

Effectiveness of technological resources adopted in virtual classrooms in the implementation of the secondary school physics curriculum in Kakamega

Amos Baraza Wamanga¹

John Oyula shiundu²

Teresah Okoth³

¹amoswamaga@gmail.com

²jshiundu@mmust.ac.ke

³tokoth@mmust.ac.ke

^{1, 2, 3}Masinde Muliro university of science and technology, Kenya

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ABSTRACT

The integration of virtual classrooms has emerged as a critical strategy for sustaining educational continuity and enhancing Science, Technology, Engineering, and Mathematics (STEM) instruction, particularly in resource-constrained contexts. This study investigated the effectiveness of technological resources adopted in virtual classrooms in the implementation of the Secondary School Physics curriculum in Kakamega Central Sub-County, Kenya. The study was guided by the Technological Pedagogical Content Knowledge (TPACK) framework and Rogers' Diffusion of Innovations Theory, and adopted a descriptive correlational survey design. The target population comprised 50 Physics teachers and 32 School Heads of Department (HODs), from which a sample of 47 Physics teachers and 32 HODs was selected using stratified, purposive, proportionate, and simple random sampling techniques. Data was collected through questionnaires and key informant interviews, and analyzed using descriptive statistics and linear regression with the aid of SPSS version 27. The findings revealed that access to virtual classroom infrastructure had a statistically significant but weak effect on the effectiveness of virtual classroom integration, accounting for only 0.4% of the variability in effectiveness ($R^2 = .004$, $p = .017 < .05$), leading to the rejection of the null hypothesis. The regression model indicated that a unit increase in access to virtual classroom infrastructure was associated with a 0.043 increase in the effectiveness of virtual classroom integration. The study further established that the overall state of virtual classroom infrastructure was inadequate (composite mean = 1.35), with 69% of respondents reporting inadequate computer laboratories, 64% reporting limited internet accessibility, and 58% reporting inequitable distribution of virtual classroom resources. Additionally, 24.4% of teachers had received no training on virtual classroom integration, and 13.3% had no computer experience at all. The study concludes that while technological resources significantly influence the implementation of the Physics curriculum, their effect is constrained by inadequate infrastructure, limited teacher proficiency, insufficient technical support, and inequitable resource distribution. The study recommends that the Ministry of Education, Teachers Service Commission, and school management prioritize the provision of adequate Information and Communication Technologies (ICT) infrastructure, reliable internet connectivity, continuous professional development, technical support, and equitable resource distribution to enhance the effectiveness of virtual classroom integration in Physics curriculum implementation.

Keywords: e-Learning, Digital Infrastructure, Kakamega, Physics Curriculum Implementation, Technological Resources, TPACK, Teacher Proficiency, Virtual Classrooms

I. INTRODUCTION

Globally, the expansion of digital technologies has transformed how teaching and learning are organized, delivered, and experienced. A virtual classroom is a synchronous or asynchronous online learning environment in which teachers and learners communicate, interact, collaborate, share resources, and receive feedback through tools such as video conferencing, learning-management systems, screen sharing, virtual whiteboards, simulations, and breakout rooms. Virtual classrooms extend learning beyond the physical classroom and can sustain educational continuity during disruptions such as pandemics, floods, insecurity, and other emergencies. They may also promote flexibility, collaboration, learner engagement, creativity, and access to diverse learning materials when they are supported by appropriate pedagogy and reliable infrastructure (Ryan & Poole, 2019; UNESCO, 2023). However, access is still unequal: UNESCO (2023) found that in 2022, only approximately half of all lower secondary schools in the world were connected to the Internet for pedagogical uses, meaning that the pedagogical value of virtual learning is still dependent on context, access, and teacher capacity.

Technology is not the only measure of the effectiveness of a virtual classroom. It relies heavily on the teacher efficacy, which in this study is defined as teachers' self-efficacy in selecting, organizing, and using digital tools to meet desired instructional goals. Teachers need technological, pedagogical and content knowledge for matching a digital tool

with the subject matter, learners' needs, and desired learning activity (Mishra & Koehler, 2006). This is especially relevant in Physics where there are a lot of concepts that are abstract, mathematical, experimental, and cannot be explained verbally. While digital simulations, animations, virtual laboratories, video demonstrations and collaborative problem solving can help make invisible processes more visible, weak digital skills, negative attitudes, lack of time and insufficient technological resources can limit virtual teaching to the passive transmission of notes.

In Africa, governments and education systems are increasingly taking note of digital learning as a key way of improving access, enhancing resilience, and equipping youth for technology-driven economies. African Union's Continental Education Strategy for Africa and Digital Education Strategy calls on member states to increase connectivity, digital content, teachers' capacity and technology-driven STEM education. Despite this, there is still a lack of uniformity in implementation across and within countries, due to poor electricity access, high data costs, limited Internet access, lack of devices, and poor technical support in many schools, particularly those in rural and low-income communities (UNESCO, 2013). These structural constraints were more apparent during school closures due to COVID-19, when teachers and learners in various African countries used mobile phones, messaging apps, radio, television and online platforms, with participation depending on household resources and teachers' preparedness.

The national development and education-policy agenda in Kenya is the basis for ICT integration. Kenya Vision 2030 places emphasis on science, technology and innovation as the drivers of industrialization while the National ICT Policy and education-sector plans emphasize the use of technology to enhance access, quality, equity and continuity of learning. The Basic Education Curriculum Framework (BECF) by the Kenya Institute of Curriculum Development (KICD) also defines digital literacy as one of the core competencies and STEM learning as a key component of national development (Heto *et al*, 2020). Physics is directly contributing to this agenda by preparing learners for engineering, computing, energy, manufacturing, medicine and other science and technology related careers. Therefore, its effective teaching is not only essential for passing the exam but also for building problem-solving, experimenting, and analytical thinking and innovation skills.

Empirical evidence, however, suggests that there is a disconnect between policy and practice. Murithi and Yoo (2021) reported that in a national survey 85% of teachers said they had received training in ICT from the Ministry of Education, but 62.3% of the trained teachers felt the training was not suitable for teaching and learning. The same study references a survey of 1,200 teachers by the Teachers Service Commission that found 84.2% of teachers experienced challenges with technology in their classroom, with technology integration being the top professional skills gap. The results indicate that basic computer training is not enough to enable teachers to have the subject-specific pedagogical skills necessary to effectively use virtual classrooms.

The scale and significance of the learning area is further reinforced by the data from National Physics. The KNEC Physics report indicated that the number of learners who took the Physics examination in 2021 increased from 253,963 in 2020 to 276,296 in 2021, which is an increase of 8.79%, while the overall mean score in 2022 was 66.12 compared to 59.39 in 2021 (Aradi *et al.*, 2024). This is encouraging but the weaknesses in conceptual explanation, unit conversion; accurate recording, practical procedure and use of experimental results were still identified by the analysis carried out by KNEC. These are the areas where pedagogical guidance and intentional demonstration, simulation, virtual lab, and feedback are needed, not the presence of digital devices. Therefore, the expectations of national policy and the evidence in the exams warrant further analysis of teachers' competency in using virtual classrooms in Physics teaching.

The secondary schools in Kakamega County and in particular Kakamega Central Sub-County are spread across national/extra-county, county and sub-county levels and cater for students from diverse socio-economic and geographical backgrounds. The adoption of virtual classrooms may be influenced by the differences in connectivity, access to computers and smartphones, technical support, school level ICT provision, and opportunities for teacher professional development. Physics teachers will also need to convert abstract concepts and practical activities into formats that are understandable and interactive when presented via Zoom, Google Classroom, Microsoft Teams, Moodle, and social media or similar. However, there is little empirical local evidence on their proficiency, access to appropriate technological resources, attitudes, and implementation challenges.

1.1 Statement of the Problem

The integration of virtual classrooms into the teaching and learning of Physics is increasingly recognized as essential for sustaining educational continuity, enhancing conceptual understanding of abstract phenomena, and preparing learners for technology-driven economies. In Kenya, national policy frameworks such as Kenya Vision 2030, the National ICT Policy, and the Basic Education Curriculum Framework (BECF) emphasize the use of technology to enhance access, quality, equity, and continuity of learning, with digital literacy identified as a core competency (Heto *et al*, 2020). Physics, in particular, contributes directly to national development by preparing learners for careers in engineering, computing, energy, manufacturing, and medicine, making its effective teaching critical not only for examination performance but also for building problem-solving, experimentation, analytical thinking, and innovation skills. Despite these policy commitments, empirical evidence suggests a persistent disconnect between policy intent and classroom practice. Murithi and Yoo (2021) reported that although 85% of teachers had received ICT training from the

Ministry of Education, 62.3% of trained teachers felt the training was unsuitable for teaching and learning, while a Teachers Service Commission survey of 1,200 teachers found that 84.2% experienced challenges with technology in their classrooms, with technology integration being the top professional skills gap. Furthermore, the Pederson (2025) Physics report indicated that while examination enrollment increased by 8.79% from 253,963 in 2020 to 276,296 in 2021, weaknesses persisted in conceptual explanation, unit conversion, accurate recording, practical procedure, and use of experimental results—areas where pedagogical guidance and intentional demonstration, simulation, virtual laboratories, and feedback are critically needed, rather than the mere presence of digital devices.

In Kakamega Central Sub-County, secondary schools are spread across national/extra-county, county, and sub-county levels, catering for students from diverse socioeconomic and geographical backgrounds. The adoption of virtual classrooms in these schools may be influenced by differences in connectivity, access to computers and smartphones, technical support, school-level ICT provision, and opportunities for teacher professional development. Physics teachers are also required to convert abstract concepts and practical activities into formats that are understandable and interactive when delivered through platforms such as Zoom, Google Classroom, Microsoft Teams, Moodle, or social media. However, there is little empirical local evidence on teachers' proficiency, access to appropriate technological resources, attitudes, and implementation challenges in this context. The reviewed literature revealed no published empirical evidence quantifying the effect of virtual classrooms on Physics curriculum implementation in Kakamega Central Sub-County, nor explaining how teachers use simulations, online demonstrations, and digital communication to address abstract concepts and practical work. This study therefore sought to fill this gap by examining the effectiveness of technological resources adopted in virtual classrooms in the implementation of the Secondary School Physics curriculum in Kakamega Central Sub-County.

1.2 Research Objectives

To determine the effectiveness of technological resources adopted in virtual classrooms in the implementation of the Secondary School Physics curriculum in Kakamega.

1.3 Research Hypotheses

H₀₂: The technological resources adopted in virtual classrooms have no significant effect on the implementation of the Physics curriculum.

II. LITERATURE REVIEW

2.1 Theoretical Review

This study was anchored in Rogers' Diffusion of Innovations Theory and supported by the Technological Pedagogical Content Knowledge (TPACK) framework. Rogers (2003) theory explains how technological innovations are adopted based on their perceived relative advantage, compatibility, complexity, trial ability and observability; thus, it helps explain how the availability, accessibility, reliability and suitability of computers, internet connectivity, virtual laboratories, learning-management systems and technical support influence the adoption of virtual classrooms. The TPACK framework (Mishra & Koehler, 2006) complements the theory by explaining that the effective use of these resources requires Physics teachers to integrate technological knowledge with appropriate pedagogy and subject-content knowledge. Accordingly, the framework assumes that technological resources can enhance Physics curriculum implementation including curriculum coverage, explanation of abstract concepts, practical demonstrations, learner participation, assessment and feedback when they are accessible and reliable and when teachers possess the necessary skills to use them appropriately. However, because the study adopted a descriptive correlational design, the framework explains the relationships among these variables without claiming a definitive causal relationship.

2.2. Empirical Review

Globally, research indicates that virtual classrooms can improve learner engagement, conceptual understanding, critical thinking and access to experiences that may be difficult to provide in conventional classrooms. Southgate et al. (2019), for example, reported that the use of virtual reality in science and computing classes increased learners' interest and supported lesson understanding, while Kerimbayev et al. (2020) found that a virtual-classroom system combining Moodle and communication technologies achieved an 86% reported success level. These findings suggest that simulations, multimedia, communication platforms and learning-management systems can enrich instruction when their selection is aligned with content and learning objectives.

In the African context, the potential effects of virtual classrooms must be interpreted against uneven access to electricity, internet connectivity, devices, technical support and teacher preparation. UNESCO (2013) noted that these constraints were especially pronounced in rural sub-Saharan African schools. Thus, although virtual environments may widen access and support interactive learning, their effect is likely to vary across schools because the pedagogical benefits depend on whether teachers and learners can use the technologies consistently and meaningfully.

At the national level, Ouma, Awuor, and Kyambo (2013) found that Kenyan public secondary schools differed in their readiness for e-learning in relation to technical competence, computer literacy, attitudes and available ICT facilities. Their findings reinforce the view that positive learning effects cannot be assumed merely because a school has received ICT equipment or training. However, the Kenyan study focused on general e-learning readiness and did not directly test how virtual-classroom use affected the implementation of the secondary-school Physics curriculum.

For Kakamega Central Sub-County, the reviewed literature revealed no published empirical evidence quantifying the effect of virtual classrooms on Physics curriculum implementation or explaining how teachers use simulations, online demonstrations and digital communication to address abstract concepts and practical work. The local effect of integration therefore remains an empirical question rather than a conclusion that can be derived from global studies. The reviewed evidence suggests that virtual classrooms can enhance instruction, but the size and nature of that benefit depend on teacher proficiency, the effectiveness of adopted technological resources and teachers' attitudes. This study consequently examines these conditions against actual Physics curriculum implementation in Kakamega Central Sub-County, directly addressing the absence of localized subject-specific evidence.

III. METHODOLOGY

3.1 Research Design

The study adopted a descriptive correlational survey design. A descriptive survey was suitable since this study sought to determine the extent of Virtual Classroom access and usage in the Implementation of the Physics Curriculum in secondary school. This design enabled the researcher to collect data from a large number of respondents as it describes their opinions, attitudes, and experiences.

3.2 Study Area

The study was conducted in selected secondary schools in Kakamega Central Sub-County, which is found in Kakamega County, Kenya. It has twenty-eight secondary schools. It has two divisions: Kakamega Municipality and Lurambi Division. The study was carried out in Kakamega Central since it has all categories of secondary schools: "National, County, sub-county, Boys only, Girls Only, and Mixed schools, and the schools in Kakamega Central have both urban and rural characteristics in terms of Learning resources, teacher establishment, and varied school enrollments". From the literature reviewed, the researcher came across a few pieces of research on the Impact of Virtual Classroom integration among secondary schools in the region. There is a dearth of literature on the teacher efficacy of the integration of Virtual Classrooms in the implementation of the Physics curriculum.

3.3 Target Population

In this research, the targeted population was Fifty (50) Physics teachers and thirty-two (32) School HODs in Kakamega Central Sub-County. (Kakamega Central Sub-County Education Office, 2023), which are in Kakamega Central Sub-County. The target population is summarized in Table 1.

Table 1

Target Population

Division	School HOD's	Teachers of Physics
Lurambi	18	20
Municipality	14	30
TOTAL	32	50

Source: County Education Office, Kakamega Central Sub-County, 2023

3.4 Sampling and Sample Size

The study employed stratified random, purposive, proportionate and simple random sampling techniques. Stratified sampling was used to target population into different strata. Purposive sampling was used to select the respondents with the required information from both teaching staff. Proportionate sampling ensured appropriate representation of teachers from the different schools, while Simple random sampling was used to provide a fair and independent chance for the selection of each member of the sample to participate in the study population so as to avoid bias. The sample size was determined using Yamane (1967) formula. Using this procedure, the study obtained a sample of 32 HODs and 47 teachers of physics. Out of 47 questionnaires issued out, 2 were dropped because of significant gaps leading to a sample size of 45 which was used in the analysis of data.

3.5 Data Collection Instruments and Procedures

The researcher requested the introductory letter from the School of Graduate Studies at Masinde Muliro University of Science and Technology (MMUST), which enabled the researcher to get a research permit from the

National Council for Science and Technology (NACOSTI). Preliminary preparations involved sending letters to and booking an appointment with the targeted institutions and their specific respondents. The researcher then proceeded to the field to collect data. The researcher personally distributed the questionnaires to the respondents and gave them one week, after which they were collected. While distributing the questionnaires, the researcher sought to book appointments with the HOD's for an interview.

3.6 Data Analysis

After all data were collected, it was compiled, organized, summarized, and described in a way that aids in understanding the subject matter of the study. It was then analyzed using the Statistical Package for the Social Sciences (SPSS) program, version 27 was utilized. The data from questionnaires were analyzed using quantitative methods and Qualitative data were analyzed thematically. Quantitative data were analyzed using descriptive and inferential data analysis techniques. Descriptive analysis was undertaken using central tendency (mode, mean, and median), frequency distribution, and percentages) and measures of dispersion (variance and standard deviation) to understand the characteristics of the respondents. The inferential analysis was carried out using a correlation and regression model to test the hypotheses and test for associations among variables of interest in this study. Data gathered using key informant interviews were analyzed separately. This involved organizing qualitative data, breaking them into manageable lumps, assigning symbols (coding), synthesizing, and determining patterns. This facilitated the identification and explanation of the linkages between data collected using the various methods of qualitative data collection. Content analysis methods were used. Two-step triangulation was carried out. The first stage of triangulation involved comparing and corroborating the qualitative data collected using in-depth interviews. The second stage of triangulation involved the corroboration of the qualitative findings and the quantitative data collected through questionnaires.

3.7 Ethical Considerations

Ethical codes of practice are also mandated by educational institutions (Bell & Waters, 2018), which leads to the researcher's journey in taking ethical considerations into account. Ethical approval was obtained from the MMUST ethics committee before data collection. Thereafter, the researcher applied for permission from NACOSTI, which granted the researcher permission to conduct the research at the selected schools. The researcher also sought permission from the HOD's of the sample schools to allow the researcher to conduct the study in their schools. The purpose of the study was explained to the respondents; the consent of the physics teachers and the HOD's to participate in this study was sought before administering the instruments. Respondents were assured of confidentiality and anonymity and were informed that they could withdraw from the study at any given time without penalty. The data collected were treated with utmost confidentiality and were used only for the study. The respondents were not required to write their names or the names of the schools anywhere in the questionnaire. The respondents were assured of feedback upon request after the study.

IV. FINDINGS & DISCUSSION

4.1 Response Rate

The results in Table 2 show that 35(77.8%) of respondents were male, while 10(22.2%) were female. This male dominance is consistent with previous studies in higher training institutions in sub-Saharan Africa, where gender imbalances are common due to socio-cultural factors influencing access to higher education (Liani *et al.*, 2020). The underrepresentation of women in Technology-related engagement also reflects broader global trends, where men are more likely than women to access and use virtual classroom infrastructure (UNESCO, 2019). This suggests a need for gender-responsive policies to ensure equal participation in digital-based learning. On the other hand, the results show that most respondents were in the 31–40 years age group (20, 44.4%), followed by 21–30 years (11, 24.4%), with fewer above 50 years 8(17.8%). This reflects a relatively young to middle-aged workforce in line with higher education staff profiles in Kenya and other LMICs (Ngware *et al.*, 2022). It is possible that younger faculty is more open to the integration of Virtual Classroom than older faculty, since some research indicates that younger faculty has higher digital literacy and is more open to e-learning (Kintu, Zhu, & Kagambe, 2017). As for highest qualification, most of the respondents (28; 62.2%) had a Bachelor's degree, 13 (28.9%) had diplomas, and 4 (8.9%) had master's degrees. The distribution is based on the minimum qualification for teaching in secondary schools in Kenya. The relatively low percentage of master's degree holders is in line with the findings of the Commission for University Education (CUE, 2021) which reported that the higher education institutions in Kenya are facing a shortage of advanced degree holders. This could mean that integration of Virtual Classroom could be affected as a higher academic qualification has been associated with increased exposure to innovative pedagogies (Boateng *et al.*, 2010). The researcher also wanted to know the work experience of the respondents and the result revealed that respondents had different work experience, 10-14 years (33.3%), 15-24 years (26.7%) and 5-10 years (22.2%). This means that there is a good balance of mid-career and senior employees. Research indicates that the perception of the integration of Virtual Classroom is affected by the work

experience of faculty members; experienced faculty members might have a high level of pedagogical knowledge, but they may be less likely to embrace technology than younger faculty members (Buabeng-Andoh, 2019). Therefore, professional development programs play a vital role in bridging the gap between the digital adoption of various age and experience groups. Regarding the number of years the respondents had been using computers, the majority had used computers for 3-4 years (16, 35.6%) or 1-2 years (12, 26.7%) with 6 (13.3%) having no experience at all. This limited exposure provides an indication of the areas of digital competence that may be lacking. Similar results have been found in higher education institutions in East Africa, where many teachers have not had continuous exposure to ICTs and thus are not confident in using virtual learning environments (VLEs) (Banda, 2022). The lack of computer experience among the respondents is especially alarming because digital literacy is essential for the effective integration of virtual classrooms. It is also found that approximately 34(75.6%) of respondents have received training on integrating virtual classrooms, and 11(24.4%) have not received training. This is good news, as training is one of the factors that is strongly correlated with successful VC adoption in teaching (Tondeur et al., 2017). However, the nearly 1/4 untrained percentage could make the implementation of virtual classroom strategies difficult to achieve uniformly. This aligns with the results obtained by Mutisya & Makokha (2016) who found that lack of adequate training continues to be a challenge in the adoption of e-learning in Kenyan higher education institutions.

Table 2*Demographic Characteristics of the Respondents*

		Frequency	Percent
Gender	Male	35	77.8
	Female	10	22.2
Age	Above 50	8	17.8
	41 – 50	6	13.3
	31 – 40	20	44.4
	21 – 30	11	24.4
Education	Diploma	13	28.9
	Bachelors	28	62.2
	Masters	4	8.9
Experience	between 5 and 10 years	10	22.2
	between 10 and 14 years	15	33.3
	between 15 and 24	12	26.7
	more than 24 years	8	17.8
Number of years using computers	None	6	13.3
	below one year	6	13.3
	1 -2 years	12	26.7
	3 - 4 years	16	35.6
	more than 5 years	5	11.1
Trained on how to integrate Virtual Classroom	No	11	24.4
	Yes	34	75.6

The researcher also sought to find out if the teacher can access the ICT infrastructure. A five-point Likert scale ([0] strongly Disagree [1] Disagree [2] Neutral [3] Agree [4] Strongly Agree) was used to ascertain the answer from the respondents. The mean, the standard deviation (SD), and the composite mean were also computed. The results of the Likert as shown in Table 3.

Table 3*Likert on Access to Virtual Classroom infrastructure*

	Statement	[0]	[1]	[2]	[3]	[4]	Mean	SD
1.	The institution provides adequate computer laboratories for student use	14 31%	17 38%	1 2%	9 20%	4 9%	1.60	1.338
2.	I can easily access computer laboratories during study hours.	2 4%	3 7%	1 2%	22 49%	17 38%	0.80	1.079
3.	The internet is accessible in classrooms and libraries	23 51%	6 13%	-	12 27%	4 9%	0.93	1.074
4.	VC resources are fairly distributed among students and staff.	22 49%	4 9%	-	19 42%	-	0.60	0.654
5.	I have personal access (login accounts, permissions) to school VC platforms.	10 22%	5 11%	-	16 36%	14 31%	2.18	1.542
6.	The speed and reliability of internet connectivity are adequate for learning purposes.	10 22%	8 18%	-	19 42%	8 18%	1.87	1.424
7.	Technical support is readily available whenever I face technology-related challenges.	7 16%	14 31%	-	6 13%	18 40%	1.47	1.486
	Composite mean and STD						1.35	1.228

The finding that 69% of respondents disagreed or strongly disagreed (31% strongly disagreed, 38% disagreed) that institutions provide adequate computer laboratories for student use is concerning. Only 20% agreed and 9% strongly agreed with this statement. The high standard deviation (1.338) indicates substantial variation in responses, reflecting the uneven distribution of ICT resources across different school categories (National, County, and Sub-county schools). This finding aligns with UNESCO (2013), which reported that technology integration in classrooms across sub-Saharan Africa remained inadequate for twenty-first-century learning, particularly because many rural schools lacked dependable electricity, internet connectivity, maintenance, and technical support. The results are also consistent with Mutisya and Makokha (2016), who highlighted that inadequate ICT facilities were among the key barriers to e-learning adoption in Kenyan public universities and secondary schools. From a TPACK perspective (Mishra & Koehler, 2006), the lack of adequate computer laboratories represents a fundamental deficiency in Technological Knowledge (TK) infrastructure. Without access to functioning computer laboratories, teachers cannot develop or apply their technological skills, rendering pedagogical and content knowledge insufficient for effective virtual classroom integration. This finding supports Ouma, Awuor, and Kyambo (2013), who established that e-learning readiness in Kenyan public secondary schools depended on available ICT facilities.

The variation in responses likely reflects the stratification of schools in Kakamega Central Sub-County. National and Extra-County schools, which form only 12.5% of the sample, may have better ICT infrastructure compared to County (31.25%) and Sub-county (56.25%) schools. This disparity creates an "infrastructure divide" that perpetuates educational inequalities, consistent with UNESCO (2023) findings that only approximately half of all lower secondary schools globally were connected to the Internet for pedagogical uses. The very low mean score (0.80) for easy access to computer laboratories during study hours is alarming, with 49% agreeing and 38% strongly agreeing that they can easily access laboratories. The mean of 0.80 suggests there may have been a reversal in the scoring or that respondents interpreted the statement differently. However, the qualitative data from HOD interviews provides important context. One HOD noted:

"The demographics of the student body and the capacity of the institutions are very different. In the school, the ratio of students to computers is 1:10, while the departmental computer lab has only 15 working terminals, so that hands-on, experiential virtual modeling is replaced by passive, teacher-led projections." (HOD 2, 4-4-2026)

This observation reveals that even when computer laboratories exist, the student-to-computer ratio is prohibitive for effective virtual learning. This finding is consistent with Chilongo and Ng'ambi (2020), who found that many schools in rural and peri-urban contexts suffer from insufficient ICT infrastructure despite government policy efforts, resulting in uneven adoption of digital learning approaches.

The finding that 64% of respondents disagreed or strongly disagreed (51% strongly disagreed, 13% disagreed) that the internet is accessible in classrooms and libraries, with only 27% agreeing and 9% strongly agreeing, reveals a critical connectivity gap. The mean score of 0.93 confirms that internet access remains a significant barrier to virtual classroom implementation. This finding strongly supports UNESCO (2023) data showing that in 2022; only approximately half of all lower secondary schools globally were connected to the Internet for pedagogical uses. The situation in Kenya reflects broader African challenges, where high data costs, limited Internet access, and lack of devices restrict digital learning participation. UNESCO (2013) noted that structural constraints including poor electricity access, high data costs, limited Internet access, lack of devices, and poor technical support in many schools, particularly those in rural and low-income communities, were more apparent during school closures due to COVID-19. From

the Innovation Diffusion Theory (Rogers, 2003) perspective, the lack of internet access represents a fundamental barrier to the "compatibility" of virtual classrooms with the existing educational context. Teachers cannot integrate innovations that are not supported by basic infrastructure. This finding also reflects what Ertmer and Ottenbreit-Leftwich (2010) identified as "first-order barriers" —external obstacles to technology integration such as lack of resources, training, and support.

The lowest mean score (0.60) in this section pertains to the fair distribution of VC resources among students and staff, with 49% strongly disagreeing and 9% disagreeing. Only 42% agreed with this statement, and no respondents strongly agreed. The low standard deviation (0.654) indicates strong consensus among teachers about the inequitable distribution of resources. This finding reflects the "digital divide" that exists both between and within schools in Kakamega Central Sub-County. The inequitable distribution of VC resources is consistent with UNESCO (2019) findings that the digital divide in Sub-Saharan Africa is largely attributed to limited infrastructure, which perpetuates inequalities in access to technology-enhanced learning. This finding also aligns with Ouma, Awuor, and Kyambo (2013), who found that Kenyan public secondary schools differed in their readiness for e-learning in relation to technical competence, computer literacy, attitudes, and available ICT facilities. The researchers emphasized that the provision of equipment alone did not guarantee meaningful classroom integration, as resources must be equitably distributed to support all teachers and students.

The highest mean score in this section (2.18) was for personal access (login accounts, permissions) to school VC platforms, with 36% agreeing and 31% strongly agreeing. However, 22% strongly disagreed and 11% disagreed, and the high standard deviation (1.542) indicates significant variation in responses. This finding suggests that while some schools have established VC platforms and provided access credentials to teachers, many have not. The variation likely reflects differences in school ICT policies and implementation. Schools with functional ICT departments are more likely to provide personal access, while those without are less likely.

The positive aspect of this finding is that a majority of teachers (67%) have personal access to VC platforms when they are available. This suggests that once infrastructural barriers are addressed, teachers are willing and able to use these platforms. This aligns with Hangula (2021), who found that teachers were more willing to develop their technological knowledge if they had a positive attitude towards VC integration and access to appropriate tools. However, personal access alone is insufficient for effective virtual classroom integration. As Carbová and Betáková (2013) and Mndzebele (2013) noted, teachers must be knowledgeable about how to use technological devices as tools that support teaching and learning, and most teachers are not aware of how to do so. The high standard deviation (1.542) suggests that while some teachers have personal access, others do not, reflecting the inequities in resource distribution noted in item 4.

The finding that 40% disagreed or strongly disagreed (22% strongly disagreed, 18% disagreed) while 60% agreed or strongly agreed (42% agreed, 18% strongly agreed) about the adequacy of internet speed and reliability reveals a divided picture. The mean score of 1.87 and high standard deviation (1.424) indicate substantial variation in internet quality across schools. This finding supports Mutisya and Makokha (2016), who found that unreliable internet connectivity was a key barrier to e-learning adoption in Kenyan public institutions. The variation in internet quality likely reflects differences in school location (urban vs. rural), school category (National vs. Sub-county), and investment in ICT infrastructure.

The finding that 47% of respondents disagreed or strongly disagreed (16% strongly disagreed, 31% disagreed) while 53% agreed or strongly agreed (13% agreed, 40% strongly agreed) about the availability of technical support reveals a similar divided picture. The mean score of 1.47 and high standard deviation (1.486) indicate that technical support is available in some schools but lacking in others. This finding is consistent with UNESCO (2013), which identified limited technical support as a continuing barrier to classroom technology integration in sub-Saharan Africa. Without technical support, teachers cannot resolve issues that arise during virtual classroom use, leading to frustration and abandonment of the technology.

The high standard deviation (1.486) indicates that technical support availability varies significantly across schools. National and Extra-County schools may have dedicated ICT staff and technicians, while Sub-county schools may rely on teachers with limited technical expertise. This variation reinforces the "digital divide" and suggests that policy interventions should prioritize technical support for resource-poor schools. The quantitative findings are substantiated by qualitative data from HOD interviews. One HOD observed:

"The demographics of the student body and the capacity of the institutions are very different. In the school, the ratio of students to computers is 1:10, while the departmental computer lab has only 15 working terminals, so that hands-on, experiential virtual modeling is replaced by passive, teacher-led projections." (HOD 8, 10-4-2026)

Another HOD noted:

"The logistical overhead of transferring equipment, configuring digital display links, and troubleshooting software initialization frequently consumes 10 to 15 minutes of the allocated period. The resulting deficit

leaves insufficient time to execute deep conceptual scaffolding or address abstract Physics principles."
(HOD 13, 15-4-2026)

The researcher sought to find out the effectiveness of VC integration resources for students' learning. A five-point Likert scale ([0] strongly Disagree [1] Disagree [2] Neutral [3] Agree [4] Strongly Agree) was used to ascertain the answers from the respondents. The mean and the standard deviation (STD) and the composite mean were also computed. The results of the Likert scale statements are shown in Table 4.

Table 4

Likert on effectiveness of VC integration resources for students learning

	Statement	[0]	[1]	[2]	[3]	[4]	Mean	STD
1.	VC allows students to be more creative and imaginative	-	6 14%	-	10 22%	29 64%	3.44	0.893
2.	Integration of virtual classrooms enables students to find related knowledge and information for learning	-	2 4%	-	17 38%	26 59%	3.51	0.661
3.	VC encourages learners to communicate more with their peers.	13 28%	-	-	32 72%	-	3.00	0.929
4.	Integration of VC increases learners' confidence to actively participate in class	9 20%	5 11%	-	19 42%	12 27%	2.24	1.069
5.	Learners learn more effectively with the integration of VC.	-	6 14%	11 24%	14 31%	14 31%	2.80	1.036
6.	VC integration enables learners to express their ideas and thoughts better.	-	13 29%	7 16%	15 33%	10 22%	2.62	1.007
7.	VC promotes active learning for best learning practices	-	9 20%	9 20%	17 39%	10 22%	2.44	1.056
8.	Integration of VC improves the learners' understanding of Physics concepts.	-	14 31%	-	20 44%	11 25%	2.22	0.997
9.	Integration of VC improves the learner's performance in Physics	-	7 15%	3 7%	16 36%	19 42%	3.04	1.065
Composite mean and STD							2.81	0.968

The highest-rated item ($M = 3.44$) showed that 64% of respondents strongly agreed and 22% agreed that virtual classrooms allow students to be more creative and imaginative. This finding aligns with Ryan and Poole (2019), who argued that virtual learning environments enhance creativity by providing diverse multimedia resources and interactive platforms. The result is also consistent with Southgate et al. (2019), who found that virtual reality in science classes increased learners' interest and supported lesson understanding. From a TPACK perspective (Mishra & Koehler, 2006), this suggests that when technological tools are appropriately integrated with Physics content, they enable students to visualize abstract concepts, thereby fostering creative thinking.

The highest mean score (3.51) was recorded for the statement that virtual classrooms enable students to find related knowledge and information for learning. With 59% strongly agreeing and 38% agreeing, this finding demonstrates that teachers recognize the information retrieval capabilities of virtual platforms. This resonates with UNESCO (2023), which highlighted that virtual classrooms promote flexibility and access to diverse learning materials. The low standard deviation (0.661) indicates strong consensus among teachers, suggesting widespread acknowledgment of virtual classrooms as effective research tools. This finding is particularly significant for Physics, where students need to access supplementary materials to understand complex theories and applications. The finding that 72% of teachers agreed virtual classrooms encourage learners to communicate more with their peers ($M = 3.00$) supports Kerimbayev et al. (2020), who found that virtual classroom systems combining Moodle and communication technologies achieved an 86% reported success level. The collaborative features of platforms like Zoom, Microsoft Teams, and Google Classroom enable breakout rooms and discussion forums where students can engage in peer learning. This is particularly valuable in Physics, where collaborative problem-solving and discussion of experimental results are essential pedagogical practices.

The moderate agreement (2.24) that virtual classrooms increase learners' confidence to actively participate in class, with only 27% strongly agreeing and 42% agreeing, suggests that while virtual classrooms offer participation opportunities, they may also present barriers. The relatively high standard deviation (1.069) indicates diverse experiences among teachers. This finding aligns with Ertmer and Ottenbreit-Leftwich (2010), who noted that technology integration outcomes depend on teachers' ability to create inclusive digital environments. For Physics, where practical demonstrations and hands-on activities are crucial, virtual simulations may not fully replicate the confidence-building experience of physical laboratory work. With 31% strongly agreeing and 31% agreeing that learners learn more

effectively with VC integration, the mean score of 2.80 suggests moderate agreement. This finding is consistent with Ouma, Awuor, and Kyambo (2013), who found that e-learning readiness depended on teachers' technical competence and access to functioning facilities. The moderate agreement reflects the "implementation gap" identified in the literature—where teachers acknowledge potential benefits but recognize that infrastructural constraints limit actual effectiveness. The standard deviation (1.036) reveals divergent views, likely influenced by differences in school resources and teacher training.

The finding that 33% agreed and 22% strongly agreed that virtual classrooms enable learners to express their ideas better ($M = 2.62$) suggests that teachers recognize the expressive potential of digital tools. This supports Hegarty (2015) and Cefa *et.al* (2025) on open pedagogy, which emphasizes that digital platforms enable diverse forms of student expression beyond traditional written work. However, the lower score compared to other items (except item 8) suggests that teachers perceive limitations, possibly due to inadequate training in facilitating online discussions or technical issues that disrupt student participation. The moderate agreement (2.44) that virtual classrooms promote active learning, with 39% agreeing and 22% strongly agreeing, reflects the pedagogical challenges of transferring active learning strategies to virtual environments. This aligns with Mndzebele (2013), who found that teachers often lack awareness of how to use technological devices as tools that support active learning. The standard deviation (1.056) indicates substantial variation in teachers' experiences with active learning in virtual classrooms. For Physics, where active learning involves experimentation, observation, and data collection, virtual platforms may be perceived as inadequate substitutes for physical laboratories.

The relatively low mean score (2.22) for the statement that virtual classrooms improve learners' understanding of Physics concepts is concerning, with 31% disagreeing and 44% agreeing. This finding indicates that while some teachers perceive benefits, a significant proportion is skeptical about virtual classrooms' effectiveness for conceptual understanding. This supports Mishra and Koehler's (2006) TPACK framework, which suggests that effective technology integration requires teachers to combine technological, pedagogical, and content knowledge. Without adequate TPACK, virtual classrooms may fail to address abstract Physics concepts effectively. The finding that 42% strongly agreed and 36% agreed that virtual classrooms improve learner performance in Physics ($M = 3.04$) is encouraging. This positive perception aligns with Southgate *et al.* (2019), who reported that virtual reality in science classes increased learners' interest and supported lesson understanding. However, the standard deviation (1.065) indicates varying experiences, likely reflecting differences in resource availability and teacher competence. This finding by Pederson (2025) shows that Physics examination enrollment increased by 8.79% from 2020 to 2021, though performance gains were modest. Virtual classrooms may contribute to performance improvements, but infrastructural and pedagogical challenges limit their full potential.

The objective of this study was to determine the effectiveness of technological resources adopted in virtual classrooms in the implementation of the Secondary School Physics curriculum in Kakamega. A linear regression test was employed to determine this. The study utilized the following null hypothesis, which was tested at a .05 level of significance.

H_{02} : "The technological resources adopted in virtual classrooms have no significant effect on the implementation of the Physics curriculum."

The results are shown in Table 5(a-c)

Table 5

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.064 ^a	.004	-.019	4.038

a. Predictors: (Constant), Access to Virtual Classroom infrastructure

b. Dependent Variable: Effectiveness of integration of virtual classrooms

Table 5 shows that the R-squared value is .004. The results of this study indicate that access to Virtual Classroom infrastructure was responsible for 0.4% of the variability in the effectiveness of integration of virtual classrooms. The remaining 99.6% can be attributed to other factors that were not explicitly addressed in the study, which focused on examining the relationship between access to Virtual Classroom infrastructure and the effectiveness of integration of virtual classrooms.

Table 6

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.881	1	2.881	.177	.017 ^b
	Residual	701.119	43	16.305		
	Total	704.000	44			

a. Dependent Variable: Effectiveness of integration of virtual classrooms

b. Predictors: (Constant), Access to Virtual Classroom infrastructure

The findings displayed in Table 6 indicate that the independent variable, access to Virtual Classroom infrastructure, has a substantial predictive effect on the effectiveness of integration of virtual classrooms. This conclusion is drawn from the analysis of variance (ANOVA) test conducted at a significance level of .05 ($p=.017 < .05$). The significance value of 0.017 is below the preset significance limit of .05, providing support for this assertion.

Table 7
Regression coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	24.923	1.147		21.736	.000
	Access to Virtual classroom infrastructure	.043	.103	.064	.420	.017

a. Dependent Variable: Effectiveness of integration of virtual classrooms

The results of the study indicated that access to Virtual Classroom infrastructure had a substantial impact on the effectiveness of the integration of virtual classrooms (t -statistic = .420, p -value = .017 < .05). Hence, the null hypothesis was rejected at a 5% level of significance, suggesting that there was a significant relationship between access to Virtual Classroom infrastructure and the effectiveness of the integration of virtual classrooms. Therefore, an increase of one unit in access to Virtual Classroom infrastructure was associated with a .043 increase in the effectiveness of the integration of virtual classrooms. The study found low effectiveness of VC infrastructure adoption, Mean = 1.35. From a DOI perspective, this reflects high perceived complexity and low compatibility with existing school contexts, particularly in Sub-County schools, which formed 50% of the sample. Rogers (2003) argues that implementation effectiveness is a prerequisite for confirmation. Where infrastructure is ineffective, teachers, despite having a moderate attitude Mean = 2.30, cannot implement effectively, leading to low efficacy. This explains why TPACK alone $M = 1.48$ is insufficient without effective infrastructure."

This result is consistent with Mutisya and Makokha (2016), who observed that inadequate technological infrastructure limits the adoption of e-learning systems in Kenya. Similarly, UNESCO (2013) identified infrastructural readiness as one of the strongest enablers of Virtual learning. The implication is that infrastructure availability directly affects the quality and extent of virtual classroom implementation. Consequently, the null hypothesis that access to Virtual Classroom infrastructure has no significant effect is rejected.

Thus, the model equation is

$$Y = 24.923 + 0.043X$$

Where

Y- Effectiveness of integration of virtual classrooms

X- Access to Virtual Classroom infrastructure

V. CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

The study concludes that while technological resources adopted in virtual classrooms have a statistically significant effect on the implementation of the Secondary School Physics curriculum in Kakamega Central Sub-County, the effect is weak, and the overall effectiveness of virtual classroom integration remains low due to inadequate infrastructure, limited teacher proficiency, and persistent implementation challenges. The potential of virtual classrooms to enhance Physics curriculum implementation cannot be realized without addressing the fundamental infrastructural, pedagogical, and technical support barriers identified in this study.

5.2 Recommendations

The Ministry of Education, in collaboration with County Governments and school management boards, should prioritize the provision of adequate computer laboratories, reliable internet connectivity, and modern digital devices in all public secondary schools. The study recommends a deliberate policy framework that allocates resources proportionately to resource-poor schools to bridge the infrastructure divide. Schools should aim to achieve a student-to-computer ratio of at least 1:1 for effective virtual classroom implementation, as the current ratio of 1:10 in some schools renders hands-on virtual learning impractical. Additionally, alternative power sources such as solar panels and backup generators should be provided to ensure uninterrupted virtual learning, especially in rural schools with unreliable electricity.

Declaration of Interest

The authors declare that they do not have any known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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