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Effects of Virtual Laboratory-Based Instruction on the Frequency of Use of Experiment as a Pedagogical Approach in Teaching and Learning of Physics in Secondary Schools in Kenya

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ABSTRACT

Information and communications technology (ICT) incorporation in teaching physics in Kenyan secondary schools cannot be overlooked, given the key roles and benefits that ICT offers in the process of teaching and learning. Consistently poor average scores in the subject currently witnessed at the Kenya Certificate of Secondary Education (KCSE) level in Physics can be attributed to low student motivation and traditional teaching strategies. For instance, in the years 2016, 2017, 2018, and 2019, Kisumu County registered low mean scores of 4.23, 4.98, 4.67, and 4.10, respectively, in physics in KCSE. Therefore, there is a need for the incorporation of more effective teaching strategies to improve performance in physics and for students' interest and attitude in learning the subject to change. Technology-based or enhanced learning leverages all learners, irrespective of their traits or socio-economic status. This study aimed at establishing the effects of virtual laboratory-based instruction (VLBI) on the use of experiments as a pedagogical approach. The study objectives were to establish the effect of virtual laboratories on the frequency of use of experimental teaching approaches in learning physics in secondary schools and to determine the extent of the relationship between physics teachers knowledge of the selected ICT frameworks and the use of virtual experiments in teaching and learning physics in secondary schools in Kenya. The study was supported by behaviourism learning theory and adopted quasi-experimental research designs. The physics teachers were purposefully sampled from each selected school. The sample size was 44 teachers and 358 students, summing up to 402 respondents. The data was analyzed using both descriptive and inferential statistics. The study concluded that virtual laboratories advance the use of experimental teaching approaches and that there was no statistical significance between the knowledge of the teacher about the selected ICT framework and the use of virtual experiments. The findings of this study would help educational planners successfully design and implement various classroom-based innovations that would enable seamless integration of virtual laboratories into classroom instruction.

Key Words: Active learning, Experiments, ICT Integration in Learning, Virtual Laboratory (VL)

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I. INTRODUCTION

Physics is among the core pillars that support development worldwide, as it plays a central role in spearheading technological advancement, promoting national wealth, improving health, and accelerating industrialization (Argaw, 2016). To achieve Millennium Development Goals (MDGs) and to realize Kenya's Vision 2030, quality teaching and learning of physics are more critical now than ever before. According to Mulhall et al. (2019), physics is perceived as a difficult subject both in its teaching and learning. The majority of learners in secondary schools generally view physics as difficult, irrelevant, and boring (Owen et al., 2018). The mathematical aspect of physics makes most learners shy away from the subject. This leads to minimal student-teacher communication, making the student and the teacher live in different worlds and speak different languages (Carter, 2018). Attempts have been made to make physics more interesting to learners and to cater for their needs, but to no avail. The major concern of this study was the poor performance of KCSE in physics by students and the low enrolment data it has as a science as compared to chemistry and biology. All these concerns point to pedagogical approaches to the implementation of the physics curriculum in secondary schools in Kenya. The study was therefore focused on exploring the urgent need to improve and better the learning and teaching of physics in secondary schools by using a new approach to student-centered teaching strategies. This study investigated the implications of ICT VLBI on the frequency of use of experiments as a teaching approach for students' learning in secondary schools in Kenya County.

1.1 Study Objectives

i. To establish the effect of virtual laboratories on the frequency use of experimental teaching approach in learning of Physics in secondary schools
ii. To determine the extent of relationship between teachers' knowledge on selected ICT frameworks and the use of Virtual Experiments in teaching and learning of Physics in secondary schools

1.2 Research Hypotheses

To achieve these objectives, the study employed two null hypotheses which were tested at 0.05 alpha levels of significance. The hypotheses tested in the study were that:

i. **H_{01}**: There is no statistically significant difference on the frequency of use of experimental teaching approach between students exposed to VLBI and those not exposed
ii. **H_{02}**: There is no statistically significant difference between the teachers' knowledge on selected ICT frameworks and the use of Virtual Experiments.

1.3 Theoretical Framework

A change in the learner's behaviour is a sign that learning has occurred. According to Altuna et al. (2015), the majority of that is reinforced through a system of positive or negative rewards. When ICT is used as a stimulus to enable students to repeat and practice the material they have learned, behaviourism theory can be applied to the integration of ICT technologies into pedagogy. This will help students realize behaviourism principles. Stimuli can be a variety of technological tools that a student uses during the learning process to acquire knowledge in an environment with ICT resources. Based on behaviourist principles, computer-aided instruction (CAI) is used to teach subject-related facts, skills, and information (Dede, 2008). These applications can engage the learner in accordance with behaviourist methods by giving them activities with which they have to interact until they get the result they want. ICT tool applications are a good way to teach material through practice and repetition because they promote the student's development of creative thinking and critical thinking skills. To put it another way, technology is at the center of students' knowledge (Siemens, 2004). The tools that the students use take on the tutoring role: They include the content of the subject, the goals that need to be accomplished, and the reinforcements that will be used during the assessment. In terms of enthusiasm and content mastery, immediate feedback and reinforcement are crucial because they provide evidence that the process of learning has taken place successfully and that the set objectives have been met. Learning happens at the learner's own pace. Since behaviourist practices and principles are still applicable in the classroom, adopting ICT based on behaviourism theory is crucial to this study. ICT has been thought of as a tool that gives out instructional materials and acts as a tutor so that the learner can interact with the material.

II. LITERATURE REVIEW

2.1 Use of Experiments in Teaching

Rahayu (2018) looked into how different teaching methods affected two different groups of grade seven students. Learners in the experimental group received instruction based on their preferences, while those in the control group were taught in a conventional manner. Students in the experimental group, who received instruction tailored to their preferred learning styles, performed better academically than students in the control group in this study. Additionally, the experimental group demonstrated an improved capacity to transfer what they had learned from one subject area to another as well as a more upbeat attitude toward learning. According to Zhang et al.'s (2020) research, students' perceptions of Physics instruction were influenced by the constructivist approach. When students were taught using the constructive approach as opposed to the traditional approach, they placed a higher take advantage of the chance to actively participate in group discussions and investigate the ideas they had previously learned. Isa et al. (2020) discovered that students gain important practical skills when they directly participate in laboratory experiments. These abilities include connecting circuits, putting instruments together, reading instrument scales, recording the results, and figuring out what they mean. These studies explained the fact that use of experimental approach leads to student-centred learning.

However, the study did not indicate whether this motivates teachers to carry out more experiments or not. Majama et al. (2019) reported that lack of basic content knowledge and outdated teaching practices have compromised the use of experimental approach in teaching in Tshwane North in South Africa. The poor teaching standards had also been exacerbated by overcrowded and non-equipped classrooms. In order to achieve educational goals, effective teaching will only be achieved if the classroom learning accommodates and adopts the use of experiments (Blundell, 2020). Moreover, there is substantial research findings that use of experimental approach in learning and teaching improves students' activeness in Physics teaching learning process (Telaumbanua, 2017). According to Chebii (2019), some science teachers are not well-equipped to teach science effectively. Some of their deficiencies include the use of unsuccessful science instruction methods, a lack of commitment, and inaccurate assessments of students' science learning outcomes. Adeyemo (2010) found out that modern and adequate laboratory apparatus were unavailable in most secondary schools in Nigeria and where they were, they were not functional, hence a few experiments were carried out by physics teachers.

Semela (2010) noted that physics in many African counties has been undergoing crisis with no or few experiments carried out in the course of learning. The reasons include inadequate laboratory equipment, weak mathematics background and unqualified teachers among others. The M.O.E. emphasizes the use of practical approach in teaching and learning of Physics as a policy in secondary schools in Kenya (R.O.K, 2006). Since the resources are intended to be used for the benefit of teachers and students, Majama et al. (2019) state that the procedure for allocating resources should be followed. The above research studies showed that limited experiments were carried out, which may be as a result of incompetent Physics teachers or inefficient laboratory equipment, or both. The studies did not, however, indicate possible experiments that the physics teachers were able to carry out. It is worth noting from the foregoing that while several studies have been done using different teacher variables, few have concentrated on the extent to which Physics' virtual resources for teaching influence the use of experiments as a classroom method in the teaching Physics. The above-mentioned researchers give a general picture of the importance of use of experiments in teaching physics. The studies further acknowledge that very few experiments, if any, are carried out in the course of teaching and learning of physics, more particularly in topics such as Radioactivity and Photoelectric effects that entail experiments that are considered hazardous. However, it could be argued that the studies lack the remedy on measures that should be taken for Physics teachers to carry out experiments in the mentioned topics. The current research has focus on the frequency of use of experimental teaching approach when VLBI is adopted in teaching Physics in secondary schools in Kenya.

2.2 Selected ICT Frameworks

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

According Fink (2013), learning frameworks assist educators in designing learning objectives in accordance with classroom activities, creating learning environments that are inclusive and motivating, and integrating evaluation into learning. Frameworks provide scaffold, multiple teaching approaches which assist learners to develop knowledge structures that are accurately and meaningfully organized, while making them aware of how and when to apply the acquired skills and knowledge (Ambrose et al., 2015). According to Sortrakul (2009), instructional learning frameworks can be effectively incorporated into the ICT field to create an active platform for teaching performance and learning challenges in a variety of settings and teaching and learning Physics. In addition, students engage more actively in the created learning environment when an instructional learning model is enhanced with ICT than when traditional classroom instruction is provided. The learning frameworks transform the learning paradigm from teacher-centered to learner-centered. Branch et al (2014) confirmed that ICT-based instruction is replacing talk-and-chalk instruction. Hundreds of teachings and learning frameworks have been developed by instructional designers to meet their requirements. According to Lee and Jang (2014), the primary goal of creating an instructional design framework is to support an understanding of instructional design reality and monitor teaching and design performance. According to Branch and Kopcha (2014), despite the fact that numerous instructional design frameworks have been developed for both general and specific use, there are still a few significant distinctions between them, allowing instructors to better put the framework into use in accordance with their goals. The reviewed technology enhanced framework includes ICT elements and instructional principles to help students get the most out of their education. Oliver (2005) asserts that there are e-learning frameworks and components that focus on defining the essential elements that can create a meaningful learning environment by influencing e-learning and other factors. This group of frameworks includes the following: The building blocks of functionality (Patten et al, 2006), Eight-dimensional e-learning framework developed by (Khan, 2006), Khan's P3 model (Khan, 2005), the SAMR model (Puentedura, 2012), the TPACK framework (Koehler and Mishra, 2006), and the ASSURE model (Heinrich et al., 1999).

III. METHODOLOGY

This study used quasi experimental research design. Quasi experimental research design was deemed the most appropriate for this research since it entails an investigation of issues as they affect an activity such ICT integration in teaching. Besides, it gives room for interrogation of a number of research questions thereby providing a holistic interpretation of a process (Zamani and Rezvani, 2015). Furthermore, quasi-experimental design was found suitable for this study since the research participants (students) were not randomly assigned to experimental and control groups and the researcher worked with the existing intact classes. Once classes have been constituted in secondary schools, they are regarded as intact groups. The sample of this research was calculated by using Taro Yamane formula with 95% confidence level (Yamane, 1977).

Taro Yamane formula was considered appropriate for the study since the study involved a finite population with a known population size. Furthermore, the formula was considered ideal for the study since it had a large population of 3500 form three students and 140 Physics teachers were stratified and random sampling was applied to establish the final samples of the attributes present in the population for a quasi-experimental research. This formula employed established a sample size of 358 students and 104 Physics teachers for the study. The sample consisted of Physics teachers who had undergone CEMESTEA in-service training on ICT integration and form three Physics students who were selected from the target population. For this research, purposive sampling was adopted in the selection of Kisumu County out of the 47 Counties in Kenya to be the county of study.Therefore the sample size for each strata is given in Table 1

Table
Sampling Frame

Units	**Population**	**Sample Size**
Teachers	86	70
Students	3,500	358
Total	**3,550**	**402**

Simple random sampling was then be employed to select three boys boarding school, three girls boarding schools and four mixed schools from each sub-county. This was a way of ensuring that each member of the target population had an equal opportunity of being selected as part of the sample. Purposive sampling technique was employed to select the Physics teachers from each sampled schools. Physics teachers selected were those that have undertaken CEMASTEA in-service training on ICT integration and therefore well-equipped about ICT integration in teaching and learning. Purposive and simple random sampling techniques were employed to select student respondents. Purposive sampling was used to select the form three classes from each sample school. Simple random sampling was then employed to select students who were studying Physics as an examinable subject.

The data collection tools employed in this study entailed questionnaires, lesson observation guide and Physics Achievement Test. These tools were selected based on the following reasons; the nature of data to be collected, the time available for the study as well as the objectives of the study (Bergman, 2015). The overall aim of this study was to enhance active learning and to improve learning outcomes through integration of virtual experiments in teaching and learning of Physics in secondary schools in Kisumu County. The main concern of the study was on teachers' and students' views, opinions, and attitudes about ICT integration in active learning of Physics. This kind of information can best obtained through the use of questionnaires (Physics Teachers questionnaires and The Physics Student Questionnaire), and lesson observation (Kothari, 2017)

IV. RESULTS

4.1 Frequency of Use of Experimental Teaching Approach

The third objective in this study was to investigate the frequency of use experimental teaching approach in the topic "RADIOACTIVITY' when Virtual Experiments and conventional methods of teaching were used to teach

Physics. The data on number of Physics experiments conducted was collected using LOS, PTQ and PSQ. Table 2 shows the summary of the results obtained.

Table 2
Independent Samples t-test for Different Number of Experiments Administered between VLIB Classes and Conventional Classes

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

According to the results presented in Table 2, students who were taught by VLBI approach had higher number of experiments carried out (42.6788) compared to those taught using the conventional methods (13.2233). The statistics indicate that the difference in the (mean of) number of experiments administered between the two cohorts was statistically significant at $\alpha = 0.05$. The significant number of experiments conducted as result of the use of VLBI is an indicator that, the use of a virtual laboratory helps an educational system achieve its goals and solves some of the issues that traditional laboratory applications face. The use of VE for laboratory instruction has numerous obvious advantages, including "portability, safety, cost-efficiency, minimization of error, amplification or reduction of temporal and spatial dimensions, and allows flexible, rapid and dynamic data displays," (Altuna & Lareki 2015).

4.2 Frequency of Use of Experimental Teaching Approach Across Experimental and Control Groups

To compare the number of experiments that were exposed to Physics students in the four cohorts that were involved in this study, a One Way ANOVA was executed. The results were presented in Table 3

Table 3
ANOVA Table for Difference in Number of Experiments Carried out Across Groups

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

The results in Table 3 show an *F*-value of 119.971, with significance level of 0.000 indicating that the number of experiments administered among the groups were statistically significant at an $\alpha = 0.05$. This infers that the number of experiments carried out during Physics lessons differ from one cohort to another among the four cohorts of classes involved in the study. This is an indication that VLBI can be a place for experiments that cannot be done in conventional laboratories and at the same time present related concepts and events. According to Kurt (2017) study, the use of virtual labs as a teaching strategy leverages the use of real experiments because they are time-consuming and expensive, inadequate lab equipment, and teachers' anxiety about curriculum completion. The higher number of experiments observed in virtual lab classrooms, is an indicator that the strategy aim at raising scientifically literate students, and hence building a strong relationship between science and technology. The students' conceptual understanding of radioactivity appeared to be improved through the use of VLBI, particularly their conceptions of measuring count rate with a GM-tube, a concept that cannot be achieved through actual experimentation in typical physics labs.

To point out how the difference in number of experiments administered is depicted, a Post Hoc comparison was done using the Duncan Multiple Range Test whose findings are in Table 4.

Table 4

Duncan Multiple Range Test for Difference in Number of Experiments Across Different Groups

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

*Means for groups in homogeneous subsets are displayed.

According to the findings presented in Table 4, Physics students in experimental cohort E_1 had the highest number of experiments (41.0) administered to them, followed by experimental cohort E_2 (39.7) while students in C_1 had the least (14.2865). The findings concur with the study conducted by Semela (2010) which established that Physics in many African countries has been undergoing crisis with no or few experiments carried out in the course of learning, with inadequate laboratory equipment being implicated. The high and improved number of experiments among the experimental groups can be attributed to the adoption of VLBI in these cohorts. Consequently, the hypothesis which stated that "There is no statistically significant difference in the number of experiments carried out between the learners taught Physics through the use of VLBI and those that use conventional methods" is thus rejected. The implication is that virtual laboratory-based instruction permits teachers and students to access practically all the experiments at comparatively lower cost. The power of experiments in enhancing learning may best be captured in the Chinese saying that:

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

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

4.3 Teachers' Knowledge on ICT Frameworks and Use Of Virtual Experiments

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

Table 5

Physics Teachers' Awareness of Selected ICT Frameworks

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

The study also establish that TPACK framework was popular (51.4%) among the teachers who took part in the study with other selected frameworks scoring below 16% in terms of popularity index.

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

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

The findings are represented in Table 6

Table 6
Independent Samples t-test for Difference on Teachers knowledge on ICT Frameworks between VLBI and Convectional methods

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

According to the results presented in Table 6, teachers that used conventional teaching methods depicted more awareness and the objectives of the selected ICT frameworks compared to their colleagues who taught the experimental groups using VLBI. The statistics however, shows that the difference in teachers' knowledge of ICT frameworks between the two groups was not statistically significant at alpha level of 0.05. Therefore the hypothesis which stated that, there is no statistically significant difference between the teachers' knowledge on selected ICT frameworks and the use of virtual laboratory-based instruction is confirmed. The implication is that whether the teachers are informed about the ICT frameworks or unaware they generally have the same bearing on the use of VLBI in teaching and learning of Physics in secondary schools.

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

To compare the teachers' knowledge on the selected ICT frameworks and the use of VLBI in the four groups involved in this study, a One Way Analysis of Variance (ANOVA) was carried out. The results are presented in Table 7.

Table 7A
NOVA Table for difference on Teachers' knowledge on ICT Framework and use of VLBI

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

The results in Table 7 show an F-Value of 1.174 whose significance level was 0.317. In this study, the teachers' knowledge on ICT frameworks and the use of VLBI were compared. The four groups, E1, E2, C1, and C2, did not differ significantly, according to the findings. The finding contradicts Koehler et al (2016) who underscore the effects of a valid ICT learning framework. Comparatively, the results show similarities with previous studies, that indicated that the use of VLBI do not require deep instructional design knowledge or high revision of design (Gustafson & Branch, 2002). The general view of the Physics teachers, coupled with the significance test (at α=0.05) result, led to the inference that the teachers knowledge on the selected pedagogical ICT framework have no influence on the use of virtual laboratory-based instruction in learning Physics in secondary schools.

V. CONCLUSION & RECOMENDATION

5.1 Conclusions

The study has revealed that using virtual laboratory-based instruction permits teachers and students to access practically all the experiments at comparatively lower cost, thus promoting use of experimental teaching strategy. Virtual laboratory-based instruction enables students to access practical aspects of learning, irrespective of the location and status of the school. The findings indicated that there was no statistically significant difference in the mean across the four groups, E_1, E_2, C_1 and C_2. The study thus concludes that the use of VLBI in teaching does not depend on the teachers' knowledge on the selected ICT frameworks in the study.

5.2 Recommendations

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

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