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Availability and Accessibility of Virtual Laboratories in Secondary Schools in Likuyani, Kakamega County, Kenya, During the 2025 Academic Year

Jacob W. Kachi[1], Samikwo Dinah[1], Jeruto Pascaline[2], Charles Nyarang'o Nyamwamu[2]

[1.] School of Education, Centre for Teacher Education Department, University of Eldoret, P. O. Box 1125 Eldoret, Kenya.

[2.] School of Science, Biological Sciences Department, University of Eldoret, P. O. Box 1125 Eldoret, Kenya.

ABSTRACT :

Although Biology plays a central role in the science curriculum and aligns closely with Kenya's national development priorities, the subject continues to register persistently poor performance among secondary school students in national examinations across all three papers. For instance, there has been persistent low Biology performance among learners in Likuyani Sub-County, Kakamega County. Thus, this study sought to assess the availability and accessibility of virtual laboratories in secondary schools in Likuyani, Kakamega County, Kenya, during the 2024 academic year. The target population comprised 2,886 Form Four Biology students in Likuyani Sub-County. Using Cochran's formula and finite population correction, a sample of 339 students was sampled drawn from 11 strategically sampled schools. Data were collected through questionnaires and analyzed using both descriptive (frequencies and percentages) and inferential (Chi-square) statistics. Instrument reliability was ensured through test-retest procedures and Cronbach's alpha. The chi-square test revealed a significant limitation in access to virtual laboratories among students ($\chi^2 = 124.58$, df = 1, $p < 0.05$), leading to the rejection of the null hypothesis. This confirmed the inequitable availability and accessibility of virtual labs in secondary schools. The study concluded that inequitable access to ICT resources and limited institutional support hinder the uniform adoption of VLBI, despite its proven potential to improve Biology learning outcomes. The study recommends that equitable ICT provision, teacher training, increased institutional support, and effective monitoring mechanisms are essential for sustainable and inclusive VLBI integration. Thus, these insights are critical for curriculum developers, policymakers and educators committed to improving science education outcomes through innovative instructional strategies.

Key Words: Accessibility, Biology Education, ICT Integration, Likuyani, Virtual Laboratory

INTRODUCTION

Virtual laboratories (V-Labs) are interactive, web-based or software-driven simulation environments that let students perform experiments, manipulate variables, observe outcomes, and repeat procedures without needing physical equipment (Radhamani et al., 2021). Over the last decade V-Labs have moved from niche research tools to mainstream educational resources because they can reproduce complex phenomena, reduce costs, and allow anytime/anywhere access to experimental learning (Deriba et al., 2024). Their uptake accelerated sharply during the COVID-19 pandemic when physical labs were inaccessible and educators turned to virtual alternatives to maintain continuity of practical science education (Schechter, 2023).

According to Raman et al., (2022), Virtual laboratories (VLs) have become an established complement to physical labs worldwide, especially after COVID-19 pushed remote and blended instruction. Bibliometric and review studies show rapid growth in VL research and deployment across education levels, and scholars highlight VLs' strengths for safe, repeatable, cost-effective experimentation and for widening access where physical facilities are limited. At the same time, reviews note persistent inequities in access (infrastructure, connectivity, teacher readiness) that shape how effectively VLs reach secondary learners (Alabi et al., 2025).

Pedagogically, virtual labs have been shown to support conceptual understanding, pre-lab preparation, and learner confidence; they often improve students' performance when used as supplements to hands-on work (Radhamani et al., 2021). For secondary schools where curriculum time, safety concerns, and resource constraints often limit hands-on opportunities V-Labs can offer configurable, risk-free practice that scaffolds inquiry and experimentation (Alhashem & Alfailakawi, 2023). Importantly, empirical studies report positive attitudinal shifts among teachers and learners when V-Labs are integrated with instruction, though results vary by design quality and teacher readiness.

Despite these benefits, availability and equitable accessibility remain inconsistent. Systematic reviews highlight that most V-Lab research and development has focused on higher education rather than K-12, and that accessibility issues (internet connectivity, device compatibility, inclusive design for learners with disabilities, and lack of localized content) persist creating an uneven landscape for secondary schools globally (Deriba et al., 2024). Infrastructure gaps (poor bandwidth, lack of devices), low teacher training in digital pedagogy, and limited integration with national curricula are frequently cited barriers to broad adoption in under-resourced secondary schools (Raman et al., 2022).

In America most school and private providers (and via widely used OERs such as PhET and commercial platforms such as Labster) virtual simulations are routinely used to supplement high-school science teaching; evidence from large platform reports and empirical studies point to measurable gains in engagement and learning when VLs are well integrated, but adoption remains uneven because of differences in device access, broadband, and teacher training (Tsirulnikov et al, 2023; Schechter, 2023).

According to the Times of India, (2025), recent large-scale deployments and targeted projects show how policy and investment can change the picture rapidly: governments and ministries (and some NGOs/universities) have begun offering curated virtual lab collections mapped to school syllabuses examples include regional deployments and platform rollouts that aim to reach many schools at once yet these programmes still face the familiar constraints of teacher upskilling and connectivity (news reports of government virtual-lab rollouts illustrate this trend). For secondary school decision-makers, the implication is clear: V-Labs can expand practical science access, but success depends on (1) reliable infrastructure and devices, (2) teacher professional development and curricular alignment, and (3) accessible design (multilingual and disability-inclusive) and locally relevant content.

Studies in Nigeria reported both promising pedagogical effects and practical barriers: intervention studies show VLs can improve achievement and attitudes in chemistry and physics where used, but large gaps in school infrastructure (power, devices, internet), variability in teacher ICT skills, and limited scale funding mean VL availability and accessibility remain highly uneven across states and school types. Recent studies and quasi-experimental evaluations document positive learning outcomes when VLs are implemented, while implementation reports call for targeted investments (Anari et al., (2025).

South African studies (especially in rural and marginalized contexts) have found that VLs can substantially expand access to experiments where physical equipment is scarce and that teacher perceptions are generally positive; however, research also highlights adoption barriers poor connectivity, limited TPACK (technological-pedagogical content knowledge) among some teachers, and unequal distribution between urban and rural schools. Implementation studies recommend contextualized roll-out, teacher training and offline/low-bandwidth VL options (Shambare & Jita 2025).

In Tanzania, quasi-experimental work and regional studies (e.g., chemistry education in Dodoma and related research) indicated that virtual lab packages can produce significant improvements in conceptual understanding and test scores for secondary students, especially when VLs are blended with classroom instruction; yet reports from Tanzania underscore the need for local content alignment and access strategies for low-connectivity schools (Munyilizu, 2023).

Kenyan studies and recent implementation reports showed growing interest and pilot activity: controlled studies in several counties report improved physics/biology outcomes where VL-based instruction was used and government/NGO training initiatives (teacher training in counties such as Wajir and pilot deployments) indicate steps toward scale (Okono et al., 2023). Nevertheless, nationwide availability is limited by the same obstacles seen elsewhere in Sub-Saharan Africa electricity, devices, bandwidth, and sustained CPD for teachers so accessibility remains highly variable across counties and school types (Alabi et al., 2025).

MATERIALS AND METHODS

Research Design

The study adopted descriptive survey. The survey captured ICT availability. Together, these designs ensured both empirical rigor and contextual depth.

Target Population

The target population comprised 2,482 Form Four Biology students and 34 public secondary schools in Likuyani Sub-County.

Sampling Techniques and sample size

Schools were selected through convenience sampling across Likuyani North, Central, and South zones, ensuring regional representation. Purposive sampling was applied to include boys', girls', and mixed schools in each zone, while one national school from Butere Sub-County was added for insights on existing virtual lab use. In total, 11 schools (26.47% of 34) were sampled as shown in Table 1.

Table 1: Schools distribution by zones

ZONES	Number Of Schools	Sampled Schools (N)	Percentage (%)
Likuyani North	11	3	27.27
Likuyani Central	11	4	27.27
Likuyani South	12	4	25.00
Total no of Schools	**34**	**11**	**26.47**

Source: Likuyani Sub-County Education Office, (2025)

This sampling proportion aligns with the recommendations by Creswell and Creswell (2023), who suggest that a sample size of 10-20% is usually sufficient in descriptive studies, particularly in small populations. Similarly, Mugenda and Mugenda, (2018) and Willie, (2024) emphasized that sample proportions within this range strike a balance between feasibility and statistical validity in educational and health-related research, recommending proportions between 10-30% depending on the research context.

From the selected schools, Form Four students studying Biology were selected by simple random sampling. The lottery method was employed: slips of paper marked "Yes" or "No" were folded and given out, and those getting "Yes" constituted the final sample, while those getting "No" were not included. This ensured the selection of student respondents without bias.

Sample Size

Using Cochran's formula with finite correction, a student sample of 339 was derived. The final sample included 339 students across 11 schools, representing 12.86% of the student population and aligning with recommended ranges for educational research. In order to arrive at a suitable sample size, Cochran's formula for estimating the sample size was used, with a 95% confidence level and a margin of error of 5%. The formula is:

$$n_0 = \frac{Z^2 - p \text{-} q}{e^2}$$

Where:

- n_0 = Initial sample size (for an assumed infinite population)
- Z = Z-score corresponding to the desired confidence level (1.96 for 95%)
- p = Estimated proportion of the population with the characteristic of interest (0.5 used for maximum variability)
- q=1−p = Complement of p
- e = Desired margin of error (0.05)

Example Calculation:

$$n_0 = \frac{(1.96)^2 \times 0.5 \times 0.5}{(0.05)^2} = \frac{3.8416 \times 0\ .25}{0.0025} = \frac{0.9604}{0.0025} = 384.16 \approx 384$$

Since the actual population size is finite (N = 2,886 Form Four Biology students), a finite population correction was applied:

$$n = \frac{n_0}{1+\left(\frac{n_0 - 1}{N}\right)} = \frac{384}{1+\left(\frac{383}{2886}\right)} = \frac{384}{1+0.1327} \approx \frac{384}{1.1327} \approx 339$$

The final sample for the study comprised approximately 339 Form Four Biology students, corresponding to 12.86% of the population in this category. This percentage falls within the recommended range of 10% to 20% for quasi-experimental research designs, which implies that both feasibility and reliability are possible in educational research (Adebayo & Musyoka, 2022).

Data collection

The student questionnaire was distributed to gather information on how the use of virtual laboratories influenced their academic performance. The questionnaire included both closed- and open-ended questions, allowing for the collection of quantitative data (e.g., academic performance) and qualitative data (e.g., students' perceptions and experiences). The questionnaire was developed by the researcher, drawing from relevant literature and previous studies such as those conducted by Smith and Brown (2023) which demonstrated that questionnaires are effective tools for collecting subjective data like attitudes and perceptions. To ensure validity, the questionnaire was first reviewed by subject matter experts in Biology education and then piloted with a small group of students from the same target population. Feedback from the pilot group led to improvements in clarity and coherence. The final version of the questionnaire consisted of closed-ended items (e.g., Likert-scale questions assessing students' perceptions of virtual labs) and open-ended items designed to capture detailed feedback about their experiences. The questionnaires were administered during regular Biology classes. A friendly introductory note explained the purpose of the study, guaranteed confidentiality, and emphasized the voluntary nature of participation. Completed questionnaires were collected on-site immediately after completion, resulting in a response rate of 97%, thereby ensuring the representativeness and reliability of the data.

Data Analysis

Comparison of academic performance between students taught using Virtual Laboratory-Based Instruction (VLBI) and those taught via traditional laboratory methods was done. Descriptive statistics (frequencies and percentages) and inferentially (Chi-square test).

RESULTS

Availability of ICT Resource Center and Access to Virtual Laboratory Resources

Majority of students (79.9%) reported access to virtual laboratory resources, whereas 20.1% lacked such access (Figure 1). This indicates substantial progress in integrating ICT tools to support Biology instruction in secondary schools. However, the data also reveal that one in five students lacked access to virtual laboratory facilities. This points to ongoing disparities in ICT infrastructure and resource availability across schools. Addressing these gaps is essential for ensuring equitable implementation of Virtual Laboratory-Based Instruction (VLBI) and promoting inclusive learning opportunities for all students.

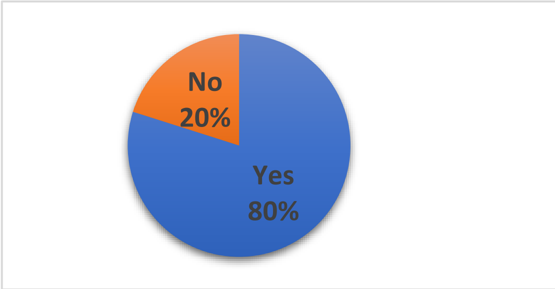

Figure 1: Student access to virtual laboratory resources (N = 339)

Key ICT Resources Available in Schools for Teaching and Learning Biology

Desktop computers were the most widely available ICT resource (28.7%), reflecting a strong reliance on fixed digital infrastructure in schools. Audio-visual or animated DVDs followed at 22.3%, with laptops and smartphones each accounting for 12.4%. Printers made up 10.9%, while projectors (8.0%) and whiteboards (5.4%) were the least available (Figure 2). These findings suggest that while many schools have invested in ICT tools to support Biology instruction, the availability of more interactive and mobile technologies such as projectors and whiteboards remains limited. Strengthening access to a broader range of ICT resources may enhance the delivery of Virtual Laboratory-Based Instruction (VLBI) and overall teaching effectiveness.

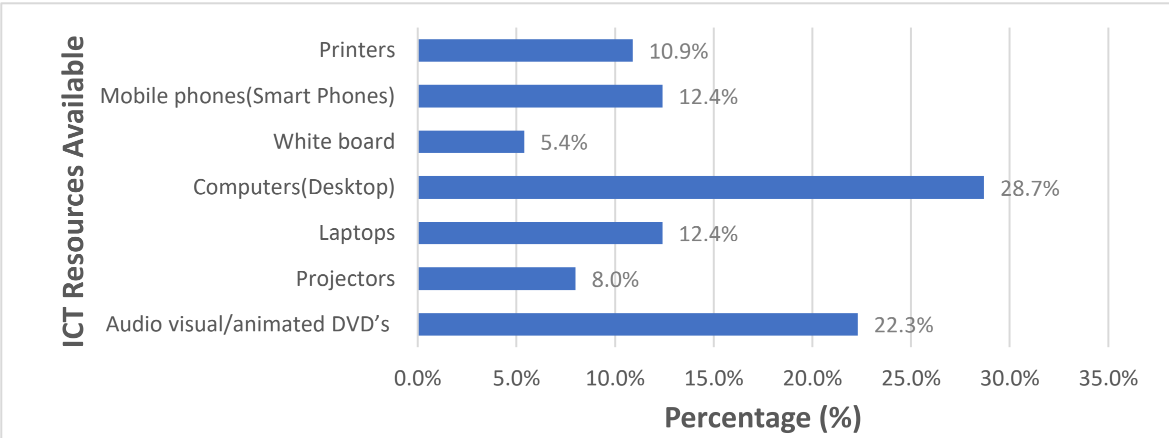

Figure 2: ICT resources available for teaching biology

Frequency of Virtual Laboratory Use in Biology Lessons

Majority, 54.5% of students indicated that they accessed virtual laboratory resources on a weekly basis, reflecting a fair degree of incorporation into their regular learning activities A smaller proportion (18.2%) indicated daily use, suggesting a limited but meaningful group of schools where virtual labs are a consistent part of the learning routine. On the other hand, 18.2% of students reported rare use of virtual labs, while 9.1% stated they never use them during Biology lessons (Figure 3). These findings point to uneven implementation of Virtual Laboratory-Based Instruction (VLBI) across schools. To maximize the potential of digital learning tools, there is a need to promote more frequent and consistent use of virtual laboratory resources across all learning environments.

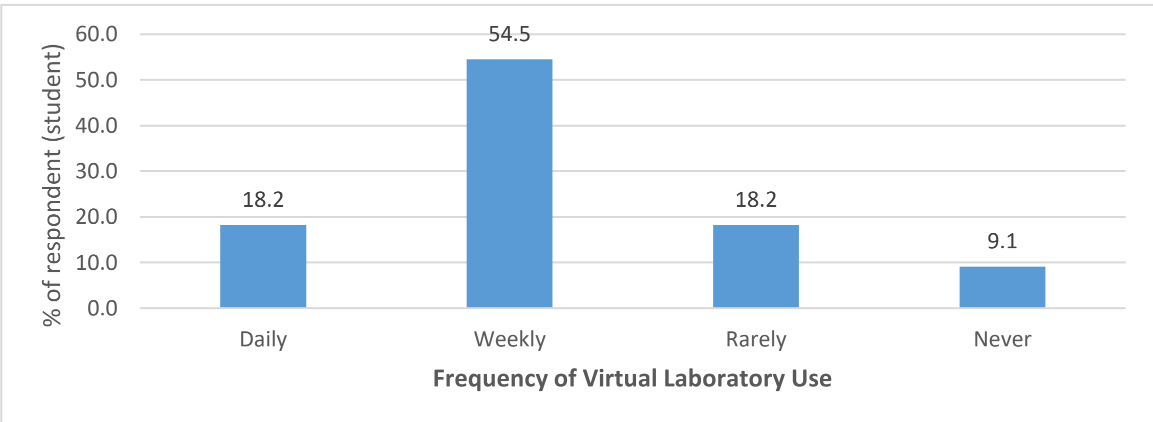

Figure 3: Frequency of virtual laboratory use in biology lessons

Institutional Support for Virtual Laboratories

A smaller proportion, 28% of schools received funding support and 27% were provided with equipment to aid the implementation of virtual laboratories A smaller proportion of schools reported receiving infrastructure support (9%) and advisory support (9%). Notably, 27% of schools indicated that they received no institutional support (Figure 4). These findings suggest that while some schools benefit from essential support particularly in the form of funding and equipment others operate without any assistance. The relatively low levels of infrastructure and advisory support may limit schools' capacity to sustain or expand virtual laboratory initiatives. The presence of schools with no support at all highlights ongoing disparities in institutional investment in digital learning tools.

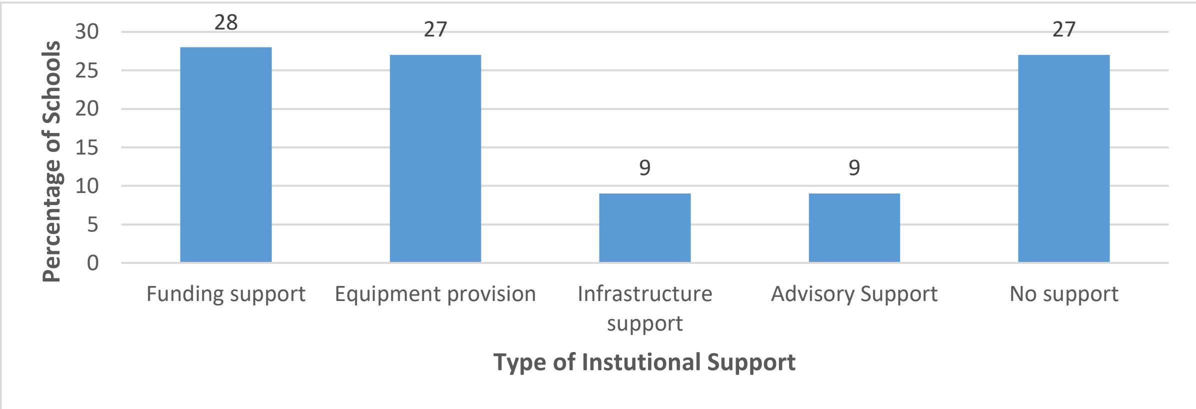

Figure 4: Institutional support for virtual laboratories

Hypothesis Testing

The null hypothesis (H_{01}) stated: There is no significant limitation in the availability and accessibility of virtual laboratories in secondary schools in Kakamega County**.** To test this hypothesis, student responses regarding access to virtual laboratories were subjected to a chi-square goodness-of-fit test. This statistical test examined whether the observed distribution of responses ("Yes" for access and "No" for lack of access) significantly differed from an expected equal distribution, which would imply no access limitation. The results are as presented in Table 1.

Table 1: Chi-Square test on student access to virtual laboratories

Access to Virtual Labs	**Observed (O)**	**Expected (E)**	**(O−E)²/E**
Yes	271	169.5	62.29
No	68	169.5	62.29
Total	**339**	**-**	**-**

Chi-square (χ^2) = 124.58
Degrees of freedom (df) = 1
P-value = 0.000
Level of significance (α) = 0.05

Chi-Square Test Results

A Chi-square test of independence was conducted to examine the association between the two categorical variables. The analysis produced a Chi-square statistic of χ^2 = 124.58, with 1 degree of freedom, and a p-value of 0.000. Since the p-value is less than the predetermined level of significance (α = 0.05), the result is statistically significant. Therefore, the null hypothesis is rejected. This finding indicates that there is a significant association between the two variables under investigation. The observed differences are unlikely to have occurred by chance, suggesting that the variables are not independent. In practical terms, this means that one variable is likely related to or influenced by the other in the context of this study.

DISCUSSION

The finding that *79.9%* of students reported access to virtual laboratory resources, with *20.1%* lacking access, revealed both commendable progress and persistent inequities in the implementation of virtual laboratory-based instruction (VLBI). This mirrors findings in Makueni County, where the integration of ICT in Biology instruction was similarly uneven: many schools had some ICT provision, but a non-trivial fraction of students remained without meaningful access (Musau, 2021). Likewise, in Migori County, studies observed that while some schools were equipped with ICT resources, many encountered constraints in using ICT meaningfully in Biology lessons because of lack of resources, inadequate facilities, or teacher skill deficits (Khatete et al., 2015).

The pattern of ICT resource availability in your study (desktops being most common; projectors, whiteboards less so) is consistent with the resource profiles reported in Rachuonyo South Sub-County, where most schools had few computers, but more advanced or interactive digital tools were rare (Mwanda et al., 2017).

Furthermore, the frequency of virtual laboratory use weekly by about 54.5% of students, daily by 18.2%, with a portion rarely or never using them suggests VLBI is being adopted in many schools but not uniformly nor deeply. This resembles findings in Makueni, where even in schools with ICT tools, teachers often rarely used them, or used them in limited capacities rather than integrating them into every Biology lesson (Musau, 2021).

Institutional support appeared mixed. About 28% of schools received funding, similar proportion equipment, but much fewer got infrastructure or advisory support, and about 27% got no support. This echoes challenges documented by Mwanda et al., (2017) which reported "inadequate infrastructure" and lack of training or advisory support as among the major impediments to integrating ICT in Biology instruction.

The hypothesis testing confirmed statistically significant limitations: the chi-square test showing that observed access is not equally distributed ($\chi^2 = 124.58$, $p < .001$) indicates that the null hypothesis (that there is no significant limitation) must be rejected. This formalizes what descriptive data suggest: that access to virtual labs is significantly constrained for a non-negligible minority of students.

Conclusions

The uneven distribution of ICT resources across schools, coupled with inconsistent usage patterns by students and teachers, affirmed the need for more comprehensive integration strategies. These should prioritize not only the provision of hardware but also capacity-building for teachers to ensure effective instructional use.

Institutional support remains limited and uneven, with most schools receiving minimal or no assistance in terms of funding, infrastructure, or advisory services. This indicates a systemic challenge that undermines the potential of VLBI to enhance learning outcomes uniformly.

Statistical evidence confirmed that access disparities are significant and not merely random. While VLBI adoption has gained momentum, inequitable access remains a critical barrier to achieving inclusive and effective Biology education.

Recommendations

Schools should invest in equitable distribution of ICT infrastructure to ensure that all students have reliable access to virtual laboratory resources. Priority should be given to under-resourced schools to bridge the gap in access and participation.

Teacher capacity-building should be strengthened through continuous professional development programs focused on the effective integration of virtual laboratories into teaching and learning. This will enhance teachers' confidence and pedagogical practices.

Government and educational stakeholders should increase institutional support by providing adequate funding, infrastructure, and advisory services. Such systemic interventions are necessary to sustain and scale up the benefits of VLBI.

Policymakers should establish monitoring and evaluation mechanisms to track ICT utilization and effectiveness in improving learning outcomes. This will promote accountability and inform evidence-based improvements in Biology instruction.

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