to male trainees-are like ICT games they play				
V-Labs and Retention of Content					
11	Virtual laboratory makes me score more as I remember more of what I was taught than learning it otherwise				
12	The organization of the content in virtual lab assists me have a better score as I remember what I have learnt				
13	I score better for my learning skills have been improved by v-labs-I remember more of content taught				
14	I score more because I remember more content obtained through v-labs by forming mental maps				
15	My score in Physics has improved because I easily recall how I practised through the content using v-labs				
V-Labs and Connection Accuracy					
16	Virtual Lab has not helped to improve my accuracy in connecting physical circuits				

17	Performing the experiment in virtual lab increases my confidence level (accuracy) in connecting actual circuits				
18	Using virtual lab in my learning enables me to accomplish physical lab tasks accurately				
19	Virtual lab makes me lazy so that whenever readings are required I get it a problem getting the accuracy needed with ease				
20	Sometimes it becomes challenging to connect real circuits as the virtual lab makes me lazy thus lowering my accuracy of connection				
V-Labs and Speed of connection					
21	Practising in the virtual lab does not help me become faster in figuring out how to connect physical circuits				
22	I get circuits in real life situations easy to interpret and connect after using the virtual lab-this increases my speed of connection				
23	I like the fact that I can try and practice several times using virtual labs, thereby increasing my speed of connection of real life circuits				
24	I get circuits easy to connect as I first try their workability before connecting actual components, increasing speed of connection				
25	I get to connect circuits faster because I start with the mental picture that I have formed of the circuits because of the practice in the Virtual Lab				

Thank you for the time you took to complete this questionnaire.

APPENDIX H: PHYSICS V-LABS TRAINERS' INTERVIEW SCHEDULE

Dear participant,

I wish to thank you for participating in the Virtual laboratories experiments and Assessment. I would like to request a few minutes of your time to take this detailed interview to allow us use this information in enhancing the experience of using virtual laboratories for other trainers and trainees.

SECTION A:

Gender: Male ◯ Female ◯

Your Age ---------------------- Teaching experience (in years) ----------------

SECTION B:

1. State and explain the challenges that you face as a trainer in using a physical laboratory to teach physics.

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2. Describe briefly the ability of your trainees to understand the procedures of the experiments properly by performing it in virtual lab.

…………………………………………………………………………………………
……..………………..…………………………………………………………………
………………………………..…………………………………………………

3. How does performing the experiment in virtual lab influence your trainees' anxiety with lab experimentation while helping them to learn new concepts?

…………………………………………………………………………………………
……..………………..…………………………………………………………………
………………………………..…………………………………………………

4. How does the virtual lab experiments influence the score in theory tests in physics?

…………………………………………………………………………………………
…………………………………………………………………………………………

5. How does performing the experiment in virtual lab influence your trainees' conceptual load? Briefly Explain.

…………………………………………………………………………………………
…..……………………………………………………………………………………
…………..………………………………………………………………………

6. What can you comment about the ease with which your trainees perform the experiments in virtual lab?

…………………………………………………………………………………………
…………………………………………………………………………………………

7. How do virtual labs influence your trainees to understand physics concepts?

…………………………………………………………………………………………
…………………………………………………………………………………………

8. Describe how fun your trainees find the experiments in the virtual lab.

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

9. Describe your experience with performance of virtual lab experiments that you give trainees to practice on their own as an assignment off the class.

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

10. How do you rate the organization of the contents in virtual lab in influencing the learning and therefore the score in physics? Briefly explain.

……………………………………………………………………………………………
……………………………………………………………………………………………

11. Describe how your female trainees compared with male trainees use the v-labs to better their scores in Physics.

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

12. How do virtual labs help your trainees in the remembering what has been taught in class? Explain.

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

13. How can you explain your feeling about using v-labs in improving your trainees' learning skills in terms of accuracy and speed?

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

14. What can you say about the utilization of virtual labs for purposes of drill and practice and retention of content?

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

15. Describe how your female trainees compared with male trainees find it easy to remember content taught using the virtual labs.

……………………………………………………………………………………………
……………………………………………………………………………………………
………………………..…………………………………………………………………..
.

16. Describe briefly how performing the experiments in virtual lab influence your trainees' confidence level for performing the same in real laboratory environment.

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

17. What can you say about the rate at which your trainees accomplish the physical lab after having practiced in virtual lab?

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

18. Describe briefly the difficulties that your trainees faced in the virtual laboratory.

……………………………………………………………………………………………...…
…………………………………………………………………………………………………
.……...……………………………………………………………………………………

19. On the overall, what do you recommend on usefulness of v-labs on skills training?

…………………………………………………………………………………………………
…..…………………………………………………………………………………………
………...………………………………………………………………………………

20. Suggest any advice to those who intend to use virtual labs to teach practical Physics.

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

APPENDIX I: PRACTICAL SKILLS ASSESSMENT TOOL - CHECKLIST

Name of Candidate:	
Name of Assessor:	
Date of Assessment:	
Unit of Competence:	
Element of Competence	
Assessment Context:	Simulated Work Place
Name of Workplace:	N/A
Procedure of Assessment:	The candidate will connect circuits and carry out electrical measurements.

Instructions to Candidate

Assemble all the circuitry materials and equipment.

Prepare the workbench for circuits correctly

Make the required circuit(s) as per the diagram(s)

Time allowed is 2 hours.

Select appropriate electrical and electronic equipment and materials

Observe Health and Safety at all times

Tools, Materials and Equipment

Variable resistor R_1
Variable resistor R_2
transistors
connecting wires
digital multimeters

breadboards
jumpers
light emitting diodes
power sources/dry battery
switch
micro-ammeter

milli-ammeter, voltmeter.

Fgure 1 shows an electronic circuit diagram. Using component, equipment and tools provided:

(a) Identify the components provided;

(b) Interpret the circuit diagram and mount the components on the breadboard;

(c) Procedure

Identify the emitter, base and collector terminals of a transistor.

Check to see that the measuring electrical Instruments are in good working conditions. Make the circuit connections as shown in figure 1.

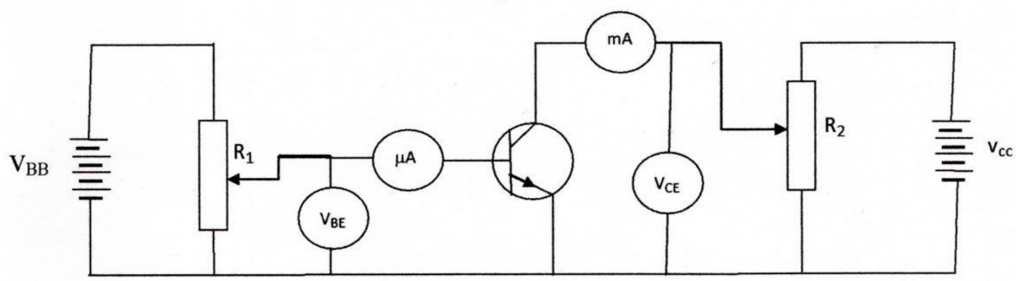


Figure 1

For every characteristic, before the circuit is closed, the potentiometer knobs must be set to read the minimum.

Input characteristics

The collector emitter voltage V_{CE} is set to 2V by varying the biasing voltage V_{CC} and is kept constant. Then the base emitter voltage V_{BE} is increased from zero in suitable steps by varying the biasing voltage V_{BB} and corresponding base current I_B is noted from the micro-ammeter. All readings are tabulated. A plot of I_B verses V_{BE} is made. The Knee voltage is measured by taking the X-intercept of the extrapolated linear portion of the curve.

Output characteristics

The base current I_B is set to 25 μA by varying the voltage V_{BB}. Then the collector emitter voltage V_{CE} is varied in suitable steps from zero to 5V and the corresponding collector currents I_c are recorded from the milli-ammeter. The procedure is repeated for $I_B = 50$ μA by adjusting V_{BB}. The readings are tabulated. A plot of I_B versus V_{CE} is made for each value of I_B. I_{c1} and I_{c2} are determined from the output characteristics. The current amplification factor β and current gain α are calculated using the formulae in (I) and (II) below.

RESULTS
TRANSISTOR CHARACTERISTICS

Input Characteristics

Dependence of I_B on V_{BE} at constant V_{CE}

V_{BE} (V)	V_{CE} = 2V
	I_B (μA)

Output Characteristics

Dependence of Ic on V_{CE} at constant I_B

V_{CE} (V)	I_{B1} = 25 μA I_C (mA)	I_{B1} = 50 μA I_C (mA)

Calculations:

Knee voltage for Base Emitter Junction =V_____V

Current Amplification Factor: $\beta = \frac{\Delta I_c}{\Delta I_b} = \frac{I_{c2} - I_{c1}}{I_{b2} - I_{b1}}$ =________ (I)

DC current gain in CB mode, $\alpha = \frac{\beta}{(1 + \beta)}$ =________ (II)

Result:

Knee voltage = ……………………………..V

Current Amplification Factor β =………………………………………..

Current gain in CB mode α = …………………………………………….

Observation Checklist

Instructions to Assessor

Use a tick (√) for Yes and a cross (X) for No and make some remarks about your observation.

ITEMS	Yes	No	Remarks
Correct choice of equipment			
Equipment safely handled			
Correct choice of tools			
Correct use of tools and equipment			
Connecting circuits correctly done			
Electrical board correctly set			
Components correctly positioned			
Circuit followed accurately			
Measurements correctly done			
Work accomplished within time (indicate time taken in minutes)			
Safety followed at all times			

Competence achieved/outcomes of the assessment

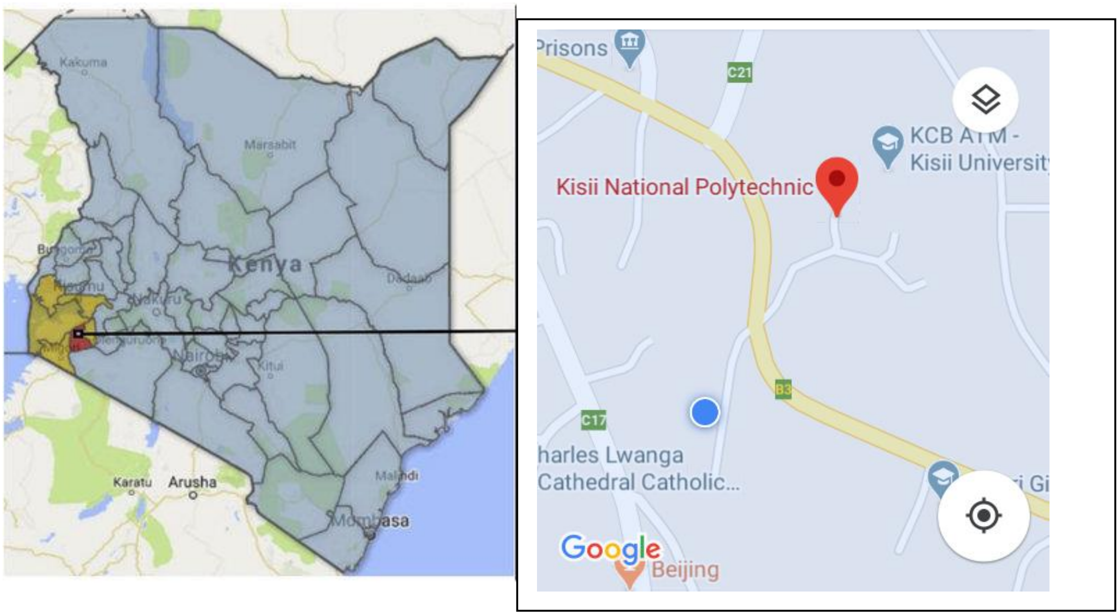
i) Competent (   )   ii) Not yet competent ( )

____
____
____

Candidate’s feedback

____
____
____

APPENDIX J: LOCATION OF THE KISII NATIONAL POLYTECHNIC



GPS Location of Kisii town is 0.6773° S, 34.7796° E, The Kisii National Polytechnic is about two (2) kilometres from Kisii Town Centre.

APPENDIX K: SCORES FOR PHYSICS ACHIEVEMENT TESTS (PATs)

Trainee ID	Group; 1 = Experimental, 2 = Control	Gender: 1 =Male, 2 = Female	PAT 1 Pretest /100	PAT 2 Posttest 1 /100	PAT 3 Posttest 2 (Retention) /100
E1	1	1	36	40	40
E2	1	1	32	38	36
E3	1	1	28	33	32
E4	1	2	48	54	52
E5	1	2	22	36	32
E6	1	2	32	38	36
E7	1	1	28	34	32
E8	1	2	30	34	32
E9	1	1	36	40	40
E10	1	2	38	38	38
E11	1	1	26	38	38
E12	1	2	28	36	36
E13	1	2	36	44	42
E14	1	2	28	38	34
E15	1	2	28	38	36
E16	1	1	34	44	40
E17	1	2	36	42	42
E18	1	1	30	36	36
E19	1	2	30	40	38
E20	1	2	22	30	28
E21	1	2	28	36	36
E22	1	2	30	36	34
E23	1	2	26	30	32
E24	1	2	28	36	32
E25	1	2	30	36	32
E26	1	2	24	32	30

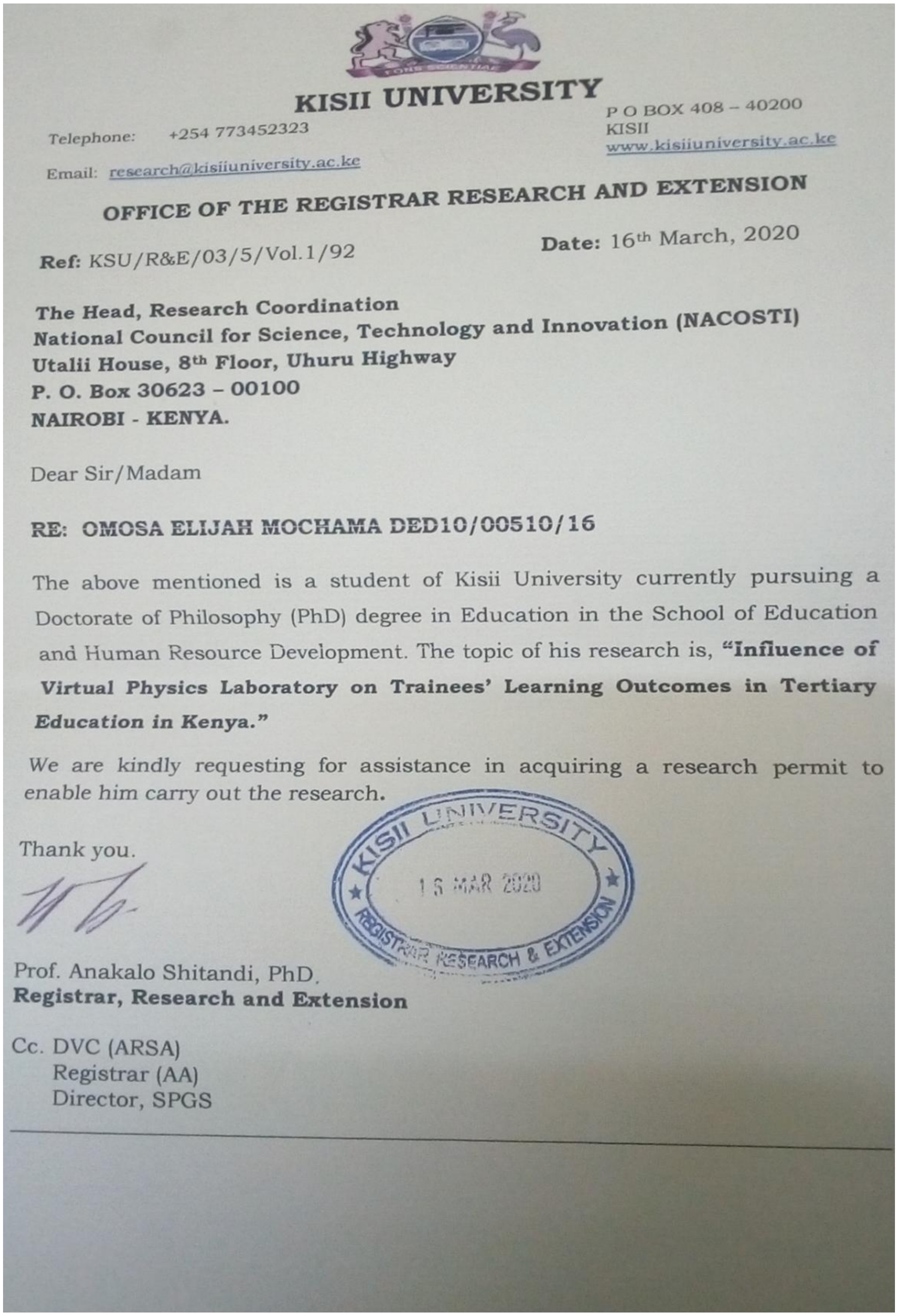
E27	1	2	22	-	-
C1	2	1	30	38	36
C2	2	2	32	40	38
C3	2	2	30	36	34
C4	2	2	30	38	36
C5	2	2	28	32	32
C6	2	1	30	32	30
C7	2	2	24	26	24
C8	2	2	24	26	24
C9	2	2	32	36	34
C10	2	2	38	40	38
C11	2	2	44	40	38
C12	2	1	34	38	36
C13	2	1	28	32	34
C14	2	2	28	38	36
C15	2	1	30	32	30
C16	2	1	42	52	48
C17	2	2	26	30	28
C18	2	2	28	36	34
C19	2	1	30	34	30
C20	2	2	36	46	40
C21	2	2	30	32	32
C22	2	2	28	30	30
C23	2	1	30	30	28
C24	2	2	26	30	28
C25	2	2	22	26	26
C26	2	2	24	24	24

APPENDIX L: SCORES FOR TRANSFER OF TRAINING

Trainee ID	Group; 1 = Experimental, Group 2 = Control	Gender: 1 =Male, 2 = Female	Connection Accuracy Pretest /25	Connection Accuracy Posttest /25	Time in Mins to Connect Circuit (Pretest)	Time in Min to Connect Circuit (Posttest)
E1	1	1	14	19	109	99
E2	1	1	11	15	110	101
E3	1	1	9	12	109	100
E4	1	2	16	21	112	101
E5	1	2	7	11	112	103
E6	1	2	10	14	111	101
E7	1	1	8	12	115	103
E8	1	2	10	14	114	105
E9	1	1	14	18	111	102
E10	1	2	14	18	121	109
E11	1	1	8	12	115	106
E12	1	2	9	13	112	101
E13	1	2	15	17	119	109
E14	1	2	9	12	113	103
E15	1	2	10	13	115	106
E16	1	1	12	15	117	107
E17	1	2	13	15	116	106
E18	1	1	11	14	118	108
E19	1	2	13	16	119	109
E20	1	2	9	11	133	121
E21	1	2	9	13	118	107
E22	1	2	9	12	119	111
E23	1	2	8	13	122	112
E24	1	2	11	14	123	114
E25	1	2	12	14	121	112

E26	1	2	9	12	120	110
E27	1	2	8	-	123	-
C1	2	1	11	14	116	109
C2	2	2	11	15	113	108
C3	2	2	11	14	111	109
C4	2	2	10	15	114	112
C5	2	2	11	13	113	110
C6	2	1	9	13	112	109
C7	2	2	10	12	114	107
C8	2	2	9	12	116	110
C9	2	2	11	14	115	112
C10	2	2	14	17	111	105
C11	2	2	16	20	114	109
C12	2	1	14	16	115	110
C13	2	1	10	12	117	112
C14	2	2	9	13	117	113
C15	2	1	10	14	119	112
C16	2	1	16	19	118	114
C17	2	2	12	16	118	113
C18	2	2	9	12	117	115
C19	2	1	10	14	121	117
C20	2	2	14	18	120	116
C21	2	2	10	14	117	114
C22	2	2	8	12	123	118
C23	2	1	12	16	118	113
C24	2	2	9	12	117	112
C25	2	2	7	11	134	129
C26	2	2	8	11	121	114

APPENDIX M: LETTER OF AUTHORIZATION BY THE UNIVERSITY



KISII UNIVERSITY

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KISII
www.kisiiuniversity.ac.ke

OFFICE OF THE REGISTRAR RESEARCH AND EXTENSION

Ref: KSU/R&E/03/5/Vol.1/92

Date: 16th March, 2020

The Head, Research Coordination
National Council for Science, Technology and Innovation (NACOSTI)
Utalii House, 8th Floor, Uhuru Highway
P. O. Box 30623 – 00100
NAIROBI - KENYA.

Dear Sir/Madam

RE: OMOSA ELIJAH MOCHAMA DED10/00510/16

The above mentioned is a student of Kisii University currently pursuing a Doctorate of Philosophy (PhD) degree in Education in the School of Education and Human Resource Development. The topic of his research is, ***"Influence of Virtual Physics Laboratory on Trainees' Learning Outcomes in Tertiary Education in Kenya."***

We are kindly requesting for assistance in acquiring a research permit to enable him carry out the research.

KISII UNIVERSITY
16 MAR 2020
REGISTRAR RESEARCH & EXTENSION

Thank you.

Prof. Anakalo Shitandi, PhD.
Registrar, Research and Extension

Cc. DVC (ARSA)
Registrar (AA)
Director, SPGS

APPENDIX N: RESEARCH PERMIT BY NACOSTI

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **316760**

Date of Issue: **28/March/2020**

RESEARCH LICENSE

This is to Certify that Mr.. Omosa Mochama Elijah of Kisii University, has been licensed to conduct research in Kisii on the topic: Influence of Virtual Physics Laboratory on Trainees Learning Outcomes in Tertiary Education in Kenya for the period ending : 28/March /2021.

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APPENDIX O: PLAGIARISM REPORT

INFLUENCE OF THE VIRTUAL PHYSICS LABORATORY ON TVET TRAINEES LEARNING OUTCOMES 19 07 2021

ORIGINALITY REPORT

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APPENDIX P: PUBLICATION OF RESEARCH PAPER 1

JRIIE Journal of Research Innovation and Implications in Education
ONLINE: ISSN: 2520 - 7504
PRINT: ISSN: 2663 - 6514

Influence of Virtual Physics Laboratory on Transfer of Skills Training: Connection Accuracy and Speed

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How to Cite:
Mochama, O. E., Obuba, E. M., & Omwenga, E. (2020). Influence of virtual laboratories on Transfer of Skills Training: Connection Accuracy and Speed. *Journal of Research Innovation and Implications in Education*, *4*(2), 241-251.

Abstract

The study investigated the influence of virtual Physics laboratory on speed and accuracy of connection of electric circuits by trainees from Craft Certificate in Science Laboratory Technology (CCSLT) in tertiary institutions in Kenya. The target population was all the trainees in the CCSLT course and their trainers. The sample consisted of 53 Second Year Physics trainees and four trainers from The Kisii National Polytechnic. A quasi-experimental design with the experimental (virtual-lab) (N= 27) and control (no-virtual-lab) (N=26) groups, was used. The virtual lab group practiced in a virtual lab while the no-virtual-lab group used the Conventional Laboratory. Both groups were subjected to a pretest and a post-test lab test using a Practical test observation checklist. Experts approved the experiment before use. A Spearman's Correlation Coefficient, r = 0.94 was obtained. A t-test, means and standard deviations to test two null hypotheses at 0.05 levels of significance. The $t_{cal}= 0.056$, df = 50, p = 0.956; Cohen's d = 0.02; implies the mean scores in connection accuracy between the virtual lab and the non-virtual lab trainees in the post-test were not significantly different. The $t_{cal} = - 4.391$, df = 50, p = 0.000; with Cohen's d = -1.22; the virtual lab trainees recorded significantly shorter mean time of circuit connection than the non-virtual lab trainees. The study recommends that trainees should be granted an opportunity to engage in virtual hands-on Physics to supplement physical laboratories.

Key Terms: Connection Accuracy, Connection Speed, Skills transfer, TVET, Virtual Laboratory

APPENDIX Q: PUBLICATION OF RESEARCH PAPER 2

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Enhancing Brains for Excellence

Influence of virtual laboratories on academic achievements in Physics: The case of tertiary education in Kenya

Authors

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Volume 1	Issue 2
Pages	7-16

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Abstract

Founded on David Kolb's experiential learning the study investigated how Virtual Physics laboratory (VPL) influences the academic achievement of the Craft Certificate in Science Laboratory Technology (CCSLT) trainees in Kenya. The target was all the CCSLT trainees and their trainers in all tertiary TVET institutions in Kenya from which a sample of fifty-three (N= 53) Year II Physics Techniques trainees from The Kisii National Polytechnic was obtained. Intact classes were randomly assigned to the virtual-lab (N= 27) and non-virtual-lab (N= 26) groups. Both groups were subjected to a pre-test and post-test using a Physics Achievement Test (PAT) that had been expert-validated. Its Spearman's reliability Coefficient, r, was 0.86. Means, standard deviations and t-test were applied for hypotheses testing at 0.05 significance levels. The $t_{cal} = 2.019$; $df = 50$, $p = 0.049$, implies the VPL trainees' mean score in the post-test was significantly higher than that of their non-VPL counterparts. The $t_{cal} = 0.203$; $df = 24$, $p = 0.84$, meant that male trainees' mean score was not significantly different from that of their female counterparts. The study recommends that trainees be afforded a chance of engaging in virtual hands-on Physics as it enhances learning by the trainees. The results of this study will be beneficial to future researchers and educators who are interested in using v-labs in Physics and related subjects.

Keywords: Academic Achievement, Learning, Hands-on, TVET, Virtual laboratory