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Original Article

Bridging the Digital Divide in Science Education: Analysis of ICT Integration by JHS Integrated Science Teachers in Semi-Urban Schools in Ghana

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Abstract

Technology in general, and more specifically ICT use in education, is crucial when it comes to improving teaching and learning outcomes in science education. However, this remains a distant goal for many schools in semi-urban Ghana due to various constraints. This study used a cross-sectional descriptive survey design to examine how Junior High School (JHS) integrated science teachers in the Komenda Edina Eguafo Abrem (KEEA) Municipality access and use ICT tools and their challenges in using these tools. The study employed a voluntary sampling procedure to select 71 (59 males and 12 females) teachers through an online survey. Data were analysed using descriptive statistics and correlational analysis. The results revealed a strong positive relationship between the availability of ICT tools and their frequency of use. The results also indicated that the teachers predominantly rely on mobile phones for their ICT-related activities because of the unavailability of more sophisticated tools. The results further revealed that the current integration of ICT tools for integrated science teaching is hampered by limited physical infrastructure, inadequate teacher preparation, inaccessible technical support, and erratic power supply. To mitigate these challenges, the study suggested implementing teacher-centred professional development programmes, setting up solar-powered ICT centres, leveraging E-Community Learning and Resource Centres, utilising iBox Technology, adopting Wireless Ad Hoc Networks, and fostering collaborative teacher networks for resource sharing and support. The study concluded that targeted interventions to strengthen infrastructure and teacher capacity are necessary to overcome the digital divide and promote effective delivery of science education in resource-limited environments.

KEYWORDS: ICT integration, Semi-urban education, Science education, ICT challenges, educational technology, solar-powered strategies, Ghana

Appianing (2025), Vol. 6, Iss. 1, Pg. 24-52
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1.0 INTRODUCTION

Technological advancement in information and communication technology (ICT) has increasingly influenced the delivery of education systems globally in a positive way (Saidu et al., 2025; Yu & Dlamini, 2025). ICT tools, including computers, projectors, digital simulations, and internet-based educational tools, have proven helpful for developing technology-rich active learning spaces. Prior research identifies the potential for teaching improvement along with student learning across schools in developing countries such as Ghana because of accessible information and communications technologies (ICTs) tools (Atuahene et al., 2024; Kaye & Ehren, 2021). However, in reality, potential in this area remains unfulfilled, owing to persistently observed barriers such as inadequate educational infrastructure, resource shortages, and inadequate teachers with the requisite technological pedagogical knowledge, particularly among those in semi-urban schools in Ghana (May & Abreh, 2017; Natia & Al-hassan, 2015). Managing these barriers, therefore, requires localised strategies that fit the unique characteristics of semi-urban environments.

Universally, ICT integration has been acknowledged as a facilitator of twenty-first-century skills, especially in science. The Internet is available and reliable in places such as the USA, Japan, and South Korea due to investment in ICT infrastructure and continuous training of teachers (Akabayashi et al., 2024; Curran, 2019), ensuring that students remain engaged and can collaborate effectively. Such efforts have shown that ICT interventions can indeed enhance learning outcomes and critical digital literacy (Alshuaybat, 2025). Nonetheless, across the globe, the effective use of ICT is not even, and those in the developing world particularly face unique challenges (Mustafa et al., 2024; Okoye & Pillay, 2022; Shou et al., 2024; Yu & Dlamini, 2025).

The scarcity of resources and inadequate infrastructure in many developing countries, especially in Asia, Latin America, and sub-Saharan Africa, limit the use of ICT in schools (Buabeng-Andoh & Yidana, 2015; Mapisa & Makena, 2024; Moses et al., 2022). As a result, innovative interventions have sought to solve the problem through models like the community ICT centres (Conradie, 2022), The Solar-Powered ICT Centres (Adeyoyin et al., 2019; Ofosu-Asare, 2024), E-Community Learning and Resource Centres (E-CLRC) (Moralde, 2023), iBox Technology (Barfi et al., 2023), and Wireless Ad Hoc Networks (Appiahene et al., 2019). Despite these efforts, the government of Ghana and other developmental partners have not fully addressed the challenges relating to inadequate computer and multimedia resources, insufficient training of teachers on how to use ICT tools effectively, unreliable technical support and power supply (Bordoh et al., 2024; Natia & Al-hassan). Findings from this study will highlight policy and practice implications that might enhance equitable uses of ICT in the teaching and learning of science in resource-constrained settings.

1.1 Study Context

KEEA Municipality, which is in the Central Region of Ghana, is made up of four traditional areas—Komenda, Edina, Eguafo, and Abrem. The Ghana Statistical Service (2014) classifies KEEA Municipality as a semi-urban area. The municipality's moderate infrastructure and diverse

Appianing (2025), Vol. 6, Iss. 1, Pg. 24-52
https://doi.org/10.5281/zenodo.15083916

economic activities, particularly in fishing and agriculture, demonstrate its semi-urban nature. While some towns within the district, including Elmina (locally known as Edina), have made strides in infrastructural development, schools in the KEEA municipality continue to face challenges typical of resource-limited contexts. As highlighted by Addokor (2020), most schools in the municipality lack basic ICT infrastructure, which is essential for effective science education. These circumstances make the KEEA Municipality an interesting context for investigating how ICT tools can be used more effectively to support science education.

Three research objectives were proposed to guide the study. The first objective was to assess the ICT tools available for teaching science and their frequency of use. The second objective was designed to identify the purposes for which science teachers use ICT tools. The third objective aimed to examine the challenges science teachers face in an attempt to utilise ICT tools for science lessons. Ultimately, this study seeks to contribute meaningfully to the discourse on ICT in education by drawing on the experiences and lessons learned from the KEEA Municipality.

1.3 Theoretical Perspective: Diffusion of Innovation Theory

The Diffusion of Innovation Theory by Rogers (1962) does an excellent job of describing exactly how an innovation, such as integrating ICT tools in the classroom, spreads through a social system. This theory is useful in explaining both systematic and personal barriers to the use of ICT in teaching among the targeted junior high school (JHS) science teachers in the KEEA Municipality. The theory identifies five key attributes that influence the rate of innovation adoption: Relative advantage, Compatibility, Complexity, Trialability, and Observability. These attributes explain the challenges as well as the facilitators of ICT integration in the study context.

Relative Advantage: Relative advantage focuses on the perceived benefits of using ICT tools over the traditional approaches to teaching. A review of the literature shows that teaching and learning are impacted positively by ICT in aspects such as students' engagement, critical thinking, and the explanation of concepts through such items as simulations and digitized images (Ghanbaripour et al., 2024; Hillmayr et al., 2020). The combination of projectors and laptops exists as a tool which increases teacher professional development and creates effective learner environments while helping with administrative procedures. Underprivileged areas face constant obstacles to implementation because of training deficits and resource constraints, among these challenges.

Compatibility: Compatibility deals with the question of how perfectly ICT tools fit into the existing practices as well as cultural attitudes. In most resource-limited schools, the traditional methods of teaching still prevail since the ICT tools are completely unavailable. While using ICT in their teaching practice, the teachers still view it as an overload, which complements their teaching approaches to education (Teidla-Kunitsõn et al., 2023). To overcome this barrier, the future use of ICT tools in continuing professional development training programmes should respect current patterns and activities. For example, the training that explains when and how ICT can support

Appianing (2025), Vol. 6, Iss. 1, Pg. 24-52
https://doi.org/10.5281/zenodo.15083916

conventional approaches, and not act as a replacement, will help to minimize opposition and ensure that users adapt properly.

Complexity: This is defined as the perceived level of difficulty in comprehending and applying ICT tools. Research suggests that inadequate preparation and the absence of technical support may cause ICT applications to appear overly complex and, therefore, unattractive (Mukomana & Chimhenga, 2024; Davidson & Ezeh, 2023). For instance, comprehensive training and support programmes, as well as intuitive interfaces of ICT tools, can reduce perceived complexity and expand use. For example, using tools that in turn become increasingly complex can assist teachers in gaining confidence progressively.

Trialability: Trialability refers to the degree to which an ICT tool can be tested before total implementation is considered. Literature supports the freedom to let teachers use and trial the ICT tools in controlled conditions (Baruch, 2016). The value of ICT tools can be proved if the tools are given to a few teachers, and the results or effects are observed through pilot implementation. Thus, positive results from such trials as increased student performance or teacher confidence can lead to an increase in the rate of other teachers' adoption of those technologies.

Observability: Observability refers to the extent of visibility of the outcomes that have been realised through ICT deployment. Teachers can invest in ICTs only when they can witness the effective use of these tools in their colleagues' classes (Rusek et al., 2017). Teachers who can utilise ICT to improve the effectiveness of teaching outcomes can then share this practice with other colleagues, illustrating the effectiveness of the innovation. Promoting Professional Learning Communities (PLCs) where the teachers present their experiences and rates of success of their implementation of ICT initiatives will enhance this impact by creating a culture of teachers' learning.

1.4 Impact of ICT on Education

1.4.1 Enhancing Student Engagement and Learning Outcomes

ICT tools like digital simulations educational software with animations, enable effective learning about different subjects, especially science (Kefalis et al., 2025). Research conducted by Tatira and Mshanelo (2024) shows how digital laboratories handle equipment shortages and increase classroom inquiry even in underfunded schools. According to Uchkurova and Tursinboyeva (2024), students learn better when they use digital science kits and whiteboards simultaneously which transform passive learning into active engagement, alongside raising their science achievement scores while motivating them towards STEM studies.

1.4.2 Expanding Access to Educational Content

Through ICT students receive wider access to several educational resources that include electronic books and video content alongside interactive digital modules. Educational technology research demonstrates how tools reduce the educational gaps between urban and semi-urban students

Appianing (2025), Vol. 6, Iss. 1, Pg. 24-52
https://doi.org/10.5281/zenodo.15083916

through their ability to rectify textbook deficits and provide customized educational experiences. Teachers possess the ability to modify their curriculum to suit various student requirements, thereby boosting both understanding and student interest (Adeshina, 2024; Olivares & Castillo, 2018).

1.4.3 Developing 21st-Century Skills and Digital Literacy

Educational integration of ICT tools supports students in developing three essential competencies, including problem-solving alongside critical thinking and technological literacy (Asare et al., 2023; Nurhikmayati & Darhim, 2023; Tampos, 2024). The use of ICT tools by students from semi-urban areas improves their practical experience and builds their self-confidence while delivering ready-made skills that match the modern working environment. Virtual laboratories coupled with simulated experiments create a major impact on science education by enhancing students' technical abilities and their understanding of concepts (Pang et al., 2025). The research by Ojo (2024) demonstrated how virtual labs equipped students with computer-based procedural tools and electronic materials that boost student motivation toward challenging concepts (Tatira & Mshanelo, 2024). According to Kashaka (2024), virtual labs bring flexible approaches to scientific experimentation that enable cost-efficient learning through innovative methods, which strengthen both conceptual understanding and procedural skills.

1.4.4 Supporting Teachers' Instructional Practices

Educational methodologies benefit from ICT revolutions that allow teaching professionals to deliver multimedia content and administer virtual laboratory work and online assessments, which boost students' active participation. The University of New South Wales developed TALIA as an educational tool that enables lecturers to design 360-degree virtual field trips which extend student learning opportunities past conventional classrooms (University of New South Wales, 2024).

Moreover, ICT facilitates professional development by connecting teachers, especially those in semi-urban and rural areas, to resources and collaborative opportunities through webinars and online platforms. The research conducted by Inal et al. (2023) revealed that teachers strongly supported webinars because they proved effective in Career development, so they wanted future training sessions to include webinars. Through its e-learning platform, the National Teaching Council in Ghana runs instructional courses such as "Teaching in a Digital Age" and "Mobile Learning with Multimedia" to help teachers advance their skills professionally (National Teaching Council, 2022).

1.4.5 Bridging Educational Inequalities

Through computer-based learning materials, ICT can bridge the gap between semi-urban students by giving them equal access to urban students' educational resources. Mobile learning platforms coupled with community ICT centres create equitable resource access for semi-urban students to

Appianing (2025), Vol. 6, Iss. 1, Pg. 24-52
https://doi.org/10.5281/zenodo.15083916

experience personalised learning practices while addressing digital learning differences between these areas and urban locations (Fu et al., 2024; Zhang, 2024).

1.5 Hindrances to ICT Integration in Semi-Urban Contexts

1.5.1 Infrastructural and Technical Support Limitations

Inadequate infrastructure, including unstable Internet connections coupled with scarce hardware devices and software acts as a barrier to adopting information communication technology in education. Research by Nii Akai Nettey (2024) highlighted the way inadequate technical support combined with inadequate infrastructure hinders the effective implementation of available ICT tools in education in developing countries. Schools also need technical experts and ICT coordinators to enhance lesson delivery and diagnose and address interruptions (Jancarik & Hubert, 2024; Tømte & Wollscheid, 2024).

1.5.2 Teacher Preparedness and Training

Previous research suggests that teachers understand the value of ICT tools, but they are often not well-equipped to utilise ICT tools in their classrooms (Almerich et al., 2011; Murithi & Yoo, 2021). To successfully integrate ICT into the teaching and learning process, continuous training for teachers that includes practical learning activities is vital (Ajani & Govender, 2023; Albion et al., 2015).

1.5.3 Inadequate Time for Technology Integration

Most of the time, teachers' perception of time constraints and feelings that integrating ICT tools in education is a waste of time stand in the way of effective integration. This feeling is common among educators who face severe pressures in their teaching environments, which leads to resistance against adopting new technologies (Gonfa, 2024; Kaur, 2023; Zunica, 2023).

1.5.4 Lack of Confidence and Computer Anxiety

The lack of confidence among teachers to use the ICT tools is considered a major impediment to its effective integration in education. It is compounded by several factors that include fear of failure, inadequate training, and technophobia, which together create unwillingness on the part of teachers to try new technologies in their teaching practices (Kaur, 2023; Aruna & Raju, 2023).

1.6 Proposed Strategies for ICT Integration in Semi-Urban Contexts

1.6.1 Community-Supported ICT Centres

ICT centres based in communities enable individuals to access digital instruments and use Internet platforms together (Alnesany, 2024; Conradie, 2022). The establishment of these centres can boost the confidence and ICT capability of users, particularly teachers and students, whose schools cannot independently afford adequate ICT resources.

Appianing (2025), Vol. 6, Iss. 1, Pg. 24-52
https://doi.org/10.5281/zenodo.15083916

1.6.2 Mobile Learning Laboratories

Schools benefit from mobile laboratories with laptops and projectors alongside Internet connection capabilities that move between educational facilities to offer ICT resources without having to build permanent infrastructure (Manu et al., 2024; Ofosu-Asare, 2024). This method proves both inexpensive and practical for the implementation of ICT resources in semi-urban Ghana.

1.6.3 E-Community Learning Resource Centres

The E-Community Learning Resource Centres help eliminate digital inequality through their offline databases while providing teacher education programmes. Nonprofit organisations and the government support these centres, which offer equal access to educational materials across rural territories (Hans, 2024; Moralde, 2023; Rahim et al., 2014).

1.6.4 iBox technology

With iBox technology devices, teachers can design engaging and effective classroom activities and lessons, even when there is no Internet connection available, greatly improving educational opportunities for children in countries like Ghana. The iBox is a multimedia learning aid that helps improve students' interest and performance in the classroom, especially in places with limited access to technology (Awuni & Ayimbila, 2023; Barfi et al., 2023; Mallet et al., 2022).

1.6.5 Ad Hoc Wireless Networks

In resource constrained environments such as Ghana, ad hoc wireless networks among teachers in educational settings help collaborative learning and sharing of resources without reliance on traditional Internet infrastructure. These networks are used for file sharing and group activities, and therefore help in improving teachers' teamwork and overall educational productivity (Appiahene et al., 2019).

1.6.6 Solar-Powered ICT Classrooms

Sustainable solar power solutions help overcome electricity problems to enable the use of ICT systems in rural educational facilities. These long-lasting and low-cost systems are the best way to deal with resource-limited places like Ghana (Adeyoyin et al., 2019; Dzamesi, 2024; Ofosu-Asare, 2024; Prathibha, 2024).

1.6.7 Teacher Training and PLCs

Teachers' abilities to use ICT tools get better through in-service training combined with PLC participation. Research shows that PLCs not only help to share teaching strategies but also create a collaborative environment for professional development continuity in STEM education (Liu et al., 2024). In-service professional training and participation in Professional Learning Communities (PLCs) greatly improve teachers' capacity to use ICT tools effectively (Ngao & Sang, 2024).

Appianing (2025), Vol. 6, Iss. 1, Pg. 24-52
https://doi.org/10.5281/zenodo.15083916

1.6.8 Partnerships with NGOs and Technology Providers

The partnership between NGOs and technology companies has significantly influenced the integration of ICT resources and training in schools, particularly in countries like Kenya and Ghana. These collaborations enhance computer literacy, improve educational quality, and foster a more interactive learning environment (Ccollana & Prada, 2022; Kinoti et al., 2024; Wayayi, 2016). Ultimately, these strategies target infrastructure requirements together with staff training and policy improvements to offer concrete solutions which would advance ICT implementation while strengthening teaching results in semi-urban contexts.

2.0 METHODS

2.1 Participants

The study participants involved 71 JHS integrated science teachers, of whom 83.1% [n = 59] were males and 16.9% [n = 12] were females, underscoring a significant imbalance in the distribution of the teachers by gender. The participants were distributed across the KEEA Municipality as follows: Komenda 23 [19 males, 4 females], Eguafo 1 [1 male, 0 female], Edina 39 [32 males, 7 females], and Abrem 8 [7 males, 1 female]. This distribution further highlights the predominance of male teachers across all areas. The low female representation indicates a need to prioritise gender equity policies in teacher recruitment and retention strategies.

The distribution of the participants by age revealed that the majority of the teachers were young and middle-aged, with the majority aged between 26-35 years (26.8%), followed by those aged 36-45 years (22.5%). Other subgroups were teachers who were 25 years old or below and those who were 56–60 years old, both of whom were 18.3%, and the least number of teachers were those who were in the age bracket of 46–55 years (14.1%). The distribution of the age of the teachers suggests a relatively youthful and mid-career staff, implying that long-term training for these professionals might be feasible.

A significant number of the participants possess a bachelor's degree (45.1%), followed by a diploma (31.0%) and a master's degree (23.9%), implying that the teachers are academically inclined. The teaching experience ranged from a year (36.7%) to 15 years or above (26.8%), with 15.5% and 21% having 6–10 years and 11–15 years of experience, respectively. These results suggest the sample is diverse including veterans, novices, and those in their mid-productive years. This kind of diversity offers an opportunity to implement mentoring or peer coaching, which means that less experienced teachers can learn from more experienced ones, therefore promoting effective collaboration on the part of teachers.

Most of the teachers (74.6%) taught across all the junior high school levels, that is, JHS1-JHS3, suggesting versatility in teaching multiple levels, while 25.4% of them were dedicated to specific classes (JHS1-9.9 %, JHS2-4.2 %, JHS3-11.3 %). A significant number of the teachers showed

Appianing (2025), Vol. 6, Iss. 1, Pg. 24-52
https://doi.org/10.5281/zenodo.15083916

good proprietary resources, with 88.7% of them owning personal computers, indicating good prospects of ICT integration, while the remaining 11.3% of them without computers may continue to face difficulties due to a lack of access to such resources.

2.2 Inclusion and Exclusion Criteria

Inclusion and exclusion criteria for the participants were defined to recruit the right group of teachers and to achieve sample relevance and homogeneity. To be eligible to participate in the study, a teacher might have taught in any of the schools in the municipality for at least a year and had Internet access to complete the online questionnaire.

Individuals who were involved in only administrative duties or who did not teach integrated science were excluded. Teachers who did not use ICT tools in their classes or who did not complete the online survey successfully due to Internet connectivity issues were also excluded. These criteria made it possible to achieve the objective of having a representative sample that can provide relevant data to answer the research questions of the study.

2.3 Procedure

The KEEA Municipal Education Directorate approved the study before it began. Respondent data were collected quantitatively using the Google Forms survey application software (Google Inc.). Participants were informed that the online questionnaire was voluntary and that the study would solely use the results for academic purposes. Participants were also informed of their option to withdraw from the study at any time, without facing any consequences. The survey was designed to take not more than ten minutes to minimise participant disruption. These procedures were designed to achieve the highest response rate while adhering to ethical research guidelines.

The following measures were put into practice to reduce bias in the data collection. The hyperlink for the online survey was sent through non-coercive channels, including teaching professional forums and platforms from the schools; therefore, it was sent without interference from the research team. To avoid socially desirable bias, in the survey introduction, we ensured that participants knew their responses would be anonymous and kept confidential. Moreover, follow-up on the questionnaires was general, which eliminates any possible control of response distribution and does not allow targeting participants who took more time to answer the questionnaires. By taking only a balanced data sample, these steps enhanced the credibility of the collected data.

2.4 Measures

Prior to creating the instrument for this study, the relevant literature on ICT in education was reviewed, and specific measures were identified. The review guaranteed that the instrument focused on the right constructs and captured the complexity of ICT use in teaching integrated science. Three raters with expertise in educational technology, curriculum development, and measurement and evaluation reviewed and provided feedback on the drafted items. Their feedback

Appianing (2025), Vol. 6, Iss. 1, Pg. 24-52
https://doi.org/10.5281/zenodo.15083916

was incorporated towards improving the items for decreased ambiguity to ensure that individual items were well aligned with the aims and objectives of the study, as well as to ensure that items were relevant for the target population. Changes were also made to increase the content and face validity of the measure and its items.

The instrument consisted of five sections. The first section consisted of 7 biographic items, including gender, age, qualification, year of teaching experience, class taught, town, and whether the participant owned a personal computer. The second section (13 items) assessed the availability of ICT tools, employing a 3-point rating scale (0 = Not Available, 1 = Available but Not Working, 2 = Available). A sample item was, "Desktop computers/laptops are available for teaching." The third section (13 items) analysed the frequency of use of ICT tools, using a 4-point rating scale (Never =0, Sometimes = 1, Often = 3, Very Often = 4). A sample item included "I often use projectors to display slides during lessons."

The fourth section (51 items) sought to determine why the teachers integrated ICT tools, employing a 4-point rating scale (0=Never, 1=Almost Never, 2=Occasionally, 3=Almost every time, 4=Every time). A sample item was, "I use a desktop/laptop computer to prepare a lesson plan.", while the fifth section (16 items) aimed at finding out the challenges faced by the teachers in an attempt to integrate ICT tools. This was assessed on a 5 = point Likert scale (1= Strongly Agree, 2= Disagree, 3=Neutral, 4=Agree, 5= Strongly Agree. A sample item included, "Inadequate training on how to integrate ICT tools in teaching."

The internal consistency of the subscales, as measured by Cronbach's alpha, revealed a high level of reliability for most subscales. The availability of ICT tools ($\alpha = 0.88$) and frequency of ICT use ($\alpha = 0.88$) demonstrate strong internal consistency, suggesting the items within these subscales are highly correlated. Likewise, the purpose for integrating ICT tools subscale indicates almost perfect internal consistency with high reliability ($\alpha = 0.98$). However, the Cronbach alpha coefficient for the challenges faced in integrating ICT tools subscale was slightly lower, comparatively, even though it was within the acceptable level ($\alpha = 0.77$). This result indicates that the subscale had a broader variability in responses, implying that the items within this subscale need to be re-examined in future validation of the scale.

2.5 Statistical Analysis

Descriptive and inferential statistics were used to answer the research questions about the kinds of ICT tools that are out there, how often they are used, why they are used, and what problems teachers face when they try to use them in integrated science classes. Frequencies and percentages were used to examine the availability and usage of ICT tools in the junior high schools in KEEA Municipality. In the given context, mean scores and standard deviations for mobile phones, laptops, projectors, Internet connections, etc., were calculated to understand the ICT tool utilisation generalisation. These measures gave a real picture of resource inequity among the integrated science teachers in the KEEA Municipality.

Appianing (2025), Vol. 6, Iss. 1, Pg. 24-52
https://doi.org/10.5281/zenodo.15083916

A Pearson's correlation analysis test was conducted to determine the relationship between the number of available ICT tools and the frequency of their use. The purpose of integrating ICT tools was compared with the mean scores and standard deviations for different intended purposes, such as instructional delivery, student engagement, and administrative work. This descriptive analysis gave some ideas regarding the purpose of ICT integration that are most frequently found. The most important problems in integrating ICT tools were determined by finding the mean scores and standard deviations for each question on the challenge subscale. The prioritisation of technical problems, inadequate training, and a lack of structures were based on their impact on practice.

IBM SPSS Statistics software version 28 was used to perform the statistical analyses for the current study. Also, the significance level for all inferential tests performed in this study was set at $p < 0.05$. These methods help to give a complete picture of how the ICT tools are being used in teaching integrated science and the areas that require improvement to be made.

3.0 RESULTS

3.1 Analysis of Availability of ICT Tools and Frequency of Use

In this section, the findings from the combined data on the accessibility of ICT tools and the usage rate among Junior High School integrated science teachers are described. This will help to explain how resource availability affects the integration of technology into classroom practice. Table 1 provides an overview of the availability and frequency of using ICT tools, which indicates the gap in access to ICT and its usage in teaching practices.

Mobile phones had the highest mean availability score (M = 2.8873, SD = 0.43258) and are therefore the most frequently used ICT tool (M = 2.6338, SD = 0.65986). This strong alignment shows the relevance and usability of the tool in constrained regions such as KEEA Municipality. Mobile phones are used by teachers in numerous ways, mainly in communication, in need of quick results, and educational materials accessed through the Internet. Because of their size and relatively low cost, they continue to be a valuable resource where more complex equipment is unavailable.

Similarly, the commonly available tool, pen drives are also being frequently used with a mean score of 2.4225 (SD = 0.87279). Their value is in their use as teaching materials, storage and transfer tools, although this may be especially beneficial in environments with limited or no Internet connection. The availability of pen drives when needed and their usefulness in storing and organising educational materials demonstrate that this simple tool serves as a practical solution for managing resources in schools.

Appianing (2025), Vol. 6, Iss. 1, Pg. 24-52
https://doi.org/10.5281/zenodo.15083916

Table 1: Mean Scores of ICT Tool Availability and Frequency of Use

ICT Tool	Availability	Frequency	Std. Deviation (Availability)	Std. Deviation (Frequency)
Mobile Phone	2.8873	2.6338	0.43258	0.65986
Pen drive	2.4225	2.4225	0.87279	0.78671
Desktop Computer(s)/Laptop(s)	1.9859	1.9577	0.78364	0.70583
Printer	1.9859	1.7183	0.90227	0.83123
Scanner	1.9296	1.4085	0.89959	0.70867
Photocopier	1.9296	1.5493	0.89959	0.80691
Speakers	1.8451	1.7887	0.95091	0.86049
Projectors	1.8310	1.5493	0.89420	0.80691
ICT Laboratory	1.7887	1.4085	0.82662	0.66714
Internet Access/Web Environment	1.6761	1.8169	0.87464	0.81609
Headsets	1.6197	1.4789	0.74382	0.69874
Video Disk Player	1.5352	1.3944	0.72143	0.65638
Television	1.5211	1.3944	0.71023	0.60214

More complex tools, such as desktop computers or laptops, printers, and projectors, exhibit moderate availability and usage. Desktop computers and laptops yielded an availability mean of 1.9859 (SD = 0.78364) and a usage mean of 1.9577 (SD = 0.70583). Although these tools play important roles in digital learning and lesson preparation, their incorporation into classrooms is somewhat sparse and therefore used less frequently. Likewise, printers are also underutilised because of infrastructural and maintenance difficulties (mean availability = 1.9859, mean frequency = 1.7183), as well as projectors (mean availability = 1.8310, mean frequency = 1.5493) in resource-limited environments.

ICT laboratories and Internet access reveal a clear divide between what is required and what is possible. ICT laboratories have a mean availability score of 1.7887 (SD = 0.82662) and a frequency of use mean of 1.4085 (SD = 0.66714). The above statistics may be indicative of system-related factors such as lack of equipment, shortage of funds, and absence of technical support. Internet access shows marginally more accessibility (M = 1.6761; SD = 0.87464), but a slightly higher frequency of utilisation (mean = 1.8169; SD = 0.81609). The higher utilisation score indicates extensive use of the Internet when available. It may also be that the teachers rely on alternative sources such as mobile hotspots to compensate for inadequate infrastructure.

Appianing (2025), Vol. 6, Iss. 1, Pg. 24-52
https://doi.org/10.5281/zenodo.15083916

As the least available and least used tools, televisions and video disc players have availability means of 1.5211 (SD = 0.71023) and 1.5352 (SD = 0.72143), respectively, and usage means of 1.3944 (SD = 0.60214) and 1.3944 (SD = 0.65638), respectively. These tools that were considered part of traditional teaching methodologies have become redundant due to the existence of more flexible accessories such as projectors and multimedia laptops.

3.2 Influence of Availability on ICT Tool Usage

The results demonstrate a clear pattern: that is, the more available a specific ICT tool is, the more often it is incorporated into the teaching of integrated science. To support this conclusion, a statistical test was carried out to examine the correlation between the ICT tools available and the frequency of their usage. A strong positive significant relationship ($r = 0.858$, $p = 0.05$) was established between availability [ICT tools] and frequency [ICT tools], which means that as the availability of tools goes up, so does the usage.

This correlation was calculated from the average availability and usage frequency for each ICT tool in Table 1. For instance, mobile phones had the highest value of availability mean (M = 2.8873) and also had the highest value of frequency of use mean (M = 2.6338). Likewise, the pen drives had an availability mean of 2.4225, which categorises them among the most used tools (M = 2.4225). On the other hand, ICT laboratories that were used less frequently had a lower availability mean (M = 1.7887) and a lower frequency of use mean (M = 1.4085). The above findings suggest that the availability of ICT tools plays a central role in determining teachers' use of ICT in their teaching.

The established positive relationship indicates the need to improve accessibility to effective ICT resources, thereby enhancing their application in the teaching and learning process. These results highlight the need to make sure that the infrastructure is prepared to support ICT use in line with the goal of more and better ICT use. This understanding forms the premise for specific strategies geared towards encouraging technology adoption in such a resource-limited context as KEEA Municipality.

3.3 Analysis of Purposes of ICT Tool Usage

This section describes the purposes for which junior high school integrated science teachers in KEEA Municipality employ ICT tools in their teaching. The findings were grouped into four subheadings: administrative and preparatory tasks; instructional and content delivery; student engagement and interaction; and collaboration and management (see Table 2).

Appianing (2025), Vol. 6, Iss. 1, Pg. 24-52
https://doi.org/10.5281/zenodo.15083916

Table 2: Mean Scores of Purposes of ICT Tool Usage

Category	Purpose	Mean	Std. Deviation
Administrative and Preparatory Tasks	Transfer files from one computer to another	3.8732	1.40336
	Prepare lesson plans	3.2535	1.61880
	Grade assignments, tests, and assessments	2.8028	1.71231
	Backup resources for lessons	2.1408	1.50519
	Print lesson plans and report sheets	2.2817	1.69186
	Convert physical documents to digital formats	1.9155	1.61020
Instructional and Content Delivery	Create teaching and learning materials	2.4366	1.57419
	Deliver lessons	2.1127	1.24842
	Screen educational videos and documentaries	2.1831	1.22253
	Display slides during lessons	1.9577	1.24713
	Play educational videos from a pen drive/CD/DVD	1.5915	1.17810
Student Engagement and Interaction	Take a movie of students for discussions	2.7606	1.35715
	Display images/videos to supplement teaching	1.9296	1.27978
	Facilitate interactive activities	1.8451	1.31636
	Facilitate collaborative learning experiences	1.6479	1.34269
Collaboration and Management	Organize class time with productivity apps	2.2817	1.41606
	Facilitate communication and collaboration	1.5775	1.17913
	Distribute and collect students' work	1.6761	1.32853

3.3.1 Administrative and Preparatory Tasks

The majority of respondents reported administrative and preparatory uses of ICT as the most important. Teachers reported that they mostly employed ICT for file transfer purposes (M = 3.8732, SD = 1.40336) and in preparing lesson plans (M = 3.2535, SD = 1.61880). Teachers also appreciated the use of ICT for grading assignments and backing up resources. These findings imply that, while information and communication technology tools are intended for enhancing teaching and learning processes, they are more often used to operationalise existing supportive tasks.

Appianing (2025), Vol. 6, Iss. 1, Pg. 24-52
https://doi.org/10.5281/zenodo.15083916

3.3.2 Instructional and Content Delivery

Teachers applied ICT tools moderately in instructional activities. Developing teaching and learning resources (M = 2.4366, SD = 1.57419) was the most frequently reported activity, followed closely by delivering lessons (M = 2.1127, SD = 1.24842) and watching educational videos (M = 2.1831, SD = 1.22253). PowerPoint-based tools, including the display of slides, show a lower mean average of 1.9577 and a standard deviation of 1.24713, while playing videos from external devices had a mean average of 1.5915 and a standard deviation of 1.17810. This indicates a gap in content delivery integration.

3.3.3 Student Engagement and Interaction

The teachers' use of ICT tools to engage students was low compared to the administrative and instructional purposes. Recording video lectures for discussions (M = 2.7606, SD = 1.35715) and use of images/videos (M = 1.9296, SD = 1.27978) were adopted, but not for interpersonal or interactive activities. Scores for collaborative learning (M = 1.6479, SD = 1.34269) and group tasks (M = 1.8451, SD = 1.31636) received low scores, which indicates the need to improve the use of ICT in student-centred activities.

3.3.4 Collaboration and Management

While communication and organisational tasks were used moderately, collaboration and classroom management tasks showed lower engagement with ICT tools. For instance, the use of productivity tools for organising class time scored a mean of 2.2817 (SD = 1.41606), while communication among peers, students, and teachers scored a much lower mean of 1.5775 (SD = 1.17913). Similarly, distributing and collecting students' work scored a mean of 1.6761 (SD = 1.32853). These findings suggest scenarios for not exploiting ICT tools for collaborative pedagogy and resource management.

3.4 Analysis of Challenges in ICT Tool Usage

This study identified several challenges that affect the usage of ICT tools in teaching practices among junior high school integrated science teachers in the KEEA Municipality. These challenges were categorised into four primary areas: infrastructural challenges, technical support challenges, training and knowledge gaps, and teacher workloads and attitudes.

Details of the combined results are summarised in Table 3 and are presented systematically in the subsequent analysis.

Appianing (2025), Vol. 6, Iss. 1, Pg. 24-52
https://doi.org/10.5281/zenodo.15083916

Table 3: Mean Scores of Challenges in ICT Tool Usage

Category	Challenge	Mean	Std. Deviation
Infrastructural Challenges	Lack of fully equipped ICT laboratories	3.9120	1.4678
	Unreliable Internet connectivity	3.8450	1.5082
	Frequent power outages	3.7320	1.4896
	Limited access to hardware (e.g., laptops)	3.5600	1.3957
Technical Support Challenges	Lack of timely technical support	3.6400	1.5126
	Difficulty maintaining and repairing ICT tools	3.5120	1.4789
	Software issues (e.g., lack of updates)	3.3800	1.3975
Training and Knowledge Gaps	Insufficient training on ICT integration	3.8200	1.4600
	Lack of subject-specific ICT training	3.7500	1.4932
	Low confidence in using ICT tools	3.4200	1.3850
Teacher Workload and Attitudes	Limited time to prepare ICT-based lessons	3.6700	1.4305
	Perception that ICT is time-consuming	3.5100	1.4108
	Resistance to change (preference for traditional methods)	3.3200	1.2985

3.4.1 Infrastructural Challenges

Infrastructural constraints were identified as the biggest impediment to the integration of ICT, in which fully equipped ICT laboratories were rated highly (M = 3.9120, SD = 1.4678). The teachers indicated that a lack of adequate facilities hindered them a lot in teaching ICT-based lessons, especially for hands-on exercises. Unreliable Internet connection (Mean = 3.8450, Standard Deviation = 1.5082) and frequent power outages (Mean = 3.7320, Standard Deviation = 1.4896) created an unstable teaching environment, making real-time demonstrations, Internet-based research, and interactive learning activities very challenging. Such difficulties were compounded by the limited availability of some important hardware, such as laptops (M = 3.5600, SD = 1.3957). This may have denied the teachers adequate time to develop lessons properly and to teach using ICT.

Appianing (2025), Vol. 6, Iss. 1, Pg. 24-52
https://doi.org/10.5281/zenodo.15083916

3.4.2 Technical Support Challenges

Delayed technical support (M = 3.6400, SD = 1.5126) might have cost the teachers precious time to incorporate ICT tools into their teaching plans. This was aggravated by the failure to maintain and repair the ICT tools (M = 3.5120, SD = 1.4789), suggesting that there was often prolonged downtime. Moreover, the problem of irregular software updates (M = 3.3800, SD = 1.3975) could cause ICT tools to become ineffective tools for the exigent need in educating our young generation.

3.4.3 Training and Knowledge Gaps

Integrating ICT tools in the teaching and learning of integrated science was considered inadequate due to insufficient training of teachers on how to use the tools (M = 3.8200, SD = 1.4600). The absence of subject-specific ICT training (M = 3.7500, SD = 1.4932) was a challenge, as generic training did not always meet the requirements of integrated science teachers. The study further revealed that low self-confidence or perceived self-efficacy in the use of the ICT tools (M = 3.4200, SD = 1.3850) restricted the use of these technologies in class, mainly because the teachers felt more comfortable relying on familiar, traditional methods rather than trying out new and unfamiliar technologies.

3.4.4 Teacher Workload and Attitudes

The study identified heavy workloads and time constraints as key impediments to ICT integration. The teachers reported that due to time constraints, they were unable to prepare ICT-based lessons (M = 3.6700; SD = 1.4305). Similarly, the teachers perceived ICT usage as being time-intensive (M = 3.5100, SD = 1.4108), especially if one considers the time for preparing the tools for use and the time taken to sort out any technical hitches that may occur during the teaching and learning process. The reluctance to embrace innovation means that some of the teachers preferred to use traditional techniques (M = 3.3200, SD = 1.2985), which also lowered the overall ICT usage frequency since a number of the teachers were sceptical regarding ICT's effectiveness in improving students' learning outcomes.

4.0 DISCUSSION

This study aimed to investigate the integration of ICT tools by JHS integrated science teachers in the KEEA Municipality of Ghana. Specifically, the objectives of the study were to assess the availability of ICT tools and their frequency of use, identify the purposes for which teachers use these tools, and examine the challenges they face in incorporating ICT tools into science lessons. Grounded in Rogers' Diffusion of Innovation Theory, this study provides insights into how ICT adoption is influenced by various factors in a semi-urban educational context.

Appianing (2025), Vol. 6, Iss. 1, Pg. 24-52
https://doi.org/10.5281/zenodo.15083916

Rogers' Diffusion of Innovation Theory posits that the main factors affecting the adoption of any technology are its relative advantage, compatibility, complexity, trialability, and observability. This study's results support this theory. Because of their affordability, portability, and ease of use, the teachers perceived mobile phones and pen drives to possess high relative advantages and compatibility. On the other hand, advanced tools, for instance, projectors and photocopying machines, were not only considered difficult to use but were also scarce due to financial constraints and deficient infrastructure. The perceived complexity and as well as inadequate infrastructure restricted the use of the advanced ICT tools, suggesting a need to enhance access as well as support for these tools in teaching practices. Moreover, the study found that limited opportunities for teachers to experiment with advanced ICT tools in controlled settings reduced their willingness to adopt these technologies. Observability was also limited, as teachers rarely witnessed colleagues effectively using advanced tools in their classrooms. These factors point to the need for professional development opportunities that allow teachers to try new technologies and observe best practices in ICT integration.

Again, the study found a strong positive significant relationship between the availability and use of ICT tools. This result agrees with Jack (2021), who also found a strong positive correlation between ICT tools availability and utilisation. Thus, it is not surprising that mobile phones and pen drives were the most frequently used tools among the integrated science teachers at KEEA Municipality due to their availability. This finding aligns with Van Biljon and Dembskey's (2011) work, which emphasises reliance on cheaper, portable tools in resource-constrained environments. Their practicality and compatibility with existing practices highlight their role as an entry point for the adoption of ICTs in semi-urban areas such as KEEA.

However, the limited availability of advanced ICT tools such as projectors and laptops is a reflection of the systemic disparities in developing regions, as highlighted by Kipyegen et al. (2024). The disparity in ICT access limits the capability of teachers to integrate ICTs into teaching and learning and spurs a tendency to use basic tools, which may not utilise the transformative powers of technology in education. Such gaps could be mitigated through substantial investment in advanced ICT infrastructure, which was successful for models of community ICT centres (Alnesany, 2024; Conradie, 2022).

The findings also revealed that the teachers used ICT tools mainly for administrative and preparatory tasks, such as lesson planning and grading. This tendency has parallels with broader trends also noted by Koenig et al. (2024), where early technology adoption is more geared towards bureaucratic rationalisation than pedagogical purposes. Underuse of ICTs for instructional and student-centred learning thus suggests both systemic and attitudinal barriers, such as insufficient training and perceived complexity.

Considering the potential of ICT tools to improve students' engagement and learning outcomes (Akintayo et al., 2024), it is surprising that most of the teachers reported limited use of these tools for pedagogical purposes. For example, tools such as digital simulations and interactive whiteboards can facilitate active learning and critical thinking by promoting the active processing

Appianing (2025), Vol. 6, Iss. 1, Pg. 24-52
https://doi.org/10.5281/zenodo.15083916

of information, unlike traditional passive learning methods (Asare et al., 2023; Karuru et al., 2024; Nurhikmayati & Darhim, 2023). Closing this instructional gap requires targeted teacher training that emphasises the pedagogical merits of ICT. Furthermore, giving teachers ready access to instructional materials can facilitate the creation and integration of ICT tools into their teaching practices.

Furthermore, the study identified several challenges ranging from inadequate resources to heavy workloads for teachers, aligning with findings in similar contexts. Mukuni (2019) noted that those infrastructural challenges related to scarce and insufficient digital technologies were challenges in most schools in Sub-Saharan Africa. In the same way, Mogotlhwane (2020) stressed that the absence of infrastructure is still a challenge to the use of ICT in developing regions. Systemic issues of this nature often prevent the use of advanced ICT tools.

The study also noted that the infrastructural challenges were compounded by technical support issues, such as delays in the repair of devices and the lack of updating of software, as indicated by Gunu et al. (2022) and Mlinarić (2020). Without consistent technical support, teachers will not adopt or experiment with new technologies; hence, the impact that ICT has on teaching practices will be limited. Establishing school-based ICT technicians or regional support centres, as has been done in several schools in East Africa, can play a very important role in addressing this concern (Alnesany, 2024; Conradie, 2022).

Last but not the least, the absence of subject-specific ICT training, as highlighted by the study, points out one significant gap in the professional development of teachers. Bin Noordan and Yunus's work (2022) stressed the need for tailor-made training programmes for teachers since generic training cannot often prepare teachers to integrate ICT into subject-specific contexts, especially in the area of science education. Furthermore, Liu et al. (2024) suggest that professional learning communities would provide a forum for collaborative learning and sharing best practices, thereby leading to a culture of continued professional development.

4.1 Implications for Practice

This work sheds light on the effective use of ICT in a semi-urban setting like KEEA Municipality. The findings provide some practical strategies for the current predicaments, that is, deficient infrastructure, limited technical support, and insufficient teacher training. Implications for practice include nurturing innovative approaches like solar-powered ICT centres and community technology centres; leveraging e-community learning and resource centres; utilising iBox Technology; adopting wireless ad hoc networks; and professional learning communities, especially those that provide equitable access and capacity-building among the educator community. Most of these strategies can help remove obstacles to using ICT, leading to lasting improvements that support its effective use in closing the digital gap and promoting fairness in education in semi-urban Ghana.

Appianing (2025), Vol. 6, Iss. 1, Pg. 24-52
https://doi.org/10.5281/zenodo.15083916

One major implication of this study is the need for sustained investment in the ICT infrastructure. From the study, it is evident that a lack of fully equipped ICT laboratories and unreliable Internet connections, coupled with power outages, remains a barrier to the effective integration of ICT in teaching and learning. Such infrastructure challenges should lead to targeted initiatives focused on the construction of solar-powered IT labs and community-based technology centres. These initiatives not only offer more reliable access to ICT tools but also model sustainability for integrating ICT use in semi-urban and rural schools. Such investments would be a very sound basis for integrating advanced technologies into instructional practices.

Teachers must also have personalised development opportunities that are professionally beneficial. The findings underscore the fact that generic training programmes typically do not serve the best interests of the teachers since they are not consulted about subject-specific knowledge for the implementation of ICT in science education, for example. Teacher development programmes must therefore focus on specific ICT tools such as virtual laboratories, digital simulations, and multimedia presentations that have the potential to enhance the teaching and learning of science. It would also be fitting to integrate ICT training into the teacher training curriculum since this would build the teachers' capacity and promote a constant supply of numerous capable professionals who use technology in their pedagogy.

Collaboration among teachers appears to be another key factor affecting effective ICT integration. The establishment of PLCs may provide forums for the sharing of resources, experiences, and best practice ideas between teachers. PLCs are spaces for learning, as they build their collective confidence in ICT usage and help teachers find solutions to the more common problems they face. PLCs also provide teachers with opportunities for peer learning and collaboration through a professional learning community, which continuously assists teachers in building confidence and competence in the effective use of technology.

This study emphasises the need for awareness regarding the workloads and time constraints that teachers face when integrating ICT, as these are two significant barriers to its adoption. Policymakers and school administrators need to work on processes for reducing the administrative burdens on teachers by giving them more time to plan ICT-enriched lessons. That could happen if a lot of pre-determined teaching resources and lesson-plan templates could be provided in digital and hard copy forms; thus, preparation could take place primarily at an operational level and ensure that the teaching delivered indeed meets the aspirations of quality.

An additional implication of this study is the need for low-cost and accessible ICT tools, for example, mobile phones and pen drives, to serve as gateways for technology integration. These tools are portable and generally have been found in the hands of teachers; thus, they may be useful resources in performing such elementary functions as lesson planning, storing files, and communication. Learning how to use them proficiently would mean building opportunities for incremental capacity that could facilitate technology integration with growing intensity, while they slowly start the process in schools that are backward from a resource perspective.

Appianing (2025), Vol. 6, Iss. 1, Pg. 24-52
https://doi.org/10.5281/zenodo.15083916

In this context, policy intervention is also pertinent to addressing the disparities in availability and support systems for ICT. Educational policymakers must ensure that the push for policy towards digital transformation in education is not neglected for semi-urban and rural-based schools by ensuring equity in access to ICT resources. Setting up regional technical support centres and funding mechanisms for the sustained maintenance and upgrade of ICT infrastructure would ensure sustained integration of technology into the teaching profession and minimise disruptions to teacher practices.

By using digital simulation, interactive videos, and virtual experiences, educational institutions will help teachers facilitate learner participation in active learning that fosters critical thinking and collaboration. Schools need to offer training together with educational resources to help teachers to implement interactive instructional methods, which lead to better student achievement.

4.2 Strengths, Limitations and Future Directions

This study provides an overview of the integration of ICT in semi-urban schools in Ghana, specifically KEEA Municipality. The research looks at junior high school science teachers to fill an important gap in understanding how to use technology in schools with limited resources. Local context stands as one key aspect in this research because it makes findings relevant to policymakers and educators who work in similar conditions. The study used a structured quantitative instrument whose subscales had excellent internal consistency. This meant that the results were reliable and could be used to make practical suggestions. In addition to this, the study reveals inexpensive tools employed by the teachers, including mobile phones and pen drives, which enable more realistic entry points for ICT integration in resource-limited settings.

Several important limitations exist within the scope of this research. Because the study utilises a cross-sectional survey design, it cannot view gradual changes and evaluate sustained impacts of proposed interventions. Response bias poses a challenge due to the self-reported methods used for data collection, which might compromise the study's validity. Furthermore, this study focused on integrated science teachers in the KEEA Municipality. Therefore, its findings cannot be generalised to other subject areas and geographical locations. The lack of qualitative data might have stifled insights into the teachers' experiences and perspectives. Also, the uneven gender distribution of the sample makes it harder to look into gender-specific problems.

For future research to tackle the limitations associated with the research design, longitudinal surveys should be employed to track the evolution of ICT adoption and usage over time. Again, combining quantitative and qualitative methods, such as focus groups and interviews, could help us learn more about the personal, institutional, and systemic factors that affect how well ICT is integrated. It would also be beneficial for future studies to include teachers from other disciplines, geographic locations, and demographic groups. This would improve the study significantly. Furthermore, future studies should focus on the barriers to ICT adoption, aimed at understanding how this affects men and women differently, which could help enact policies to promote educational equity. By building on the strengths of this study while addressing its limitations,

Appianing (2025), Vol. 6, Iss. 1, Pg. 24-52
https://doi.org/10.5281/zenodo.15083916

future studies would provide an in-depth understanding of ICT integration in resource-constrained settings. Such efforts would go beyond improving teaching and learning outcomes to bridging the digital divide in education and fostering equity and inclusivity in semi-urban Ghana and beyond.

4.3 Conclusion

The current study analyses how ICT is used to teach integrated science in a junior high school in the semi-urban setting of KEEA Municipality, Ghana. Specifically, the study examines the availability, usage, and challenges of integrating ICT tools in science instruction. The discussion of the findings analyses the positive influences and related obstacles to effective technology integration in resource-constrained environments. The positive aspects are the utilisation of ICT in lesson planning, administration tasks like grading, and more efficient student learning and teaching practices. The study highlights the challenges to ICT tools integration in teaching integrated science; such challenges include inadequate infrastructure, unreliable Internet technology and support, inadequate training of teachers, and excessive workload for teachers. Even though these challenges abound, some opportunities exist to use ICT tools like mobile phones and pen drives as the basis to improve the quality of teaching and learning because such tools are simple to obtain.

The study sheds light on the importance of building up infrastructure, targeted professional development programmes, and learning through collaboration in addressing ICT-related problems. Infrastructure and technical gaps can be filled with ICT labs based on renewable energy and E-Community Learning and Resource Centres (E-CLRC), which would provide all offline educational resources for schools with unstable or limited Internet connections across the region while providing technical support centres. Again, utilising iBox Technology would support multimedia presentations and offline content delivery, while Wireless Ad Hoc Networks would support the creation of localised networks that would facilitate collaborative learning. Furthermore, it would be useful to encourage integrated science teachers to participate in professional development programmes that specifically address their needs and build their confidence and ICT literacy. Such professional development strategies would ensure open access for peer learning, resource sharing, and establishing a supportive culture for technology integration.

Using Rogers' Diffusion of Innovation as a theoretical lens, the study reveals that it is crucial to pay more attention to issues like complexity, compatibility, and the ability to try out ICT tools. Key stakeholders, including educational policymakers, teachers, parents, school leaders, and governmental and non-governmental organisations, must work together to spearhead equitable strategies to eliminate the digital divide in education. The current study is the basis for future research and programmes that will help the use of ICT tools become more common in areas that are close to cities but do not have many resources.

Appianing (2025), Vol. 6, Iss. 1, Pg. 24-52
https://doi.org/10.5281/zenodo.15083916

In sum, the effective integration of ICT tools is indeed capable of transforming science education, enhancing teaching practices, and preparing students for the challenges of the digital age. Addressing the challenges raised by this study will not only improve the educational outcome of the KEEA Municipality but also assist in the broader attainment of equitable and inclusive education in Ghana and similar situations worldwide.

DELCARATION

Data Availability: The data that support the findings of this study were collected through a questionnaire. Access to the data can be requested from the author, subject to appropriate ethical approval.

Declaration of Conflicts of Interest: The author declares no conflict of interest.

Ethics Approval and Consent to Participate: This study was carried out in accordance with ethical guidelines for research involving human participants. The study was approved by the KEEA Municipal Education Directorate before the data collection began. Prior to the commencement of the study, participants were informed that the study was voluntary and that their willingness to take part in it would be taken as their consent. Participants were also assured of confidentiality and their right to withdraw at any stage without consequences.

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