Awareness and Utilization of ICT Tools and Methods in Teaching Biology in Kitui County, Kenya

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ABSTRACT

The integration of Information and Communication Technology (ICT) in education has transformed instructional practices globally. In Kenya, national policy frameworks such as Vision 2030 emphasize digital transformation in education. Despite increased awareness of ICT tools, disparities persist between awareness and actual classroom utilization, particularly in rural settings. This study investigated the awareness, utilization, perceived impacts, and barriers influencing ICT integration in teaching biology in secondary schools in Kitui County, Kenya. A descriptive survey design was adopted involving 220 respondents (200 students, 13 biology teachers, and 7 principals). Data were collected using structured questionnaires and analyzed using descriptive statistics through SPSS version 22.

Findings revealed high levels of ICT awareness (90%), yet classroom utilization remained low. Traditional teaching methods such as textbooks and blackboards dominated instructional practice. Major barriers included limited ICT infrastructure, inadequate teacher training, heavy workload, unreliable electricity supply, and low digital self-efficacy. Despite these challenges, respondents acknowledged that ICT improves student performance, enhances content delivery, and saves instructional time when effectively implemented. The study concludes that bridging the gap between awareness and practice requires sustained professional development, infrastructure investment, institutional support, and policy reinforcement. Strengthening ICT integration in rural secondary schools can enhance learner engagement, promote studentcentered learning, and improve academic outcomes.

Keywords: ICT integration, biology education, teacher competence, rural schools, Kenya, student performance

INTRODUCTION

The integration of Information and Communication Technology (ICT) into education systems has become a global priority aimed at enhancing instructional delivery and improving learner outcomes. Digital tools such as computers, projectors, tablets, and mobile technologies have transformed pedagogical approaches from teachercentered to learner-centered models (Tondeur et al., 2017). In developing countries, ICT integration is increasingly viewed as a catalyst for improving access, quality, and equity in education (World Bank, 2004).

In Kenya, ICT adoption in education aligns with Vision 2030 and Ministry of Education reforms intended to modernize learning environments. However, rural counties such as Kitui face infrastructural, financial, and capacity-related challenges that may limit effective integration. While awareness of ICT tools may be widespread, actual classroom utilization often remains inconsistent (Kiptalam & Rodrigues, 2010).

Biology, as a science subject, particularly benefits from ICT integration through simulations, animations, and multimedia visualizations that simplify abstract concepts. However, the degree to which biology teachers in rural secondary schools effectively utilize ICT tools remains underexplored.

This study therefore sought to examine:

1. The level of awareness of ICT tools in teaching biology.

2. The extent of ICT utilization in classroom instruction.

3. The perceived impact of ICT integration on student outcomes.

4. The barriers and enablers influencing ICT use in biology teaching.

LITERATURE REVIEW

ICT Integration in Secondary Education

The integration of Information and Communication Technology (ICT) in education is widely recognized as a driver of effective teaching and enhanced learning outcomes. Globally, ICT adoption has shifted pedagogy from traditional teacher-centered methods to interactive, learner-centered approaches that promote engagement, collaboration, and higher-order thinking skills (Tondeur et al., 2023; Msafiri, Kangwa, & Cai, 2023; Aidoo, 2024).

In science education, digital tools such as simulations, animations, and virtual laboratories enhance visualization of abstract concepts, thereby improving conceptual understanding (Bingimlas, 2009).

In Sub-Saharan Africa, ICT implementation remains uneven, particularly in rural schools, due to limited infrastructure, unreliable electricity, and insufficient institutional support (Mwapwele, Marais, Dlamini, & Van Biljon, 2019; Sithole & Mbukanma, 2024). While awareness of ICT tools among Kenyan teachers is often high, actual classroom utilization remains inconsistent, reflecting gaps in both teacher competence and resource availability (Odunga, 2024; Chemnjor, 2024).

This gap between awareness and practical application highlights systemic challenges that extend beyond access to include teacher preparedness, institutional support, and policy implementation.

Teacher Competence and ICT Utilization

Teacher competence, particularly digital literacy, pedagogical confidence, and attitudes toward technology, strongly predicts ICT adoption and integration into classrooms (Masry-Herzallah, 2025; Hu, 2025; Paetsch, 2023). Teachers with higher digital self-efficacy and TPACK-informed pedagogical knowledge are more likely to implement ICT meaningfully in biology and other science subjects (Shambare & Jita, 2024; Zhang & Liu, 2025; Nurdin & Sari, 2025).

Teachers with positive perceptions of ICT are more likely to experiment with innovative teaching strategies (Teo et al., 2007). Conversely, limited technological skills and low digital self-efficacy often result in resistance or superficial use of technology.

Research further shows that professional development programs play a critical role in equipping teachers with Technological Pedagogical Content Knowledge (TPACK), which enables meaningful integration of digital tools into subject-specific instruction (Agyei & Voogt, 2012).

Infrastructure and Institutional Support

Infrastructure remains a major determinant of ICT integration. Reliable electricity, internet connectivity, and access to functional hardware are critical for sustaining ICT use, particularly in rural settings (Scott & Naidoo, 2023; Wanjiru & Keraro, 2023; Sithole & Mbukanma, 2024). Schools lacking these resources face persistent underutilization of available technologies despite teacher willingness and awareness.

Rural schools in Sub-Saharan Africa often face severe constraints including low funding, minimal technical support, and unstable power supplies, which hinder sustained ICT integration (Mwapwele et al., 2019; Sithole & Mbukanma, 2024; Zulu, 2024).

Gender disparities and low teacher self-efficacy further compound these challenges, affecting consistent use of technology in classrooms (Volman & Van Eck, 2019; Chemnjor, 2024). In rural Kenyan counties, limited funding and maintenance support often hinder sustained ICT implementation (Wanjala et al., 2011).

Impact of ICT on Student Outcomes

ICT-enhanced instruction improves student motivation, engagement, and academic performance when integrated effectively, especially through subject-specific tools like biology simulations and virtual laboratories (Akinsola & Tella, 2023; Bhila, 2026; Tomczyk, 2023). ICT adoption also facilitates interactive and differentiated learning, supporting conceptual understanding in abstract scientific domains (Nurdin & Sari, 2025; Shambare & Jita, 2024).

The present study builds on this literature by examining ICT awareness, utilization, and barriers within the specific context of biology education in Kitui County.

THEORETICAL FRAMEWORK

This study is grounded in two complementary models: the Technological Pedagogical Content Knowledge (TPACK) framework and the Technology Acceptance Model (TAM).

Technological Pedagogical Content Knowledge (TPACK*)*

The TPACK framework (Mishra & Koehler, 2006) posits that effective ICT integration occurs when teachers develop an intersection of three knowledge domains:

- Content Knowledge (CK) – Mastery of biology subject matter
- Pedagogical Knowledge (PK) – Understanding of instructional strategies
- Technological Knowledge (TK) – Competence in using digital tools

Meaningful integration requires synergy among these domains. Limited technological knowledge or weak pedagogical alignment can hinder effective ICT use.

Technology Acceptance Model (TAM)

The Technology Acceptance Model (Davis, 1989) explains technology adoption through two primary determinants:

1. Perceived Usefulness (PU)
2. Perceived Ease of Use (PEOU)

Teachers are more likely to integrate ICT when they believe it enhances student performance and is easy to implement.

By combining TPACK and TAM, this study explains both competence-related and perception-based determinants of ICT utilization.

Evidence indicates that teachers' TPACK development and digital self-efficacy are central to successful ICT integration. Studies in Sub-Saharan Africa demonstrate that teachers with strong digital skills, confidence, and pedagogical knowledge are more likely to incorporate technology meaningfully into subject instruction (MasryHerzallah, 2025; Hu, 2025; Shambare & Jita, 2024; Zhang & Liu, 2025). Professional development and targeted mentorship enhance both self-efficacy and tool adoption, addressing barriers in rural and resource-constrained contexts (Paetsch, 2023; Tomczyk, 2023).

METHOD

Research Design

A descriptive survey design was employed to examine the awareness, utilization, perceived impacts, and barriers influencing ICT integration in teaching biology in secondary schools in Kitui County. This design was chosen

because it allows for the systematic collection of quantitative data from multiple respondent groups while providing a snapshot of current practices and perceptions (Creswell & Creswell, 2018).

Participants and Sampling

The study involved a total of 220 respondents, comprising:

1. 200 students
2. 13 biology teachers
3. 7 school principals

A stratified purposive sampling technique was used to ensure representation across different school types (public and private), geographic locations (urban vs. rural), and participant roles (students, teachers, principals). Within each stratum, participants were selected based on their enrollment or employment in biology classes to ensure relevance to the study objectives.

All distributed questionnaires were returned, yielding a 100% response rate. This unusually high response rate was achieved through in-person administration by the research team, with questionnaires completed under supervision during scheduled school hours, minimizing non-response and ensuring that all selected participants were available and engaged.

Instruments

Data were collected using a structured questionnaire consisting of closed-ended items measured on a five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). The instrument was organized into four sections:

1. Awareness of ICT tools and methods
2. Frequency of ICT utilization in classroom instruction
3. Perceived impacts of ICT integration on student outcomes
4. Barriers and enablers influencing ICT use in biology teaching

To ensure content validity, the questionnaire was reviewed by a panel of three education and ICT experts. Reliability analysis using Cronbach's alpha indicated high internal consistency across the four sections: Awareness ($\alpha = 0.87$), Utilization ($\alpha = 0.91$), Perceived Impacts ($\alpha = 0.89$), and Barriers/Enablers ($\alpha = 0.85$), suggesting the instrument was suitable for quantitative analysis.

Data Collection Procedure and Ethical Considerations

Ethical approval for the study was obtained from the Kenya National Commission for Science, Technology, and Innovation (NACOSTI) (Approval No. XXXX).

Additionally, permission to access schools and participants was granted by the Kitui County Education Office. All participants provided informed consent, and for students under 18, parental or guardian consent was also obtained. Participation was voluntary, and confidentiality was strictly maintained by anonymizing all responses.

Data Analysis

Data were coded and analyzed using the Statistical Package for Social Sciences (SPSS) version 22. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were computed to summarize participant responses. The data were presented in tables and charts to illustrate patterns in ICT awareness, utilization, perceived impacts, and barriers/enablers across the study population.

RESULTS

Demographic Characteristics

Of the 220 respondents, 114 (51.82%) were female and 106 (48.18%) were male. Most respondents (90%) were aged between 16 and 18 years

Table 1.0

sex	frequency	percentage
Female	114	51.82%
Male	106	48.18%
Total	220	100%

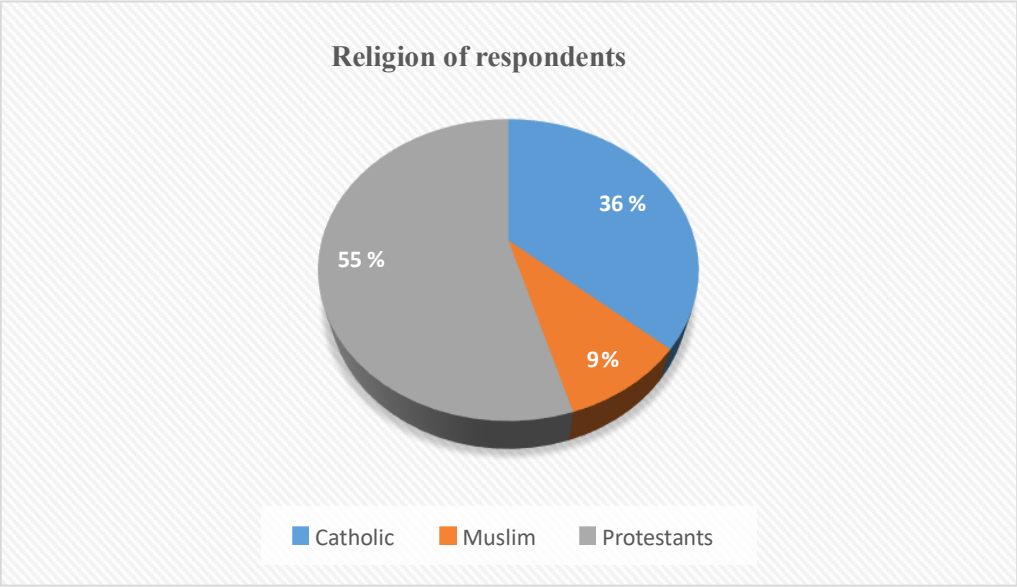
From the table above, the response was dominated by the female gender with a total of 114 female respondents who made 51.82% while 106 of the respondents went for the male gender, which represented 48.18%.

Table 2.0

Age	Frequency	Percentage
13-15 years	10	5%
16-18years	180	90%
19-21 years	10	5%

From the table, most of the population that participated in the study were between the ages of 16 to 18 years, making up 90%. This is dominated by youths who are in the transition rate to either their parents or new jobs. This was followed by 5% for both age 13-15 years and ages 19-21years.

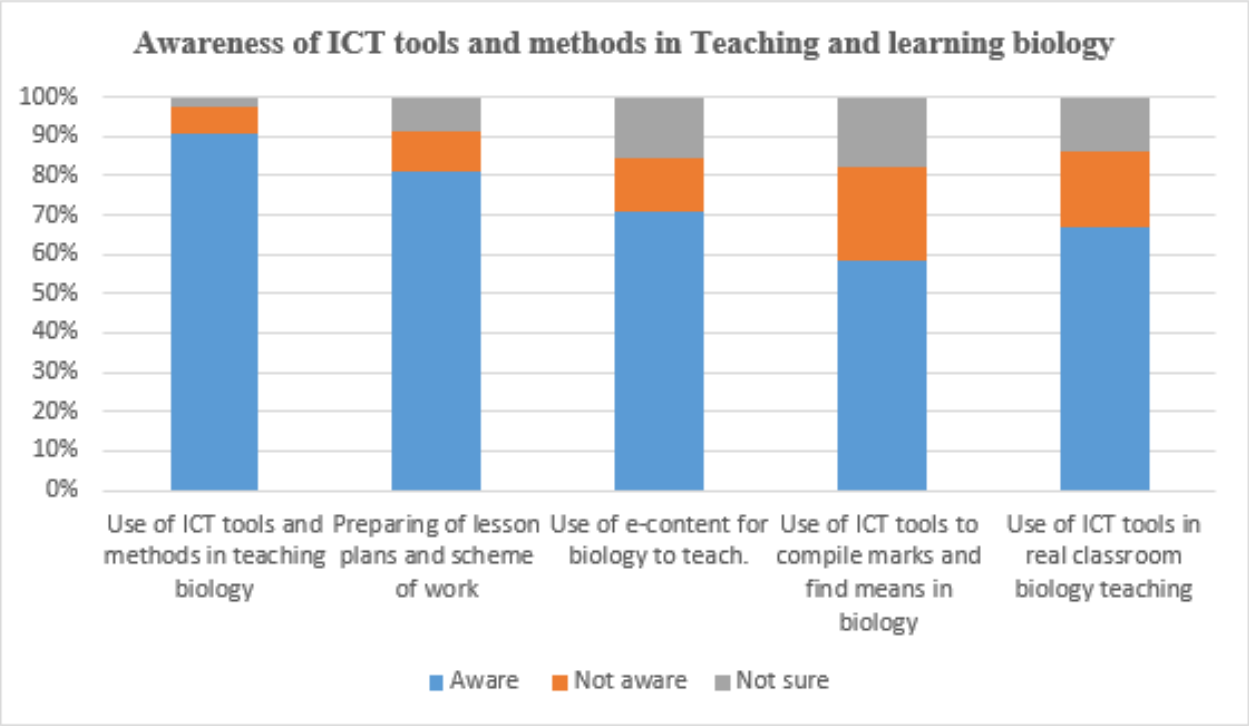
Chart 1.0. Religion of the respondents



The analysis of the chart shows that 55% of the respondents are protestants, 36% are Catholics, and 9.% of the respondents are Muslims.

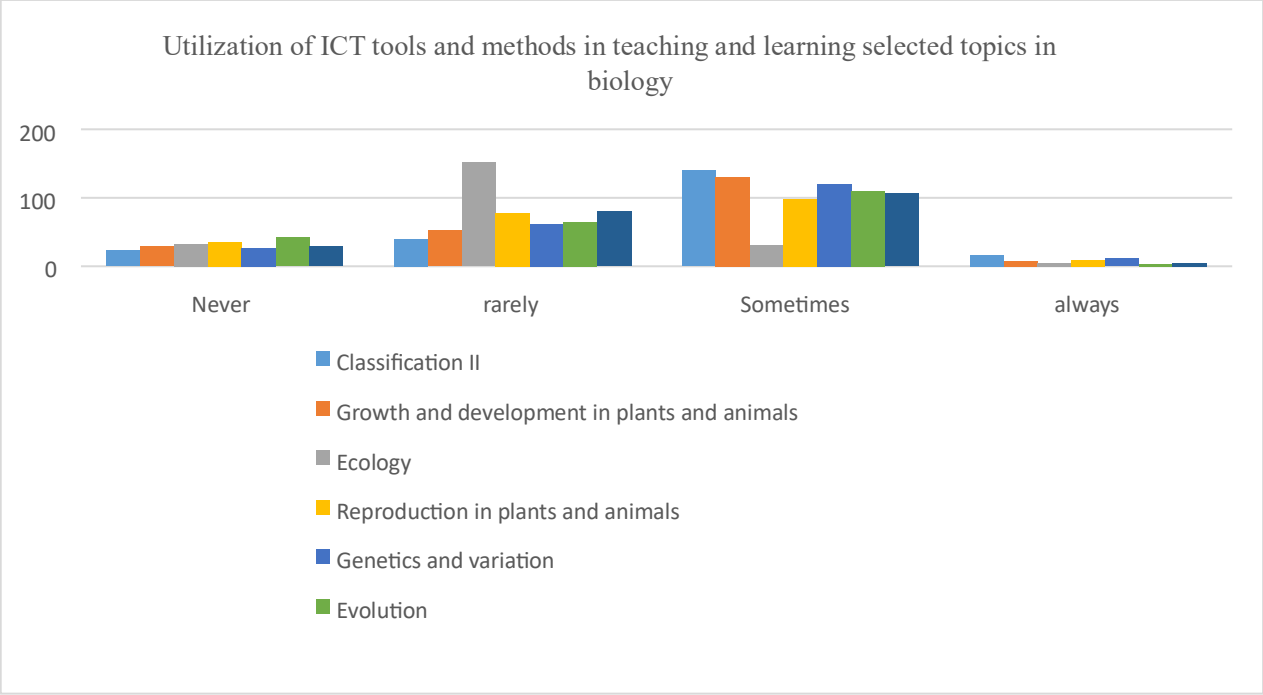
Awareness of ICT Tools

Awareness of ICT tools and methods in teaching biology



The study sought to test the awareness of ICT tools and methods in teaching biology in Kitui County. The study shows that a larger percentage of individuals, 90% are aware of the use of ICT tools and methods in teaching and learning. Results indicated that 90% of respondents were aware of ICT tools and methods used in teaching biology. This demonstrates widespread recognition of digital technologies in educational settings.

Utilization of ICT tools and methods in teaching biology



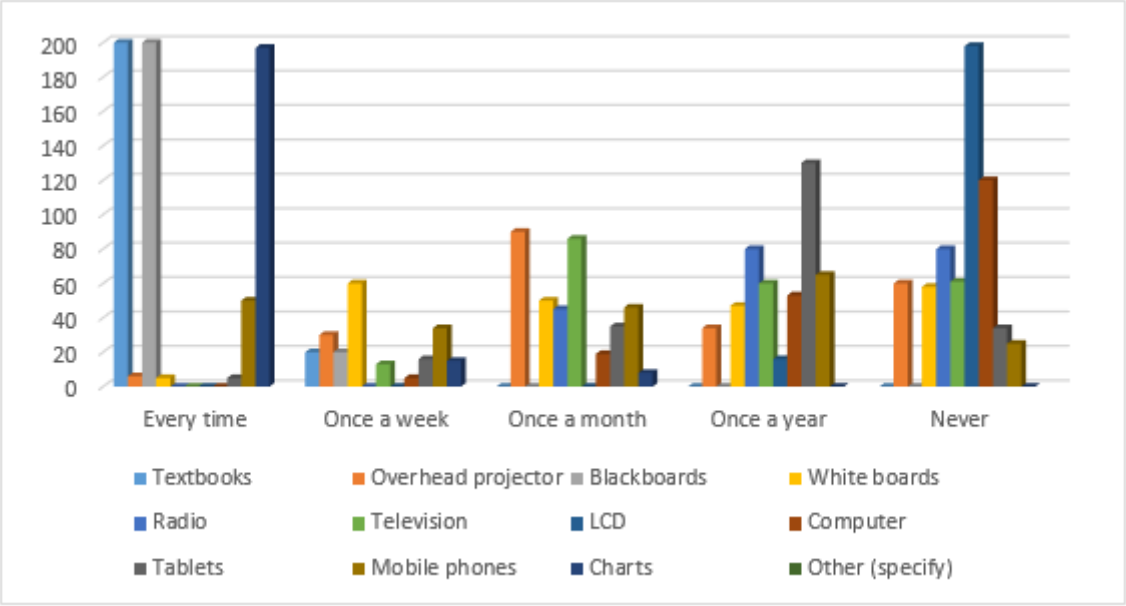
It was noted from the study that less than 1% of participants always use ICT to teach or learn biology, while approximately 4% never use technology in studying. The most notable contrast was in one topic, ecology, which can easily be accessed using technology, had the highest number of those who rarely use computers to learn or teach.

Utilization of ICT Tools

Extent to which ICT facilities and tools are used in teaching biology in comparison to the conventional methods

Table 3.0

Technology	Every time	Once a week	Once a month	Once a year	Never
Textbooks	200	20	0	0	0
Overhead projector	6	30	90	34	60
Blackboards	200	20	0	0	0
White boards	5	60	50	47	58
Radio	0	0	45	80	80
Television	0	13	86	60	61
LCD	0	0	0	16	198
Computer	0	5	19	53	120
Tablets	5	16	35	130	34
Mobile phones	50	34	46	65	25
Charts	197	15	8	0	0



The findings presented in Table 3.0 illustrate a significant disparity between the use of conventional teaching methods and the adoption of ICT facilities and tools in the teaching of biology. The data indicate that traditional instructional resources, particularly textbooks and blackboards, remain the dominant teaching tools in secondary schools across Kitui County. Both textbooks and blackboards were reported to be used *every time* by virtually all teachers (200 respondents), demonstrating their central role in classroom instruction. This strong reliance on conventional materials suggests that most teachers still depend on familiar, low-cost, and readily available methods to deliver biology lessons.

In contrast, the use of modern ICT tools such as computers, LCD projectors, tablets, and television is notably limited. For instance, none of the respondents reported using LCD projectors regularly, and 198 out of 214

indicated that they *never* used them at all. Similarly, 120 teachers reported *never* using computers in their teaching, while 53 used them only once a year. These statistics highlight the minimal integration of computerbased technologies into classroom instruction despite ongoing government efforts to enhance ICT capacity in schools. The low frequency of ICT use reflects challenges such as inadequate infrastructure, insufficient training, and poor maintenance of available facilities.

Moreover, the limited use of radio and television for instructional purposes reveals an underutilization of government-sponsored broadcast education programs. A large proportion of respondents (80 for radio and 61 for television) reported *never* using these media in teaching, while only a small number indicated monthly use. This outcome suggests that many teachers and students either lack access to the broadcast learning programs or do not find them practical for their classroom needs. It also points to a potential disconnect between national elearning initiatives and actual classroom implementation in rural areas.

Interestingly, while mobile phones were reported to be used more frequently than other digital tools, with 50 teachers using them *every time* and 34 *once a week*, their use remains limited due to strict school regulations prohibiting students from owning handsets. Despite their potential as learning tools, especially for accessing digital content, mobile phone use in secondary schools remains largely restricted to teachers, limiting their educational impact on students.

The findings also reveal that charts continue to play an essential role in teaching biology, with 197 teachers using them *every time*. This suggests that while ICT integration remains low, teachers continue to adopt visual aids to enhance understanding of scientific concepts. Charts, being low-cost and easy to reproduce, serve as an accessible alternative to digital visual tools such as projectors and animations.

Whiteboards and overhead projectors occupy a middle ground between traditional and modern teaching methods. Although they are used more frequently than computers and LCDs, their use is still sporadic. Only 5 teachers use whiteboards *every time*, and 6 use overhead projectors *every time*, while most others rely on them occasionally. This pattern suggests that some teachers may be transitioning gradually toward modern teaching aids but still face barriers such as insufficient resources, lack of confidence, or inadequate training in their effective use.

The narrative emerging from these findings points to systemic challenges that hinder effective ICT integration in teaching biology. Financial constraints were identified as a major barrier, as many schools lack the funds to procure, maintain, and update ICT tools. Moreover, teachers often lack sufficient training and technical support to incorporate technology meaningfully into their lessons. As a result, even when ICT resources are available, their potential remains underutilized.

In summary, while the traditional tools of instruction, such as textbooks, blackboards, and charts, remain the backbone of biology teaching in Kitui County, the integration of ICT tools and methods is still at a nascent stage. The sporadic and limited use of computers, projectors, and other digital resources underscores the need for targeted interventions, including enhanced funding, regular teacher training, improved infrastructure, and supportive policies to promote technology-based instruction. Addressing these gaps will be essential for achieving meaningful ICT integration in biology education and improving the quality of teaching and learning outcomes in the county.

Impacts of utilization of ICT facilities on learners' outcomes

Table 4.0

Indicated by using the following keys. Tick only once per statement. Strongly Disagree (SD), Disagree (D), Not sure (NS), Agree(A), Strongly Agree (SA)

STATEMENT	SD	D	N	A	SA
a) Utilization of ICT facilities is adding extra cost unnecessarily.	137	50	21	8	4

b) Utilization of ICT facilities in teaching biology increases students' performance.	4	10	20	60	126
c) Utilization of ICT facilities in biology enhances content delivery.	6	14	30	56	114
d) Utilization of ICT reduces syllabus coverage	40	24	40	60	56
e) Utilization of ICT in teaching biology influences content understanding.	46	48	47	30	49
f) Use of ICT motivates learners	42	38	56	32	52

The findings presented in Table 4.0 reveal important insights into how the utilization of ICT facilities impacts learners' outcomes in the teaching and learning of biology. The responses reflect a generally positive attitude toward ICT integration, although certain reservations remain regarding its practical implementation and effects on learning processes.

A large majority of respondents (186 teachers) either agreed or strongly agreed that the utilization of ICT facilities in teaching biology enhances students' performance. Specifically, 60 teachers agreed and 126 strongly agreed with this statement, indicating widespread recognition that ICT tools can improve learners' understanding, retention, and achievement. This finding aligns with studies by Onguko and Ng'eno (2016) and Tondeur et al. (2017), who reported that ICT integration leads to improved engagement, critical thinking, and better examination performance when appropriately implemented. The results also resonate with Kafyulilo (2019), who observed that ICT-based learning environments provide students with opportunities for interactive participation, leading to deeper conceptual understanding.

Similarly, a significant proportion of respondents (56 agreed and 114 strongly agreed) affirmed that ICT enhances content delivery in biology. This underscores the potential of digital tools such as animations, simulations, and multimedia presentations in simplifying abstract biological processes and making lessons more engaging and comprehensible. These findings are consistent with Aduwa-Ogiegbaen and Iyamu (2005), who argued that ICT tools make science subjects more concrete and relatable, especially when dealing with microscopic or complex biological phenomena that are difficult to demonstrate using conventional methods.

However, the perception of ICT's influence on syllabus coverage and content understanding presents a more mixed picture. Regarding syllabus coverage, 40 respondents strongly disagreed, 24 disagreed, 40 were not sure, 60 agreed, and 56 strongly agreed that ICT reduces the pace of syllabus completion. This divided response suggests that while some teachers perceive ICT as time-consuming due to setup, technical challenges, or lack of familiarity, others see it as an efficient tool for streamlining content delivery once mastery is achieved. Similar concerns were raised by Mugambi (2018) and Nyaribo and Orodho (2016), who found that limited teacher competence and unreliable electricity supply often impede the smooth flow of ICT-assisted lessons, leading to delays in syllabus coverage.

On the matter of content understanding, responses were evenly distributed: 46 strongly disagreed, 48 disagreed, 47 were not sure, 30 agreed, and 49 strongly agreed. This indicates uncertainty or inconsistency in how ICT influences conceptual comprehension among students. Some teachers may not yet be fully adept at integrating technology pedagogically, which can reduce its potential effectiveness. As Ghavifekr and Rosdy (2015) observed, the success of ICT in improving understanding depends heavily on teachers' digital literacy, the pedagogical design of lessons, and the alignment of technology with learning objectives.

A similar pattern emerged regarding the motivational effect of ICT on learners. Although 84 respondents (32 agreed and 52 strongly agreed) believed that ICT motivates learners, a notable portion (80 respondents) disagreed or strongly disagreed. This contrast suggests that while digital tools can increase learner enthusiasm through interactivity and visual appeal, challenges such as distracting pop-ups, advertisements, and off-task behaviors may limit their motivational benefits. As noted by Khan et al. (2019) and Tella (2011), distractions from

nonacademic online content and inadequate classroom management during ICT use can diminish the learning experience and cause students to lose focus.

Interestingly, a majority (187 respondents) either strongly disagreed or disagreed with the statement that ICT utilization adds unnecessary extra cost. Only a small fraction (12 respondents) agreed or strongly agreed. This finding suggests that most teachers view ICT not as a financial burden but as a valuable investment in quality education. However, this positive view may mask underlying institutional challenges such as inadequate funding for ICT infrastructure, maintenance, and training, which remain barriers to full-scale implementation in many Kenyan schools (Ministry of Education, 2020).

In summary, the findings demonstrate that teachers generally recognize the positive impacts of ICT utilization on students' performance, content delivery, and learner motivation. However, mixed perceptions persist regarding its effect on syllabus coverage and content understanding, reflecting variations in teachers' technological competence, school-level ICT support, and contextual limitations such as power supply and connectivity. The results highlight the need for comprehensive teacher training, better ICT infrastructure, and context-specific implementation strategies to maximize the pedagogical benefits of ICT in biology education. When these factors are addressed, ICT integration has the potential to transform biology teaching into a more engaging, effective, and learner-centered process.

Barriers and enablers influencing the utilization of ICT facilities in teaching Biology.

Indicated by using the following keys. Tick only once per statement. Strongly Disagree (SD), Disagree (D), Not sure (NS), Agree (A), Strongly Agree (SA)

STATEMENT	SD	D	NS	A	SA
There is limited knowledge and skills among biology teachers on the utilization of ICT facilities in teaching.	0	0	20	50	150
Workload hinders Utilization of ICT.	5	8	20	145	42
I feel competent using ICT tools to teach.	3	130	50	35	2
Teachers' attitude affects utilization of ICT in teaching biology.	6	2	7	180	25
Males gender utilize ICT facilities more compared to females.	3	5	10	120	82
Availability of power affects the utilization of ICT facilities.	7	8	10	22	173
ICT facilities are readily available for use in teaching.	186	20	10	4	0
ICT use in teaching saves time	10	13	27	90	80

The findings presented in Table 4.7 reveal a complex interplay of barriers and enablers influencing the utilization of ICT facilities in teaching biology. The responses highlight both structural and personal factors that either promote or hinder effective ICT integration in the classroom.

A majority of respondents (50 agreed and 150 strongly agreed) acknowledged that limited knowledge and skills among biology teachers constrain the use of ICT facilities in teaching. This suggests that despite growing awareness of ICT's pedagogical value, a significant skills gap persists among educators. This finding aligns with Mugendi, Nyaga, and Muriithi (2020), who observed that most teachers in rural Kenyan schools lack adequate ICT literacy and confidence to integrate technology effectively into classroom practice. Similarly, Tondeur et al. (2017) emphasize that teacher preparedness and ongoing professional development are critical determinants of successful ICT adoption. The data therefore underscore the need for structured capacity-building initiatives and continuous professional training to improve teachers' technological competence.

Another major barrier identified is teacher workload, with 145 respondents agreeing and 42 strongly agreeing that it hinders ICT utilization. This indicates that heavy workloads may discourage teachers from incorporating

ICT-based approaches, which often require additional lesson preparation time and technical management. Studies by Hennessy, Harrison, and Wamakote (2010) and Pelgrum (2001) similarly note that large class sizes and overloaded timetables limit teachers' flexibility to experiment with digital tools, thereby constraining innovation in teaching methods.

Interestingly, a significant portion of respondents (130 disagreed and 50 were not sure) expressed low selfconfidence in using ICT tools to teach. Only 37 respondents felt competent. This finding reflects a widespread lack of digital self-efficacy among teachers, consistent with findings by Kafyulilo (2019) and Kiptalam and Rodrigues (2010), who found that limited hands-on exposure and inadequate training often lead to anxiety or reluctance in ICT use. Such low confidence levels act as psychological barriers to technology adoption and necessitate mentorship programs and peer-support mechanisms to build competence through practice.

The results also highlight the influence of teachers' attitudes on ICT use. A large majority (180 agreed and 25 strongly agreed) believed that teacher attitudes significantly affect ICT utilization. This reflects the assertion by Teo (2014) that positive attitudes and beliefs about technology are among the strongest predictors of its classroom adoption.

Teachers who perceive ICT as beneficial to learning are more likely to integrate it meaningfully, whereas skepticism or resistance often leads to underutilization. Therefore, fostering positive pedagogical attitudes through awareness campaigns, incentives, and demonstration of ICT's instructional value is essential.

Gender differences were also evident, with 120 respondents agreeing and 82 strongly agreeing that male teachers utilize ICT facilities more than their female counterparts. This finding echoes earlier studies by Volman and Van Eck (2001) **and** Markauskaite (2006), which found persistent gender gaps in ICT use, often attributed to differences in confidence levels, training exposure, and cultural perceptions of technology. However, Kay (2006) argues that such disparities are narrowing with improved access and training opportunities. Nevertheless, the current findings suggest that gender remains an influencing factor in ICT utilization in biology teaching in Kitui County.

The availability of power supply emerged as another critical factor. A striking 173 respondents strongly agreed that inconsistent electricity affects ICT use. This highlights infrastructural challenges, particularly in rural areas, that undermine sustained ICT integration. The finding corroborates reports by Wanjala, Khaemba, and Mukwa (2011) **and** Mwania, Mutisya, and Mulwa (2017), who identified unreliable power and internet connectivity as major impediments to ICT-based instruction in Kenyan schools. Without stable electricity, the functionality of computers, projectors, and digital content delivery is severely compromised.

On resource availability, 186 respondents strongly disagreed that ICT facilities are readily available for teaching, confirming a pervasive lack of adequate technological infrastructure. This is consistent with Kiptalam and Rodrigues (2010) **and** Ministry of Education (2020) findings, which reported that many secondary schools in semi-rural Kenya possess limited ICT hardware, software, and maintenance support. Such shortages limit teachers' opportunities for hands-on experience and reduce students' exposure to digital learning environments.

Despite these challenges, the data also reveal enabling factors. A total of 170 respondents (90 agreed and 80 strongly agreed) believed that ICT use in teaching saves time. This suggests that when properly integrated, ICT can streamline lesson delivery, assessment, and resource sharing. Studies by Ghavifekr and Rosdy (2015) **and** Tella (2011) support this finding, indicating that ICT tools can increase instructional efficiency by simplifying lesson preparation, enhancing feedback mechanisms, and facilitating quick access to instructional materials.

In summary, the findings reveal that ICT utilization in biology teaching is influenced by both individual-level factors (such as teacher skills, attitudes, confidence, and gender) and institutional-level factors (such as infrastructure, power supply, and workload). The key barriers include insufficient training, limited infrastructure, and unreliable electricity, while enabling factors include time-saving potential and positive teacher attitudes. Addressing these challenges through capacity building, infrastructure investment, and supportive policy frameworks will be vital for promoting equitable and effective ICT integration in biology education across Kitui County.

Impact of integrating ICT tools and methods on student learning outcomes

Academic Performance

A substantial majority of respondents (186 out of 220; 84.5%) either agreed or strongly agreed that ICT integration improves students' academic performance in biology. Teachers reported that multimedia explanations, digital diagrams, and animations supported improved conceptual clarity, particularly in topics such as genetics, ecology, and human physiology. However, 14 respondents (6.4%) disagreed, suggesting that performance gains depend on effective pedagogical implementation rather than mere availability of tools.

Content Delivery

170 respondents (77.3%) indicated that ICT enhances content delivery. Teachers reported that PowerPoint presentations and downloaded visual simulations helped simplify microscopic biological processes that are otherwise difficult to demonstrate using chalkboard explanations alone. However, 50 respondents (22.7%) remained uncertain or disagreed, indicating inconsistencies in instructional execution.

Syllabus Coverage

Responses regarding syllabus coverage were divided. While 116 respondents (52.7%) believed ICT improves lesson efficiency, 64 respondents (29.1%) believed it slows coverage due to time spent setting up equipment or resolving technical problems. This finding confirms that infrastructure reliability directly influences instructional pacing.

Conceptual Understanding

Responses were nearly evenly distributed. Although 79 respondents (35.9%) agreed that ICT enhances understanding, 94 respondents (42.7%) disagreed or strongly disagreed. This suggests that ICT use does not automatically translate into deeper comprehension unless aligned with pedagogical objectives.

Learner Motivation

84 respondents (38.2%) agreed that ICT motivates learners, whereas 80 respondents (36.4%) disagreed. Teachers reported that motivation increased during interactive sessions but declined when technical disruptions occurred.

The findings indicate that ICT integration in Kitui County produces conditional benefits rather than universal impact. Positive outcomes are most evident when:

1. Teachers demonstrate confidence in ICT use,
2. Equipment functions reliably,
3. Lessons are pedagogically structured.

Where these conditions are absent, ICT integration yields inconsistent or neutral learning gains.

CONCLUSION AND RECOMMENDATIONS

This study establishes that while ICT awareness among biology teachers in Kitui County is high, classroom utilization remains significantly limited. The disparity between awareness (90%) and consistent classroom integration suggests structural and competence-based constraints rather than attitudinal resistance alone. Limited digital self-efficacy, inadequate infrastructure, unreliable electricity, and heavy workload collectively undermine effective implementation.

Importantly, ICT integration yields measurable academic and motivational benefits only under conditions of pedagogical alignment and infrastructural stability. Therefore, policy emphasis must shift from mere device distribution toward sustainable teacher capacity development and rural infrastructure stabilization.

Recommendations

1. Implement structured, competency-based ICT professional development aligned with TPACK.
2. Establish rural ICT maintenance units at county level.
3. Provide solar-powered backup systems in electricity-unstable zones.
4. Integrate digital pedagogy into teacher performance appraisal frameworks.
5. Conduct longitudinal studies examining ICT impact on KCSE biology outcomes.

In conclusion, while ICT awareness among biology teachers in Kitui County is commendable**,** utilization remains limited due to infrastructural, financial, and competence-related constraints. By prioritizing teacher training, resource provision, and curriculum reform, Kenya can move closer to realizing its Vision 2030 goal of a digitally empowered education system capable of enhancing learning outcomes even in its most remote regions.

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