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How academic achievement in Physics in tertiary education in Kenya is influenced by virtual laboratories

Research article

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Abstract

Founded on David Kolb' 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.

Public Interest Statement

The study adds the current body of knowledge on how virtual Physics laboratories influence learning outcomes of trainees in the TVET segment of education and training in Kenya. This is because: (1) The question of the influence of v-labs as a teaching-learning resource is still not resolved; (2) A similar investigation in Physics at this level of education has not been conducted. (3) There is every need for as many young people to become scientists with high competencies, engineers and technologists in Kenya. It will serve as a source of documented literature for trainers, curriculum developers and future researchers.

Introduction

Education in science and technology enables one to skills that are relevant in enhancing an individual's productivity and better quality of a nation's living (Porter, Ketels & Delgado, 2007; Farooq, Chaudhry, Shafiq & Berhanu, 2011; Government of Kenya, 2007). Development in many nations have been enhanced by adapting and implementing well organized and linked Technical, Vocational and Entrepreneurship Training (TVET) systems (Edwin, & Stela, 2016). Challenges facing the modern society such as; climatic changes, emerging diseases, housing, security, terrorism, genetically modified organisms, energy and population crises and others such as biotechnology require Physics knowledge so that they can be handled rationally (UNESCO, 2017). Among the natural sciences, Physics looks the most challenging because majority of concepts in Physics are perceived as abstract by learners (Jian-Hua & Hong, 2012). The understanding of its concepts, laws, principles and theories are based on how the physical phenomena are perceived (Ayoubi, 2018). The decline in the competence of TVET graduates of late has been attributed to poor pedagogy, inadequacy of training equipment, poor inadequate work experience and lack of proper supervision while the attaches are on industrial attachment (Aderemi, Hassan, Siyanbola & Taiwo, 2013).

UNESCO (2017) reports on the education of Science, Technology, Engineering and Mathematics (STEM) of girls and women show that up to date, there is underrepresentation in opting to study the various STEM disciplines and as paths towards their possible careers. The low registration and dismal performance of trainees in the CCSLT Physics Techniques subject examinations has made educational researchers, parents, sponsors and other stakeholders to be concerned about the quality of training in our technical training institutions (Kenya National Examinations Council CCSLT Report, 2010, 2012, 2018). There is therefore a need for looking for ways and means of improving the learning and therefore the performance. Many science instructors choose the normal expository methods of instruction, lecture being the most preferred method of teaching. It is evident that the incapacity of science instructors to use inquiry strategies is hinged to issues which include: lack of laboratories geared up with facilities in schools, overcrowded classes with very few science teachers and competency issues springing up from science teacher training (Ngesu, Gunga, Wachira & Kaluku, 2014). Among the David Kolb's experiential models of learning is lab work. The importance of education in engineering and science as a whole, Physics not left behind using the laboratory is of great importance and has been well researched (Hofstein & Kind, 2012). Research shows that the success and motivation for a student to the study of science dramatically improve when learners are afforded the opportunity of constructing information on their own and in mastering to use that know-how in the analysis of processes in science (Lerman, 2014). However, it costs a fortune to set up and maintain the labs and procure the equipment to assist in the carrying out the experiments. Tatlı and Ayas (2013) maintain that physical laboratories have been found not being used effectively due to reasons like a few schools having them, the cost of setting up them and their maintenance and the lack or inadequacy of these tools. For the teacher it is not only tedious to plan and execute hands-on activities, but also consumes a lot of time. Tüysüz (2010) opines that performance by trainees throughout the experiments in laboratory cannot easily be checked by the teacher due to the fact that it is time consuming and requires one to labour a lot, particularly in classes with very large numbers of learners. Onyesolu (2009), observes that constructivism in science is hindered by the inadequacy or lack of experimental materials and equipment in schools. Studies by Akeyo and Achieng (2012) find the same factors hindering hands-on for trainees in the technical training institutions in Kenya.

When these challenges are taken into consideration, it becomes inevitable that an alternative that may work better be looked for, hence, the use of v-labs has been suggested (Smetana & Bell, 2012). A v-lab, that seems to make contributions to constructing knowledge is becoming more acceptable because: it has many applications in education, simulations based on Physics that copy natural phenomena and conditions in experiments (Tatli & Ayas, 2013; Zacharia & Olympiou, 2013). However, researchers appear wholly agree on how effective the v-labs are in teaching and learning (Corter, Nickerson, Esche, Chassapis & Ma, 2007). A big debate lingers on how effective the v-labs are in the physics education. Researchers also seem not to agree on how virtual laboratories impact on academic achievement by male and female scholars alike. Several studies observe that virtual labs are not used in Lebanon in curriculum instruction have been identified (Zgheib, 2013). They range from the inadequacy of hardware and software to lack of knowledge, skills and attitudes toward the infusion of technology in education. In Kenya ICT have not been infused in curriculum delivery to its maximum potential (Kirimi, 2014). Chesitit (2015) strongly recommended that the Kenyan Ministry of Education, Science and Technology

(MOEST), proceeds to integrate ICT skills with other teaching strategies but this is yet to be fully embraced.

1.2 Statement of the Problem

Physics experiments are not often carried out in most tertiary TVET colleges in Kenya because of the inadequacy or lack of real physical equipment or the large numbers involved (Akeyo & Achieng, 2012). In order to alleviate these problems virtual laboratories have been suggested. However, there is a massive debate on their effectiveness in skills training 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. 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. This is as far as issues of how achievement in academics is influenced by use of v-labs for learning Physics and their potentiality to be a replacement or in complementing the activities in the conventional or the physical laboratory tertiary TVET education in Kenya. Therefore, this study was performed to study the influence of the use of v-labs in training CCSLT trainees. Specifically, it examined how v-labs influence the academic achievement in the topics of electronics and electricity.

1.3 Research Objectives

The following two objectives guided the study:

1. To establish whether the trainees taught Physics utilizing a virtual laboratory score significantly differently from those taught using conventional Physics laboratory.
2. To investigate whether if virtual Physics laboratory is used to teach trainees male trainees significantly different means score from that of their female counterparts.

1.4 Research Hypotheses

The two research hypotheses formulated and tested at α =.005 were:

H_{01}: The mean academic achievement score of trainees taught Physics using the virtual Physics laboratory did not differ statistically significantly from that of those of trainees taught using the conventional Physics laboratory.

H_{02}: The difference between mean scores of male and female trainees taught using virtual Physics laboratory were not statistically significant.

2 LITERATURE REVIEW

2.1 Virtual laboratories and Academic Achievement

Information Communication Technology (ICT) has penetrated many facets of our lives, education not left behind. In education they enhance how teaching and learning takes place in our classes world over (Sasidharakurup, Radhamani, Kumar, Nizar, Achuthan & Diwakar, 2015). Researches point to many advantages of application of v-labs as compared with the real laboratories. First; executing experiments that normally consume a lot of time within a short duration, conducting experiments that are dangerous in an environment that is safer for working, reproduction of real events or procedures of experiments that are not easily to do or observe in an actual labs, in virtual labs, which is an amicable alternative way to solve the problem of expensive real labs, which empower learners to cover content at a pace that is best suited to them, give learners feedback that is immediate so that cross-checking of their progress in acquisition of knowledge and skills can be enhanced (Tsihouridis, Vavougios, Ioannidis, Alexias, Argyropoulos & Poulios, 2015; Saldikov et al, 2017; Smetana & Bell, 2012).

Secondly, use of v-labs significantly improves the performance of learners who had prior exposure to v-lab learning than their partners in the physical laboratory learning (Tatli & Ayas, 2013; Zacharia & Olympiou, 2013). Third, v-labs are considered a cheaper undertaking for providing opportunities for experiencing the physical world, costly or complicated or even harmful in working which are simulated and reproduced in virtual world in a safe way, hence the gaps that exist in the traditional labs can be bridged (Achuthan & Murali, 2015). Lastly, remote labs are utilized to supplement real lab activities (Diwakar et al., 2016), including the components of the virtual world interacting with real ones. Gambari, Gbodi, Olakanmi and Abalaka (2016) found that learners using computer simulations become motivated and also change their attitude towards the chemistry subject.

However, some comparison studies conducted fail to discover any difference that is of statistical significance between the achievements in terms of academics of learners educated utilizing v-lab and those instructed using normal physical laboratory (Bayrak, Kanlı & Kandilingeç, 2007; de Jong et al., 2013; Sabah, 2011). Therefore, researchers do not agree wholly on how much influence virtual laboratories have on the achievement of learners in academics and again as far as his achievement by gender is concerned.

2.2 Virtual laboratories and Trainees' Academic achievement by gender

Gin (2011) opines that gender inequality is classification of women and men is a world where predominance lies patriarchal values in the contemporary world; it is a world where women are perceived to be inferior to men. Gender issues influence most aspects of our lives and societies. That is why gender issues were incorporated into the

United Nations' Sustainable Development Goal 5, *"so as to accomplish gender equality, girl and women empowerment,"* (UNESCO, 2017; Republic of Kenya, Constitution, 2010). At the advent of schooling, in many countries the educational landscape was dominated by single-sex schools with the male learners being taught science and engineering related subjects while those dealing with cooking, nursing and teaching the like were aimed at female students (Trueman, 2015). Although presently fairly equal opportunities have been afforded to both genders to learn almost all of countries, girls are found more often than not opting to study areas that impact on humans socially as opposed to those that involve STEM subjects as the boys do, because of 'gendered' education (Hill, Corbett & Rose, 2010; Miyake, Kost-Smith, Finkelstein, Pollock, Cothen & Ito, 2010). Inequalities in gender are results of unfair rising from political, social, cultural and at times processes in the economy and organization which degrade the terrain of quality education offered (Aikman & Unterhalter, 2012).

In 2015, Trends in International Mathematics and Science Study (TIMSS) collected a 20-year trends at the fourth grade and the eighth grade; and TIMSS Advanced for learners who were registered in special advanced physics and mathematics subjects and in their final year of secondary school for countries that were evaluated in the first assessment in 1995. Baye and Monseur (2016) using the TIMSS data spanning over 20 years, clearly indicated that male students were overrepresented and also posted a better performance than female students in mathematics and science. In another study in Germany, only 21% of the total students registered for STEM courses in year 2014 were female pursuing engineering (Statistisches, 2016). Sjaastad (2012) observes that the learners can be influenced by two kinds of people into choices in STEM courses, those they perceive as role models or as definers. The STEM professionals, STEM lecturers, parents and anyone displaying a STEM professional entity act as role models while definers include but not limited to parents or any other persons who help young scholars in their setting of goals, defining ethos which identify more strong educational aspects of choosing (Ayub, 2017). Nwona and Aogun (2015) noted that there was inequality against females in STEM. A study by Ssempala (2005), indicated that gender imbalances were happening in laboratory assignment. In the Kenyan situation, there are serious disparities in gender as far as enrollment, retention, performance and transition in STEM fields (Akeyo & Achieng, 2012).

Some studies have found, however, that female trainees who have persistently and consistently been in the STEM fields of study comfortably do all that their male counterparts can do (Espinosa, 2011). Ezeliora and Anagbogu (2007) maintain when utilizing science skill technique in for instruction, young ladies outperform their male counterparts, in any case, Orabi (2007) and Gambari (2010) have documented that gender does not seem to impact achievement of learners academically. For the last several years Kenya National Examination Council results in Physics Techniques indicated that males do better than female trainees (Kenya National Examinations Council CCSLT Report, 2010, 2012, 2018).

There are efforts being made to lure more women to STEM at either global, regional or national, for example, STEM and Gender Advancement (SAGA) is a worldwide initiative with an ultimate goal to reduce the gender gap in various fields in STEM at all levels of education (Meinck & Brese, 2019; UNESCO, 2017). The United Kingdom has the girls' only workshops where girls act as scientists facilitated by female tutors facilitating the interest in STEM subjects by girls and eventually related careers. STME (Science, Technology and Mathematics Education) Clinics in Ghana brings girls from various secondary school together with female scientists acting as role models. Kenya conceived and is applying STEM campus, a one-week STEM activity fair in which female students carry out exciting experiments and also get a chance visit various companies offering STEM jobs (Meinck & Brese, 2019; UNESCO, 2017).

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 university for Science and Technology, the Kiriiri Women University for Science and Technology which is a women's only university, established for the sole purpose of encouraging more women into science. At the tertiary level of education, 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 females in all training programmes in TVET institutions, promoting education equity, empowering the women with skills, whether formally or non-formally for the sole purpose of the economy's improvement.

Different teaching approaches and methods to motivate engagement benefit male and female trainees differently. Some studies did not establish any gender-based orientation distinction in achievement of students trained with v-labs (Gambari, 2010; Orabi, 2007). Some studies have however, shown that when female students utilize virtual laboratory they outperform their male counterparts (Gunawan, Suranti, Nisrina, Ekasari & Herayanti, 2017; Koksal, 2014). Wachanga and Anditi (2016) obtained similar results in a study that found computer assisted experiments motivate girls as well change their attitudes of learning chemistry.

The literature reviewed seems not to agree on the influence of utilization of virtual laboratory on academic achievement and also on academic achievement by gender. This area of research is of great importance to education in science because of the existing controversies over whether there are differences in achievement based on gender (Scantlebury, 2012). Minimal literature exists on influence virtual laboratory on academic achievement and on this achievement by gender at the TVET tertiary level of education not only in Kenya but worldwide. Again, the researches that exist were in either university or secondary school settings. It is against this backdrop that the researchers got moved and investigated how achievement in academics is influenced by virtual Physics laboratories and how these labs impact on achievement by male trainees and their female counterparts in the TVET Physics courses. As far as the Kenyan education system particularly at tertiary level, virtual lab is an innovative way of carrying out experiments, therefore, this study examined the influence of v-lab on the academic achievement by trainees in tertiary in Physics Techniques subject in Kenya.

Thinking about this constrained application, the researchers feel that virtual laboratory cannot replace the physical labs yet they can greatly alleviate the challenges experienced with the establishment and use of real labs and could also contribute a lot in the advancement of learning process. Hence the need for this research that dealt with the influence of v-labs on the CCSLT trainees' academic achievement in Physics Techniques.

3 RESEARCH METHODOLOGY

3.1 Research Design

The Quasi-experimental approach was of the non-equivalent pre-test, post-test, control group experimental research design was applied in this study. The Quasi-experimental research design is capable of addressing many of the internal validity issues that can easily plague a research.

3.2 Population, Sample and Sampling Techniques

All the Year II Physics Techniques trainees in the course, Craft Certificate in Science Laboratory Technology (CCSLT) course and their trainers in all tertiary TVET institutions in Kenya were targeted for this study. The sample was 53 CCSLT Year II Physics Techniques trainees of The Kisii National Polytechnic in Kenya (16 male and 37 female trainees) and four (4) trainers were also sampled; two for the control class and two for the experimental class. Here two intact classes of the Second Year CCSLT trainees of The Kisii National Polytechnic, Kenya were randomly assigned to the experimental and control groups. The group in experimental (v-lab, N = 27; 8 males, 19 females) practised in the virtual laboratory while the control (no-virtual-lab, N = 26; 8 males, 18 females) group participants were subjected to physical Physics laboratory. A Physics achievement test (PAT) was used to check the learning of the selected learning outcomes. Pre-test - Post-test was used to check the effect of the treatment. Second Year class was chosen because at this point the trainees had been introduced to Physics as a subject and Physics practicals in Year One. Both groups were involved in identical pre-tests and post-test (practical test). Table 1 shows the experimental and control groups progressed from pre-test through treatment to post-test using the PAT.

Table 1. Experimental design adopted.

	Observation 1	Treatment	Observation 2- Theory Test, Post-test 1	PT2 – PT1
Group 1 (Virtual-lab)	Pre-test, PT1; Theory	Virtual Lab Practice (5 trials)	Post-test 1, PT2	
Group 2 (Non-virtual-lab)	Pre-test, PT1; Theory	Real Lab Practice (5 trials)	Post-test 1, PT2	

3.3 Research Instruments:

3.3.1 Treatment - The Virtual Lab Experiments

Because the costs of creating are quite prohibiting, searching on the internet was done and the DCAC Circuits Online Virtual Laboratory was settled and used as a treatment. These simulations allow students to vary physical quantities such as voltage, current, resistance, and it allows the users to receive feedback that is real-time on the results of the variations they make on the set-up of the experimental. Throughout the period of implementation, the those in the experimental group studied the same content, doing the same experiments as control group trainees, except that they used the Virtual Lab learning activities as did the control group trainees. For both groups, a Physics Training Module which consisted of the activities and experiments to be followed when teaching the topics electricity and electronics were designed, developed and evaluated for use.

3.3.2 Physics Achievement Test (PAT) Tool

The research tool used in the collection of data for the study was a Physics Achievement Test (PAT) created and adopted by the researchers. It consisted of 50 items set to standards of CCSLT Kenya National Examinations Council using the KNEC July Series examinations for the years 2003-2019, but the test was of the objective type, unlike the KNEC which normally has short-answer questions. For each of the PAT items there were four possible answers (A - D) for each test item from which a trainee selects the most suitable option using the letter representing the answer. The PAT was validated by experts. For reliability of the, a pilot study was carried out on two trainers of the Year Three (3) class - 20 trainees, because the trainees in it had characteristics that are similar to the members who were sampled. The half-split was utilized for the PAT was applied to obtain the Pearson correlation coefficient of reliability. An r of at least 0.7 had been set as suitable of making accurate enough inferences. Therefore, an r = 0.86 for the PAT made the research tool to be accepted for use in the study. The PAT was used to as a pre-test to the v-lab group and the non-v-lab groups.

3.4 Method of Data Collection

The researchers sought to be permitted to carry out the study and cooperation from The Kisii National Polytechnic to conduct the study there. The sampled trainers were trained by the lead researcher and made to be research assistants; two in the v-labs group and two were research assistants in the non-v-labs group, therefore they were trained on how to use the respective research tools. The lead researcher led the collection of data with the assistance of the trainers who were trained and made assistants in the research.

Pre-test using PAT on the pre-requisites for learning the topics electricity and electronics was used to test if there the scores by the v-labs were statistically significantly different from those of the non-v-lab. The items were reshuffled and used again as a post-test. To ensure that same standard of marking was applied for all trainees, the lead researcher only scored the trainees' pre-test scripts by awarding '1' for every correct answer and a '0' for an answer that was wrong. Whatever a trainee scored was converted to a percentage by doubling the score so that it was easy to compare. For six weeks of treatment the researchers, assisted by the research assistants administered to both the v-labs and non-v-labs groups the PAT as a post-test and evaluated just like was done with the pretest. To test the influence of the v-lab on the academic achievement on the different gender, the scores of the PATs were analyzed based on gender and comparisons done across male and female trainees.

3.5 Data Analysis

The Statistical Package for the Social Sciences (SPSS) - version 23.0 was used to analyse the collected data. Mean scores, standard deviations and an independent t-test was applied to determine whether there was any significant difference in learners' achievement in academics between the group exposed to virtual Physics laboratories and those not exposed to them. To check how the v-labs affect the academic achievement of the trainees by gender, analysis was done and comparisons between the scores female trainees and male trainees.

4 RESULTS

4.1 Virtual laboratories and academic achievement for experimental and control groups

Null Hypothesis 1. The mean score in the post-test in Physics for the trainees who were exposed to virtual laboratory was not statistically significantly different from that of those who were not exposed to the physical laboratory. The mean score of 30.22 for the v-labs group with a 5.693 standard deviation with that of the non-v-labs groups' mean score of 30.15 with standard deviation of 5.244. A t-test, $t = 0.045$, $df = 51$, $p = 0.964$ on pretest scores for academic achievement showed that the trainees in either group were almost similar before the treatment. Therefore, the groups can be treated as similar achievement academically before treatment was done. In order to do the t-test, the distributions of the academic achievement score for both the control and experimental groups at the post-test were checked. The distributions appeared almost similar and they meet all the criteria for a t-test. The results of the independent t-test scores for the post-test between the control and experimental groups are presented in Table 2.

Table 2: t-test comparison of post-test mean scores of the control and experimental groups

Variable	No. of trainees	Df	Mean	SD	t-value	Sig.(2-tailed)
Experimental Group	26	50	37.58	4.900	2.019*	0.049
Control Group	26		34.38	6.400		

*: Significant level: 0.05

From Table 2, the t-value of 2.019 with degrees of freedom of 50 and the two-tailed p - value = 0.049 was associated with the test. Using the decision rule: If $p \leq \alpha$, then reject H_0, then H_{01} was rejected as in the study $p < .05$. This means that the mean score of 37.58 in post-test academic achievement in Physics of the trainees exposed to the virtual Physics laboratory statistically significantly higher than the 34.38 scored by the non-virtual laboratory trainees' score. This implies that there is a significant difference between the Post-test (academic achievement test) mean scores in Physics of the VPL and the CPL trainees. This has the implication that virtual lab trainees gain content better than the non-virtual lab trainees. A Cohen's d = 0.56 of medium effect size was obtained, meaning that the mean score attained the experimental group trainees in the post-test in academic achievement is 0.56 standard deviations higher above the mean of the control group.

4.2 Virtual laboratories and Academic Achievement by Male and Female trainees

Null Hypothesis 2. The mean score in academic achievement attained by the male trainees is not statistically significantly different from that attained by the female trainees when trainees of both gender are taught using virtual Physics laboratory. A t-test on pretest scores for academic achievement showed that the 31.25% mean score by the male trainees with a standard deviation of 3.845 and the female trainees' 29.79% with a standard deviation of 6.356 were not statistically significantly different (t_{cal} = 0.601, *df* = 25, *p* = 0.553). In order to do the t-test, the distributions of the academic achievement mean scores for the male trainees and female trainees at the post-test were checked and were found to be normally distributed and met criteria for t-test. The results of independent t-test on the mean scores in the post-test for the control and experimental groups are shown in Table 3.

Table 3: t-test comparison of post-test mean scores in academic achievement for male and female trainees

Variable	No. of trainees	Df	Mean score	SD	t-value	Sig.(2-tailed)
Male trainees	8	24	37.88	3.563	0.203^{ns}	0.841
Female trainees	18		37.44	5.480		

ns: not significant level: 0.05

Source: Fieldwork, (2020)

The calculated t-value (t_{cal} = 0.203, *df* = 24, *p* = 0.841) was not significant at α = 0.05. Therefore, the mean score of 37.88% by the male trainees is not significantly higher than the 37.44% mean score by the female trainees. In other words, the male trainees within the v-lab score almost the same mean score as their female counterparts in academic achievement test. The calculated negligible Cohen's d = 0.09 means that the post-test mean score by the v-lab male trainees is 0.09 standard deviations above that of their female counterparts.

4.3 Discussion of Findings

The study found out that virtual laboratory significantly improves the academic achievement in electricity and electronics. The result agrees with what earlier studies realized, that significant improvements in the academic achievement of learners exposed to the virtual laboratory than their counterparts exposed to the physical lab (Tatli & Ayas, 2013; Zacharia & Olympiou, 2013). The researcher linked this to the fact that v-labs helps the learner to access places or situations that are not normally attainable such as the nucleus of an atom and direction of flow of the electrons versus that of the conventional current through the simulations.

However, this result contradicts the findings of Bayrak, Kanlı and Kandilingeç (2007) who opined that executing hands-on in the v-labs and those who were instructed in the real labs were not statistically significantly different. The study, again, maintains that there is no statistically significant difference in academic achievement between male trainees and their female counterparts when both are instructed by use virtual laboratory. This result is in agreement with the results of some researchers who did not find out any distinction between male and female trainees in achievement of learners both of whom were trained with virtual laboratory (Gambari, 2010; Orabi, 2007). However, this result contradicts the findings by Koksal (2014) and those of Wachanga and Anditi (2016) which show that when female students utilize virtual laboratory the outperform their male counterparts.

5.1 Conclusion

It can be inferred from the results of this study that the virtual Physics laboratory produced superior results than those of conventional Physics laboratory as far as it concerns achievement in academics in TVET Physics. However, gender of a trainees who used virtual Physics laboratory does not have an effect on the score in PAT. This means therefore that male trainees and female trainees exposed to Physics v-labs acquire information to the same extent. Basing on these findings, investing in not only the development but utilization of virtual labs in the learning and by trainees in electrical and electronic circuitry or related areas is a worthwhile undertaking so long as the pedagogically authentically meets the threshold of learning. The findings of this study will contribute in the increment of the current body of knowledge on the influence of v-labs on learning of Physics at the tertiary TVET education and training. Using this knowledge, the trainers of Physics related subjects, science and technology may additionally be able to maximize the benefits of the use of the Physics virtual laboratories as a learning and teaching resource.

5.2 Recommendations

These recommendations are based on the results, discussions and conclusions from this study: (i) TVET trainees should be afforded opportunities to engage in meaningful learning activities through the use of v-labs in Physics so as to promote constructivism in the trainees. (ii) 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 Physics with no fear of spoiling equipment and components. (iii) V-labs give trainees extra practice opportunities. Other possibilities include; ‘touring’ the inside of a nuclear reactor, a hot furnace or even deep space, a trainee is enabled to see the direction and speed of flow of electrons which is not possible in the real lab setup. (iv) There is need by the Ministry of Education, Science, Technology and Innovation through its Semi-Autonomous Government Agencies (SAGAs) such as TIVETA, KICD, KNEC, and other stakeholders should plan and hold workshops on how to enhance meaningful learning in TVET by utilization of v-labs. (v) Kenyan teacher training programmes should be improved so as to the teachers can be well prepared to be able to use v-labs in the learning and teaching physics. (vi) The designers and developers of instructional materials, instructional designers and computer programmers should develop relevant virtual laboratories for use within the Kenyan TVET institutions.

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Conflicts of Interest: The authors declare no conflict of interest.

Disclaimer Statement

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science, technology and mathematics education, improvised learning resources, gender and STEM education

Authorship and Level of Contribution

Level of Contribution by authors: Omosa Elijah Mochama - 40%; Dr. Enock M. Obuba – 30% and Dr. Ezekiel N. Omwenga – 30%.

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