Digital Infrastructure and the Implementation of Science, Technology, Engineering, and Mathematics Subjects in Public Junior Schools in Kenya

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ABSTRACT

This article is an extract of a PhD thesis that investigated the influence of digital resource integration and the implementation of Science, Technology, Engineering and Mathematics subjects in junior public schools in Kitui County, Kenya. Digital resources have gradually become important in enhancing curriculum implementation in all educational levels, and their integration plays a key role in implementing the STEM curriculum. The study investigated the influence of the adequacy of digital infrastructure and the implementation of STEM subjects in junior public schools in Kitui County, Kenya. The study was guided by the Technological Pedagogical Content Knowledge (TPCK) theory of digital integration by Mishra and Koehler (2006). The study adopted the embedded mixed-method research design. The study target population was 3661 junior school teachers, 1102 headteachers and 19 Sub-County Quality Assurance and Standards Officers (SCQASOs). A sample of 670 respondents, including 294 headteachers, 360 teachers and 16 SCQASOs was sampled. The researcher established face validity by ensuring that all questions and interview schedules were developed from the study objectives and relevant literature and content validity through piloting selected schools across the county by choosing participants with similar characteristics to the target population. Schools which were piloting were not included in the sample of the research instruments. To establish reliability of the research instruments the researcher used the test–retest method**.** The questionnaires were administered to the pilot group of respondents drawn from public junior schools outside the main study sample**.** After a two-week interval**,** the same instrument was re-administered to the same respondents. The two sets of scores were correlated using Pearson's Product Moment Correlation Coefficient to determine the stability of the instrument over time. A reliability coefficient of 0.81 for the headteachers' questionnaire and 0.84 for the teachers' questionnaire. The overall reliability coefficient for the instrument was 0.83. Data was collected by use of structured questionnaires for headteachers and teachers, while interview schedules were used to collect data from Sub-county Quality Assurance and Standards Officers. Data was presented in descriptive statistics such as frequencies, tables, percentages, graphs, means and Standard deviation. Quantitative data was analysed aided by Statistical Package for Social Sciences (SPSS) software program version 28. Qualitative data from open-ended questions, opinions and interviews were analysed using the content analysis technique. The findings from interviews were reported and transcribed into themes and presented in narrations and direct quotes. A Pearson product-moment correlation was conducted to examine the relationship between independent and dependent variables, while regression was used to test the hypothesis. The study findings showed that mobile phones and tablets were relatively available but science laboratories, ICT laboratories, smart boards, interactive boards, reliable internet connectivity and standby power systems were found to be inadequate. While some schools had access to basic digital tools, such as mobile devices and tablets, the general state of these infrastructures in the majority of the public junior schools was inadequate for the successful implementation of STEM subjects. The study findings showed a strong positive correlation of 0.702 between the adequacy of digital infrastructures and the implementation of STEM subjects in public junior schools of Kitui County. The study therefore concluded that STEM subjects are not well implemented in junior schools of failures and inadequate digital infrastructures in the majority of junior schools. The study recommends that the Ministry of Education should priorities construction of key STEM infrastructures, that includes Science laboratories, ICT labs, technology workshops in schools, to facilitate proper CBE curriculum implementation, the government should develop a policy on school digital resource sharing so that schools can use labs and workshops in other institutions to solve the existing infrastructure gaps in their schools.

BACKGROUND TO THE STUDY

Education plays a central role in skills development by equipping individuals with the knowledge, competencies, and attitudes necessary for personal empowerment, employability, and lifelong learning. According to UNESCO (2023) quality education fosters both foundational skills such as literacy, numeracy and problem-solving while technical and vocational skills needed for work and sustainable livelihood. This means that education is the foundation for developing the skills people need to succeed in life and work as it prepares them for employability and productivity in the society. Education policies world-wide have geared towards Competence-Based Education (CBE) with much emphasis on Science, Technology, Engineering and Mathematics (STEM). One of such policies that anchors the need of STEM in schools is the Sustainable Development Goal (SDGs), goal number 4 which emphasizes promoting quality education and lifelong learning opportunities for all by 2030 (UNESCO,2015).

In order to achieve this plan, educational institutions are required to provide resources to ensure quality teaching and learning. Sessional paper No.1 of 2019 emphasizes the need of STEM through a policy framework that seeks to modernize education for sustainable development by improving the acquisition of knowledge and skills in STEM fields. The Information, Communication and Technology (ICT) policy, Republic of Kenya (2020) explains that digital inclusion and accessibility should be provided for all learners, particularly in the teaching of science and technology subjects. Digital integration supports the teaching of STEM subjects as it enhances the visualization of abstract concepts in science and the real-world application of STEM to practical use in industries. While there are several ways digital tools can be used in teaching, this study concentrated on digital infrastructure, digital content, teachers' digital competency and the influence of the technical support team and the implementation of STEM subjects in junior public schools in Kitui County, Kenya.

According to UNESCO (2020) digital resources are materials or any electronic materials, tools and services in digital form that are used to support teaching, learning, or research and educational management. These resources may include digital documents, e-books, online journals, databases, educational websites, multimedia content (audio, video, simulations), and interactive tools that are accessible via digital devices such as computers, tablets, white boards, projectors and LCD screens.

The concept of STEM education, an acronym for Science, Technology, Engineering and Mathematics which originated in the United States through the National Science Foundation (NSF) in the early 2000s. It was introduced to address the growing demand for a skilled workforce capable of driving innovation and technological advancement in a rapidly changing world (National Science Foundation, 2000). Initially referred to as Science Mathematics Engineering and Technology (SMET)**,** the term further evolved into STEM to promote an integrated, interdisciplinary approach to teaching and learning. STEM education emphasizes hands-on, inquiry-based learning**,** critical thinking and the application of knowledge to real-world problems (UNESCO, 2023).

Digital implementation refers to the systematic adoption, integration, and use of digital technologies to enhance the effectiveness of teaching and learning processes (UNESCO, 2021). In education, digital implementation goes beyond the provision of digital devices and infrastructure to include teacher capacity building, integration of digital content into pedagogy, and supportive institutional policies. Effective digital implementation in schools requires alignment between technology use, curriculum objectives and instructional practices that positively influence learning outcomes (OECD, 2015) In this study, STEM implementation will be measured through, quality of instructional practices such as the use of inquiry-based, problem-solving, and learner-centered teaching pedagogies aligned to Competency-Based Education (CBE), curriculum coverage and integration, learner engagement in STEM lessons such as active participation, collaboration, experimentation, project based learing, problem based learning that sustain interest in STEM learning activities, learner performance, skills development and acquisition of STEM competencies such as critical thinking, creativity, problem-solving, and application of knowledge.

According to a study carried by Fahadi et al. (2022) in Chicago, on technology enhanced teaching in engineering education in senior schools and colleges, it found that teachers' knowledge construction used Technological Pedagogical Content Knowledge (TPACK) framework which was purposeful integration of digital tools, platforms, and resources. When the framework was integrated in instructional practices it improved teaching effectiveness and student learning outcomes. The study further found that in science teaching, digital tools aroused students' interest not only in acquiring learning outcomes, but also on interacting and collaborating with their friends or peers more freely. The study concluded that, the use of digital tools in teaching science education had imparted general knowledge, a broad-minded attitude and enhanced creativity among learners in schools in Chicago. This meant that the use of digital tools was a better way of motivating students and that it contributed to effective teaching and learning of sciences. This implies that using digital resources is very important in teaching STEM subjects in public junior schools. While this study focused on the engineering education in senior schools and colleges in Chicago, this study was to establish whether junior school teachers in Kitui county of Kenya use any digital tools or platforms and how such use has imparted on the teaching and learning of science and technology subjects in schools.

In Nigeria, Alaku et al. (2023) found that digital resource implementation in schools enhanced effective science curriculum delivery. The study revealed that digital tools enabled teachers to deliver curriculum more effectively especially in monitoring and assessment of learning activities. Nigeria's introduction of ICT and digital resources in education had been gradual, starting in the 2000s with donor and partner pilots such as laptop donations and teacher training pilots and formal policy development following that. Large-scale, coordinated policy work was consolidated more recently when the National Policy on ICT in Education revised and approved 2019 and accompanying National Implementation Guidelines 2019 were the clearest formal signals of when Nigeria moved from scattered pilots toward a national roll-out strategy. The study further found typically improvements in access, engagement and sometimes procedural skills on the use of simulations, virtual labs, but robust nationwide learning gains in STEM are not consistently documented. Positive STEM imparts outcomes are concentrated where virtual labs, blended learning and teacher support programs were implemented well otherwise, constrained by poor labs, lack of devices, weak connectivity and limited localized digital content. The findings were applicable to the current study since it showed that digital tools and teacher's digital competency had greater influence in implementation of STEM subjects in public junior schools in Kitui county, Kenya.

The Kenyan Government, through its Bottom-up Economic Transformation Agenda (BETA) which is a National blueprint for Kenya, emphases that education should provide manpower for development in housing, agriculture, health and digital super highway. This draws its strength in the teaching and learning of STEM subjects in Junior schools, Senior schools and Technical Vocational and Educational Training (TVET) institutions (Republic of Kenya, 2019). The National ICT Policy Guidelines, Republic of Kenya (2020) revealed the need of integrating ICT in education through digital literacy programs, e-learning and ICT centers in schools. The policy further proposed the deployment of a nationwide e-education system, interconnecting schools, higher educational institutions, training facilities and knowledge centers into one. The National Education Sector Support Programme, NSSP (2018 – 2022) further emphasized the use of digital resources in education improved teaching and learning, and further improved education management outcomes. The policy further encouraged the development and use of digital content to supplement textbooks and other traditional learning resources that supported the introduction of e-learning platforms in schools, teacher training colleges and universities. According to KICD (2023) ICT is a core subject in the national CBE curriculum from junior school to senior school. The curriculum further required learners to infuse digital skills as a core competency such as creativity, critical thinking and learning to learn. This implied that digital resources were key determinant in the implementation of CBE and particularly the STEM pathway.

According to Benita et al. (2021) referred to digital infrastructure for schools as foundational technologies, systems and facilities that support the use of digital tools and online learning in educational institutions for teaching and learning. They included hardware such as computers, tablets, interactive whiteboards, and projectors, Connectivity such as internet access, Wi-Fi networks, mobile data, Software and platforms such learning management systems (LMS), digital content, educational apps, and data storage systems and technical support systems such power supply, ICT maintenance and cybersecurity measures. According to Kachope et al (2025) digital resources plays critical roles in STEM education such as it enhances practical learning through simulations, use of virtual labs, and modeling software that allow learners to conduct experiments digitally, especially where physical laboratories or materials are limited. It promotes Inquiry-Based learning (IBL) and experiential learning where digital tools help learners in collecting, analyzing and visualizing data, fostering critical thinking and problem-solving skills. It also fosters collaboration and innovation through online platforms such as One Note which enables students to collaborate on STEM projects, share ideas and work on global challenges and lastly it expands access to learning resources where teachers and learners have a wide poll of online materials, open educational resources (OER) and video tutorials that enrich classroom learning and improves assessment and feedback through use of digital systems that make it easier for teachers to track learners' progress through quizzes, e-portfolios and automated feedback tools such as Kahoot.

Key Words: Digital resources, STEM subjects, Digital Implementation, Digital Infrastructures, Competence-Based Education (CBE)

Statement Of The Problem

Digital resources have gradually become important in enhancing curriculum implementation in all educational levels. The integration of digital resources plays a key role in implementing the STEM as it enhances the teaching and learning of STEM subjects by making it more interactive, accessible and relevant to real-world applications (UNESCO,2020). The Kenyan government has emphasized the need for STEM in its national BETA agenda at all levels of education. Despite national policies promoting ICT and STEM integration in Kenya's CBE curriculum, many public junior schools in arid and marginalized counties like Kitui county still faces challenges related to integration of digital resources. According to data from the Kitui County Education Office (2024) some schools reported low levels of effective STEM teaching, limited use of digital resources and uneven teacher readiness in digital skills acquisition. In order to utilize digital tools in teaching and learning, schools should have adequate internet, computer laboratories, electricity and other technology rooms in order to effectively implement STEM. The County Quality Assurance and Standard Officer (2024) on teachers' capacity building report showed that about 30 percent of junior school teachers had undertaken the ICT course, leaving a larger number of untrained teachers who are mandated to implement STEM. The government of Kenya has made efforts to address these challenges through initiatives such as the Digital Literacy Program where teachers have had to undertake a mandatory course on ICT to enable them to effectively integrate use of digital resources into their teaching (KICD, 2017). Despite these efforts, the implementation of STEM subject's curriculum is still a challenge yet STEM accounts for 60 percent of learners transiting to Senior School (MOE,2025). Studies have been done in Kitui county on other aspects of the curriculum implementation but none focussed on STEM implementation in junior schools. Whereas digital resources are recognized as key determinants of STEM curriculum implementation by KICD, their tangible integration into teaching and learning is still under-studied in Kitui County. This study investigated the influence of digital resource integration and the implementation of STEM subjects in public junior schools in Kitui County, Kenya.

Study Objective

To establish the influence of the adequacy of digital infrastructure and the implementation of STEM subjects in public junior schools in Kitui County, Kenya.

Study Hypothesis

H_01: There is no statistically significant influence between adequacy of digital infrastructure and the implementation of STEM subjects in public junior schools in Kitui County, Kenya.

Study Theory

This study was anchored on the Technological Pedagogical Content Knowledge (TPACK) theory which was developed by (Mishra & Koehler, 2006). The theory states that effective teaching with technology requires teachers to integrate the three types of knowledge that is technology, pedagogy and content together rather than treating them separately. The theory relates to this study since it showed that effective teaching of STEM education required integration of technology, understanding of the tools and how they connect with pedagogy and STEM content to foster deep learning and engagement. The theory showed that successful digital resource integration in STEM and other disciplines is influenced by teacher technological proficiency, availability of digital technology to enhance pedagogy and digital content to enable effective classroom curriculum delivery. The theory has three components which include Technology Knowledge (TK), Pedagogical Knowledge (PK) and Content Knowledge (CK). The TK aligns with this study such that it enhances mastery of various digital tools and platforms relevant to STEM education, such as simulations, coding environments, virtual labs, AI-driven tutors and collaborative online platforms. These tools enhance interactive and personalized learning experiences for students. The Pedagogical Knowledge (PK) one aligns to the understanding of how to design and implement instructional strategies that incorporate technology effectively. This includes blended learning, flipped classrooms, active learning strategies, project-based, collaborative learning and formative assessment using digital resources. Finally, Content Knowledge (CK) which is a solid grasp of STEM subjects' content which ensures that digital resources align with curriculum goals and promote critical thinking, creativity, problem-solving and real-world application of STEM principles. The framework advocated using technology to create engaging, student-centered learning environments that supported diverse learning styles and encouraged collaboration. It supported the use of digital tools for visualization, simulation, modeling, data analysis, and peer interaction. The theory had been widely used to develop teacher educational programs in developed countries like the United States, Australia, and Finland to prepare educators for technology-rich classrooms (Mishra & Koehler ,2006). One of the major strengths of the theory is that it provided a comprehensive framework that helped educators integrate technology effectively with content knowledge and pedagogical skills, enhancing student engagement and learning outcomes, hence making it the most suitable for this study. However, a major limitation is the access to appropriate resources and technologies that can limit the implementation of TPACK, contributing to inequalities in educational standards. Despite this weakness, it was the best suited theory for this study as it looked at digital resource integration not as an add-on but as intertwined deeply with STEM content delivery and pedagogy to prepare students with the necessary skills required for the 21st Century learner and technology-rich future STEM workforce.

LITERATURE REVIEW

The adequacy of digital infrastructure and the implementation of STEM subjects in public junior schools in Kenya

Digital infrastructure refers to the foundational technological systems and resources that support the delivery of digital learning. According to Ansari et al. (2022) the infrastructures include hardware devices like computers, tablets, smartboards, projectors, science lab devices, connectivity such as reliable internet, networking systems, bandwidth, Software's and platforms such as learning management systems (LMS), virtual labs, simulation software and the support systems such as ICT policies, technical support staff, electricity and data storage**.** These tools are used to enhance teaching of science curriculum by boosting student engagement, enabling visualization of complex concepts and providing interactive experiences that outshine traditional ones. If they are not available, some content in the curriculum may not be taught while others may be taught theoretically leading to inadequate syllabus coverage and understanding.

In Pakistan, Ansari et al. (2022) studied the impact of technological and infrastructural facilities on university students' learning in Sindh province, Pakistan. The study used a quantitative research approach and data was collected using questionnaire. The target population was 437 students from public universities. The results showed that students' learning experiences can be enhanced by technological and infrastructure amenities at higher education institutions. This study was to establish whether digital infrastructures such as ICT laboratories have impacted the implementation of STEM curricula in public junior school in Kitui County. While the study concentrated on students from public universities in Sindh province in Pakistan and the research design used was quantitative, the current study focussed on the public junior schools in Kenya and targeted the headteachers, teachers and Sub-County Quality Assurance and Standards Officers in Kitui County and used a mixed design approach.

In Philippines, Derder et al. (2023) investigated the interplay between digital infrastructure and teaching effectiveness in public high schools' teachers. The study adopted a quantitative research design. The target population comprised public-school teachers at Old Damulog National High School in the Philippines where the study was conducted. The sample of 60 teachers was thus drawn from the pool of teachers employed at Old Damulog National High School, Philippines**.** Questionnaires were used to collect data from 60 teachers drawn from junior and public school. The collected responses were organized numerically and computed using descriptive statistics such as the means and percentages to summarize teachers' access to digital infrastructure. The study showed that there was moderate accessibility to technological infrastructure. The study further found that teachers believed that, digital infrastructure does improve aspects of teaching effectiveness particularly by increasing student motivation and enthusiasm, enabling timely and constructive feedback, helping accommodate different learning styles, facilitating more teaching strategies and promoting better student engagement in class. The study also emphasized the importance of a robust feedback mechanism for infrastructure improvement and the necessity for comprehensive backup plans. This implies that students' engagement, different learning styles and motivation when incorporated with digital resources, learning becomes enjoyable and most concepts are easily understood especially when implementing the STEM curriculum. While the study only applied quantitative design with a sample of 60 teachers, the current study adopted an embedded mixed design with a sample of 670. Further, this study sought to find whether digital infrastructure and content will increase student's motivation to perform better in STEM subjects in public junior schools in Kitui county.

In another study by Wang and Wang (2023) on the influence of technology infrastructure while exploring the relationship between educational ICT resources, student engagement, and academic performance. The study collected secondary data from Asian countries namely Hong Kong, South Korea and Singapore.The results indicated that educational ICT resources are negatively associated with student academic performance. On the contrary there was a positive correlation between educational ICT resources and academic performance such that having more ICT resources sometimes boosts engagement, but how that translates into performance depends on how those resources are used and whether the student was engaged. At school and home educational ICT resources such laptops, touch screens and LMS showed strong relations with curriculum-based learning and cognitive-motivational engagement among many learners. This meant that availability of digital resources and learner engagement levels impacted students' scores. Whereas the study collected data from secondary source the current study used the questionnaires and interviews schedule. This study sought to establish whether students' engagement levels on use of digital resources and content influenced the implementation of STEM subjects in pubic junior schools in Kitui county.

According to a study by Khumalo et al. (2025) on digital infrastructure in inclusive primary and secondary schools in Lesotho. The study adopted a qualitative multiple case approach. The study was conducted in two rural schools, primary and secondary and the participants were teachers and principals from those schools. The target population comprised of teachers and school principals working in the inclusive primary and secondary schools in rural Lesotho, whose experiences and practices regarding digital literacy in education were relevant to understanding how digital tools and skills are being integrated into inclusive schooling contexts. The findings showed that there was lack of technological tools like computers, smartphones and inconsistent electricity which hindered effective implementation of the new education curriculum. The study further showed that many teachers were not adequately prepared to use digital literacy tools, which impeded the full implementation of curriculum mandate. This implied that more and better-targeted investment such as providing schools with sufficient devices, reliable power supply and connectivity ensured that rural and marginalized schools are able to implement STEM in Kitui county. The study in Lesotho adopted case study design and was conducted in two rural primary and secondary whereas this study adopted mixed method design and was conducted in public junior schools from urban and rural schools in Kitui county of Kenya. Similarly, the current study was to establish whether the adequacy of digital resources, reliable power supply had influenced the implementation of STEM subjects in rural and urban junior schools in Kitui county of Kenya.

In Nigeria, Victor Ndubuisi and Ifeoma Roseline (2025*)* evaluated the availability, utilization, and impact of digital infrastructures and resources for research in Colleges of Education in the South-East geo-political zone of Nigeria. The study employed a descriptive evaluation research design. The study sampled 300 lecturers from 15 departments across six colleges of education (federal, state, and private), selected through multi-stage sampling techniques. The findings revealed that digital infrastructures and resources are generally inadequate, with lecturers demonstrating minimal utilization, resulting in limited impacts on research processes. They further identified key barriers such as time wastage in using e-resources, poor motivation and inadequate power supply in the state. The study sampled lectures from various departments across six colleges, this study sampled teachers and headteachers from the 294 junior schools across Kitui county. The study further sought to establish whether barriers such as time wastage in using e-resources, poor motivation and inadequate power supply influenced the implementation of STEM subjects in junior schools in Kitui county.

In Uganda, Bileti et al. (2024) studied the influence of digital infrastructure management on curriculum implementation in public universities in Northern Uganda. The study was guided by a concurrent mixed-methods research design where questionnaires were used to collect quantitative data from 123 respondents while qualitative data was collected from 26 participants through interviews. Focus group discussions were also conducted with eight respondents. The study revealed that the levels of curriculum implementation were low and didactic infrastructure management was moderate. In addition, didactic infrastructure management had a significant influence on curriculum implementation in public universities in Northern Uganda. The study concluded that didactic infrastructure management is significant for curriculum implementation. This implied that enhancing physical infrastructure such as libraries, sports facilities, computer labs and ICT halls is not just a matter of comfort or prestige, it has measurable impact on key aspects of curriculum implementation. Poor infrastructure correlates with weaker preparation, delivery and assessment during teaching and learning. When not properly managed would greatly slow the implementation of curriculum in schools. This study targeted on public university students on curriculum implementation and the current study targeted teachers and headteachers in public junior schools in Kitui County. This study also sought to establish whether physical infrastructure have influenced the implementation of STEM subjects in public junior schools, Kitui county.

In Kenya, Nyongesa and Otieno (2020) studied the effect of ICT infrastructure on effective teaching and learning in public primary schools in Trans Nzoia County, Kenya. The study targeted 185 headteachers and teachers from 37 public primary schools. A descriptive survey design was used and data collected using questionnaires administered to sampled teachers and headteachers. The findings showed that provision of ICT infrastructure such as ICT laboratories and accessible internet enabled teachers to use technology in teaching effectively. The internet provision and laptop accessibility also enabled technology adoption in the learning process. The educators had more prospects to utilize instructional technology when the ICT infrastructures were provided in a well manner. This implied that when teachers are provided with the necessary ICT infrastructure, they are able to visualize complex concepts during their lessons influence the implementation of STEM subjects. This study used descriptive survey design while the current study used mixed method design. This study further sought to find whether provisions of necessary digital infrastructures such as adequate internet provisions had imparted on the digital content and implementation of STEM subjects in public junior schools in Kitui county.

In another study by Kibera (2021) on the influence of integrated information communication technology on public education institutions in Kenya. The study used a desk study review methodology and thus there was no empirical sample of respondents. The findings showed that the use of ICT in schools, led to educational and pedagogical outcomes which was useful to both the facilitators, teachers and students. The use of ICT across educational institutions promoted collective, zealous and long-life learning, enhancing students' enthusiasm, provide better convenience to information, enhance shared working resources, generating and deepen comprehension, and help learners reason and express communication creatively. This meant that if educational institutions are given the required digital infrastructure the learning process would be learner centred thus enhance critical thinking which is one of the key competencies being developed in CBE curriculum. Whereas the above study focussed on desk study review methodology the current study will focus on embedded mixed methodology and sought to establish whether use of digital resources in schools aroused learners' motivation, deepened understanding of complex principles imparting the implementation of STEM subjects in public junior schools in Kitui county of Kenya.

In a study by Nyambane et al. (2020) on the impact of ICT infrastructure on performance of public secondary schools in Kisii County, Kenya. Results showed that the school ICT infrastructure included ICT hardware, application software, internet connectivity and connectivity speed. Their study further found that enhancing human resource capability**,** physical infrastructure**,** and a supportive institutional environment all meaningfully contribute to better organizational performance in public secondary schools in Kisii County. Their study underscored the need for comprehensive investment across these ICT dimensions to uplift educational outcomes. This implied that despite availability of ICT infrastructure in most public secondary schools in the county, technology was not effectively utilized to realize its full potential and as a result most schools were still faced with operational inefficiencies, traditional teaching and learning methods and declining academic outcomes. While the above study focussed on public secondary schools in Kisii, the current study focussed on public junior schools in Kitui county.

RESEARCH METHODOLOGY

The study adopted the embedded mixed method research design with the dominant one being the quantitative method and the embedded one being the qualitative one. The target population for this study was 4782 participants comprising of 1102 headteachers of these schools because they are mandated to manage junior schools, 3661 teachers who are involved in the actual implementation of the STEM subjects, drawn from public junior schools in Kitui county. The 19 Sub-County Quality Assurance and Standards Officers (SCQASOs) formed part of the study population since they monitor, assess and evaluate the quality of teaching standards in these schools. From these 22 headteachers and 72 teachers participated in piloting, leaving a population of 1080 junior schools and 3589 junior school teachers. The sub counties were clustered into 19 clusters from which the researcher picked the study sample in proportions to the sub-county's population. This ensured fair representation and unbiases towards larger or smaller sub-counties. Proportionate stratified random sampling was used to determine the number of schools per sub county. The headteachers and SCQASOs were purposively sampled to supplement since there was only one headteacher per sampled public junior school and one SCQASOs per sub-county. The Yamane's 1967 formula $n = \frac{\mathrm{N}}{1+\mathrm{N(e)2}}$ was used to determine the numbers of teachers and schools. Where; n=Number of samples, N= Total population and e= Error tolerance (0.05) as shown below: -

$$\frac{3661}{1+3661(0.05)2} = 360 \text{ Teachers}$$

$$\frac{1102}{1+1102(0.05)2} = 294 \text{ Junior schools}$$

From the formula above, 294 schools and 360 teachers were sampled for the study. Simple random sampling was used to select a sample of 294 schools from the 1,102 public junior schools from the 19 clusters. A sample of 670 respondents including 294 headteachers, 360 teachers and 16 SCQASOs was sampled. Data was collected by use of structured questionnaires for headteachers and teachers, while interview schedules were used to collect data from SCQASOs. Quantitative data was analysed aided by Statistical Package for Social Sciences (SPSS) software program version 28. Data was presented in descriptive statistics such as frequencies, tables, percentages, graphs, means and Standard deviation. Qualitative data from open ended questions, opinions and interviews was analysed using content analysis technique. The findings from interviews were reported and transcribed into themes and presented in narrations and direct quotes. A Pearson product moment correlation was conducted to examine the relationship between independent and dependent variables while regression was used to test the hypothesis.

The researcher established face and content validity of the research instruments. To establish face validity, the researcher ensured that all questions and interview schedules were developed from the study objectives and relevant literature. To establish content validity, the researcher subjected the questionnaire and interview schedule to judgement by supervisors. Their feedback was used to revise the ambiguous and irrelevant items before the final data collection. To enhance content validity, piloting was done in selected schools across the county by choosing participants with similar characteristics to the target population. Schools which were used for piloting were not included in the sample. Therefore, 2% of headteachers and teachers were drawn from 2% of public junior schools outside the main study sample for piloting. This translated to 22 head teachers and 72 teachers. The pilot schools were not included in the study sample. After piloting the questionnaires were adjusted to cater for any inconsistencies such as ambiguous or unclear questions.

To establish reliability of the research instruments the researcher used the test–retest method**.** The questionnaires were administered to the pilot group of respondents drawn from public junior schools outside the main study sample**.** After a two-week interval**,** the same instrument was re-administered to the same respondents. The two sets of scores were correlated using Pearson’s Product Moment Correlation Coefficient to determine the stability of the instrument over time. A reliability coefficient of 0.81 for the headteachers’ questionnaire and 0.84 for the teachers’ questionnaire. The overall reliability coefficient for the instrument was 0.83. For most research standards, a reliability coefficient of 0.70 or higher indicates that the instrument was reliable for data collection (Fraenkel et al., 2019). Therefore, the questionnaire was considered sufficiently stable and consistent for the main study.

Study Findings

The study objective sought to establish the influence of the adequacy of digital infrastructure and the implementation of STEM subjects in public junior schools in Kitui County, Kenya.

Response Rate

The study's research instruments were questionnaires given to headteachers and teachers, while interview guides were provided for the Sub-County Quality Assurance and Standards Officers (SCQASOs). A total of 670 respondents were sampled. The response rate is presented in Table 1

Table 1: Return Rate of Research Instruments

Respondents	Sample size	Number Collected	Return rate (%)
Headteachers	294	290	98.6
Teachers	360	305	84.7
SCQASOs	16	16	100.0
Total	**670**	**601**	**Average 94.4**

The head teachers' return rate was 98.6 %, teachers at 84.7 %, and SCQASOs was 100 %. The average response return rate was 94.4 %, which was considered adequate and acceptable for a social sciences study. Mugenda and Mugenda (2019) indicated that a response rate of 60% is good, a response rate of 70% or above is very good for a descriptive survey research, and a response rate of 50% is sufficient for reporting and analysis. Since more than 90 % of the population participated, the response rate was high and considered excellent. The feedback improved sample representation and sincere generalization by providing the necessary information for data analysis. The relatively higher response rate of 100 % SCQASOs indicated stronger institutional participation as well as the willingness of the educational officials to participate in the study.

The head teachers and teachers were asked to indicate the available digital resources in their schools and state whether they are used in teaching and learning of STEM subjects. Results were presented in Table 2

Table 2: Responses of Head teachers and Teachers on the Availability and Utilization of Digital Infrastructure.

Digital Infrastructure	Head Teachers (N=290)			Teachers (N=305)		
	Available (%)	Used in Teaching (%)	Never Used (%)	Available (%)	Used in Teaching (%)	Never Used (%)
Computers/Laptops/Projectors	64.8	15.2	53.8	64.3	11.8	53.1
Mobile Phones and Tablets	85.5	21.0	3.4	88.2	14.8	3.0
Hard Disks/Flash Disks	25.2	5.2	9.3	23.9	2.0	8.2
Internet Connections/WiFi/Routers	51.0	11.0	6.6	25.9	5.2	6.6
Uninterrupted Power Supply / Solar	44.5	10.3	4.8	44.9	5.6	5.6
LCD Screen / Smart Boards	11.0	1.7	12.8	8.9	0.7	1.6
Interactive Boards	14.1	3.4	11.7	13.4	0.7	9.8
ICT Laboratory	4.8	0.7	13.4	6.2	0.0	8.2
Science Laboratory	6.6	1.7	11.7	13.8	1.0	8.9
Makeshift Laboratory	31.0	4.8	7.6	28.2	3.0	7.9

The results presented in Table 2 showed the availability and utilization of digital resources and infrastructures in junior schools. For head teachers reported that computers/Laptops/Projects were 64.8% available,15.2% used in teaching,53.8% never used, Mobile Phones and tablets was at 85.4% available,21% used in teaching, 3.5% never used, Hard disks/Flash disks were 25.1% available,5.3 % used in teaching, 9.4 % never used, Internet connections/WiFi/Routers at 50.9 % available,11.1 % used in teaching, 6.4 % never used, Uninterrupted Power Supply / Solar at 44.4 % available,10.5 % used in teaching, 4.7 % never used, LCD Screen / Smart boards at 11.1 % available,1.8 % used in teaching, 12.9 % never used, Interactive boards at 14.0 % available,3.5 % used in teaching, 11.7 % never used, ICT Laboratory at 4.7 % available,0.6 % used in teaching, 13.5 % never used, Science Laboratory at 6.4 % available,1.8 % used in teaching, 11.7 % never used, Makeshift Laboratory at 31.0 % available,4.7 % used in teaching, 7.6 % never used.

For the teachers, the results on the availability and utilization of digital resources and infrastructures showed that :- Computers/Laptops/Projects was 64.3% available, 11.7% used in teaching,53.1% never used, Mobile phones and tablets was 88.3 % available,14.8 % used in teaching, 3.1 % never used, Hard disks/Flash disks were 24.0 % available,2.0 % used in teaching, 8.2 % never used, Internet Connections/WiFi/Routers at 26.0 % available,5.1 % used in teaching, 6.6 % never used, Uninterrupted power supply / Solar at 44.9 % available,5.6 % used in teaching, 5.6 % never used, LCD Screen / Smart boards at 8.7 % available,0.5 % used in teaching, 9.7 % never used, Interactive boards at 13.3 % available,0.5 % used in teaching, 9.7 % never used, ICT Laboratory at 6.1 % available, 0.0 % used in teaching, 8.2 % never used, Science Laboratory at 13.8 % available,1.0 % used in teaching, 8.7 % never used, Makeshift Laboratory at 28.1 % available,3.1 % used in teaching, 7.7 % never used.

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The headteachers and teachers were also asked to pick a model of digital infrastructure use that their school has adopted in cases of insufficient resources. Findings were presented in Table 3

Table 3: Responses of Headteachers and Teachers on the Model of Digital Infrastructure use

Statements	Head Teachers (n=290)		Teachers (n=305)	
	F	**%**	**F**	**%**
Sharing of ICT lab and Science workshops between schools	66	22.8	50	16.4
Rescheduling of STEM lessons to availability of resources	176	60.7	177	58.0
Linkage to nearby well-equipped schools and TVETs center's	39	13.4	53	17.4
A centralized ICT hubs at the zones/sub- county offices.	9	3.1	25	8.2
Total	290	100	305	100

The results in Table 3 showed a severe shortage of digital infrastructure in the public Junior schools of Kitui County, which has largely affected the implementation of the STEM subjects' curriculum in Junior schools. From the results, 22.8 % of head teachers shared ICT laboratory and science workshops between schools, 60.8 % rescheduled STEM lessons to availability of resources, 13.4 % linked their schools to a nearby well-equipped school and TVETs centers, and 3.1 % of schools used centralized ICT hubs at the zones/sub- county offices. The results from the teachers showed that 16.4 % of teachers agreed on the use of shared ICT laboratory and Science workshops between schools, 58.2 % rescheduled STEM lessons to the availability of resources, 17.4 % noted linking their schools to a nearby well-equipped school and TVETs centers, and 8.2 % used centralized ICT hubs at the zones/sub-county offices.

The headteachers and teachers were further asked to tick on the extent to which they agreed with the listed statements on digital infrastructure. Results were presented in Table 4

Table 4: Responses of Headteachers and Teachers on the Perceptions on the Adequacy of Digital Infrastructure

Statements	Head Teachers(n=290)		Teachers (n=305)	
	M	**Std.**	**M**	**Std.**
The school has science labs for use in science subjects.	1.62	1.08	1.70	1.14
The school has computer hardware & updated software for use.	1.90	1.19	1.68	1.09
The school has a fast and reliable internet connection /Wi-fi	2.10	1.32	1.60	1.06
The school has access to reliable electricity/ solar to support digital learning.	2.45	1.50	2.49	1.38
The school has standby power supply and/or UPS to avoid data loss during power outage/ blackouts	1.73	1.24	1.66	1.203
Average	1.96	1.26	1.82	1.17

The results in Table 4 showed that the means and standard deviations for headteachers were as follows, the school has science labs for use in science subjects (M=1.62, Std. =1.08), the school has computer hardware & updated software for use (M=1.90, Std. =1.19), the school has a fast and reliable internet connection /Wi-fi

(M=2.10, Std. =1.32), the school has access to reliable electricity/ solar to support digital learning(M=2.45, Std.=1.50), the school has standby power supply and/or UPS to avoid data loss during power outage/ blackouts(M=1.73, Std. =1.24).

For the teachers the means and standard deviations were as follows, the school has science labs for use in science subjects (M=1.69, Std. =1.11), the school has computer hardware & updated software for use (M=1.68, Std. =1.09), the school has a fast and reliable internet connection /Wi-fi (M=1.60, Std. =1.06), the school has access to reliable electricity/ solar to support digital learning(M=2.49, Std. =1.38), the school has standby power supply and/or UPS to avoid data loss during power outage/ blackouts(M=1.66, Std. =1.20).

The headteachers and teachers were asked to indicate the main challenges the schools faced regarding digital infrastructure and its utilization in the teaching of STEM subjects. Results were presented in Table 5

Table 5: Responses of Headteachers and Teachers on the Challenges Faced in Digital Infrastructure and Utilization

Challenges	Head teachers (n=290)		Teachers (n=305)	
	Frequency	**Percentage**	**Frequency**	**Percentage**
Inadequate Digital Devices (computers, tablets, laptops)	88	30.3	89	29.2
Poor Internet / Network Connectivity	71	24.1	76	24.9
Unreliable Power Supply	64	22.1	70	23.0
Lack of ICT and Science Laboratories	32	11.1	44	14.4
Financial Constraints	20	6.9	13	4.3
Poor Maintenance & Technical Support	15	5.2	19	6.2
Limited Teacher Skills / Training	10	3.4	9	3.0

The results on Table 5 show the percentages in responses from headteachers on various challenges they faced during digital infrastructure and utilization as, inadequate digital devices (computers, tablets, laptops) 30.3 %, Poor internet / Network connectivity 24.1 %, unreliable power supply 22.1 %, Lack of ICT and science laboratories 11.1 %, financial constraints 6.9 %, poor maintenance and technical support at 5.2 %, and limited teacher skills and training at 3.4 %. For the teachers the responses were 29.2 % inadequate digital devices (computers, tablets, laptops), 24.9 % Poor internet / Network connectivity, 23.0 % unreliable power supply, 14.4 %, lack of ICT and science laboratories, 4.3 % faced financial constraints, 6.2 % reported poor maintenance and technical support, and 3.0 % was on limited teacher skills and training.

The headteachers and teachers were asked to indicate the measures adopted to resolve challenges of digital infrastructure experienced above. The findings were presented in Table 6

Table 6: Responses of Headteachers and Teachers on the Measures Adopted to Resolve Inadequate Digital Infrastructure

Measures to resolve digital infrastructure challenges	Head teachers (n=290)		Teachers (n=305)	
	Frequency	**Percentage**	**Frequency**	**Percentage**
Improvisation & Personal Devices (Use of	128	44.1	142	46.6%

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smartphones, personal laptops, Mi-Fi				
Infrastructure & Funding Efforts (Construction of labs, CDF assistance)	49	16.9	24	7.9%
External Support & Sourcing (Borrowing from nearby schools, NGO/CBO support, well-wishers)	36	12.4	48	15.7
Strategic Planning & Advocacy (seeking Govt help, parental involvement)	27	9.3	42	13.8
Virtual labs			27	8.9

The results showed the various measures the headteachers highlighted as solutions to digital infrastructure issues raised as improvisation and personal devices (Use of smartphones, personal laptops, Mi-Fi**)** at 44.1 %, infrastructure and funding efforts (Construction of labs, CDF assistance) is 16.9 %, external support and sourcing (Borrowing from nearby schools, NGO/CBO support, well-wishers) at 12.4 % and 9.3 % on strategic planning and advocacy (seeking Government help, parental involvement) and 0.0 % on virtual laboratories. The results highlighted by the teachers as solutions to digital infrastructure issues raised were improvisation and personal devices (Use of smartphones, personal laptops, Mi-Fi**)** at 46.6 %, infrastructure and funding efforts (Construction of labs, CDF assistance) is 7.9 %, external support and sourcing (Borrowing from nearby schools, NGO/CBO support, well-wishers) at 15.7 % and 13.8 % on strategic planning and advocacy (seeking Government help, parental involvement) and 8.9 % on virtual laboratories.

To gain a better understanding of the state of digital infrastructure in public junior schools and to improve the quantitative findings, interviews were conducted with SCQASOs in Kitui County. Their responses were then organized thematically as presented in Table 7

Table 7: Responses of SCQASOs on Qualitative Findings on Digital Infrastructure and the Implementation of STEM

Theme	**Sub Theme**	**Quotes**
State of Digital Infrastructure in Schools	**Inadequate digital infrastructure**	"Approximately 39.8% of our schools report that the problem of inadequate laboratories remains entirely unresolved, with many stakeholders describing the situation as a nightmare." "About 12.3% of our Junior Schools are forced to neighbor with established Senior Secondary schools, traveling long distances so learners can access functional laboratories."
	Limited availability of computer laboratories	"Many schools have resorted to multi-purpose spaces, often setting aside small corners of regular classrooms or using lockable cupboards to store the few devices available." "Approximately 39.8% of schools report that inadequate laboratories remain a completely unresolved issue"
	Inadequate government digital devices	The supply of government-provided gadgets is insufficient, leading to unfair distribution and high student-to-device ratios."
	Reliance on teachers'	"Because official supplies are low, 21.6% of digital instruction relies on the personal smartphones and laptops of

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	personal devices	the teaching staff.
Electricity Challenges	**Frequent power interruptions**	"Power remains a major bottleneck; many schools report that the digital curriculum is hardly taught due to a lack of electricity or frequent power failures."
	Need for alternative power sources	"There is an urgent, unmet need for solar power backups and standby batteries to ensure learning continuity during power failures."
Internet connectivity	**Poor network coverage**	"Network connectivity is often described as failing or non-existent in the more remote parts of the sub-county."
	High internet connectivity costs	"Where connectivity exists, it is often funded by teachers' personal data bundles or school Mi-Fi devices." The lack of unlimited, free network boosters' forces teachers to use personal funds for data."

The opinions of the SCQASOs reflected a critical condition of digital infrastructures in public junior secondary schools in Kitui County. Although the government has been focusing on digital integration in line with the CBE, most schools still struggle with a lack of laboratories, digital devices, electricity and internet connectivity. They reported that there is a challenge of unreliable electricity supply. Mobile phones and tablets were also available in moderate numbers in schools with teachers and head teachers indicating that they were among the most accessible digital resources.

The study further conducted cross-tabulations to establish whether there was a significant difference between the availability of digital infrastructure and the implementation of STEM subjects. The results are presented in Table 8

Table 8: Availability of Digital Infrastructure vs Implementation of STEM subjects

Implementation of STEM subjects	Greater extent	High extent	Low extent	Moderate extent	No extent	Total
Low	14(7.1%)	5(2.6%)	4(2.0%)	7(3.6%)	0(0.0%)	30(15.3%)
Moderate	31(15.8%)	14(7.1%)	6(3.1%)	15(7.7%)	1(0.5%)	67(34.2%)
High	43(21.9%)	27(13.8%)	8(4.1%)	21(10.7%)	0(0%)	99(50.5%)
Total	88(44.9%)	46(23.5%)	18(9.2%)	43(21.9%)	1(0.5%)	196(100.0%)

The cross-tabulation results showed that there was a close relationship between the availability of digital infrastructure and STEM implementation in public junior schools in Kitui County. The schools that reported higher levels of availability of digital infrastructure at 21.9% showed high implementation of STEM subjects at 50.5%, with higher levels of implementation linked to higher levels of digital infrastructure. The results also showed that the schools with medium digital infrastructures of 15.8% had a medium to high level of implementation of the STEM subjects at 34.2% the schools with low availability of digital infrastructure had mostly low levels of STEM implementation. The results also revealed that very few respondents reported that STEM implementation did not exist at any level at 0.5%, indicating that while the school infrastructure issues hampered the implementation of STEM, most schools were implementing some level of STEM implementation

Regression analysis was conducted to understand how a unit change in digital infrastructure may affect the implementation of STEM subjects in public junior schools in Kitui County, Kenya. The coefficient of determination showed how a statistical model is expected to predict future results as shown in Table 9.

Table 9: Regression Results on Digital Infrastructure and Implementation of STEM Subjects

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.568[a]	.323	.320	1.192

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	131.554	1	131.554	92.574	.000[a]
	Residual	275.686	194	1.421		
	Total	407.240	195			

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.207	.322		3.744	.000
	Digital Infrastructure	.720	.075	.568	9.622	.000

a. Dependent Variable: Implementation of STEM Subjects

The model summary of the results in Table 9 indicated that digital infrastructure explains 32.3% of the variance in the implementation of STEM subjects (R-squared=0.323). Further, the F-test statistic ($F = 92.574$, $p = .000$) shows the fitness of the regression model, which means that digital infrastructure was a significant predictor of the implementation of STEM subjects.

DISCUSSIONS AND INTERPRETATIONS

The headteachers and teachers were asked to indicate the digital devices and infrastructures that were available in their schools. Results from Table 2 established that the majority of headteachers and teachers indicated that digital infrastructure influences the implementation of STEM subjects. Mobile phones and tablets were the most available devices at 86.8%. However, utilization remained low at 17.9%. This illustrates that the teachers often use their personal devices, which are rarely incorporated into structured STEM lessons. This suggests that while mobile devices can be used by both teachers and students, they do not appear to be widely used by teachers for instructional purposes. The data showed that teachers primarily did not utilize their phones for daily tasks like communicating with students or administrative tasks, rather than providing STEM instruction through the use of mobile devices. However, the relatively high level of mobile device use compared to other forms of digital technology could support the potential for mobile learning technology to provide STEM education to students in underserved schools. These findings agree with the findings of UNESCO (2021), in a study on a new social contract for education that found mobile technologies are increasingly being adopted as alternative instructional tools in low-resource school settings.

The use of hard disks/flash disks was found to be low at 25% as shown in Table 2, their use in teaching was also minimal at 3.6 percent indicating that the majority of junior schools did not have enough capacity for digital media storage and content exchange to support the delivery of STEM instruction. Limited access to and use of technology could limit the ability of teachers to store, share and access the digital resources necessary for implementing STEM in the classroom. As a result, digital content dissemination within the school remains unclear particularly in rural areas where internet connectivity is exceedingly unreliable. There was a notable discrepancy between head teachers at 50.9% and teachers at 26.0% regarding the availability of internet connections/Wi-Fi/Routers. This could be an indication that internet access may be limited to the administration block where head teachers have access while the rest of the teachers and students have no access. With a usage rate of less than 11%, as shown in Table 2 there is severely limited access to online resources, virtual labs, and digital content necessary for the delivery of STEM. The results showed that the internet infrastructure in many junior schools in Kitui County is still inadequate. The lack of internet connectivity restricts access to digital research tools, virtual laboratories, e-learning platforms and online STEM resources. As a result, it becomes challenging to implement competency-based STEM education as learners and educators struggle to interact and inquire with digital content. The findings support Mutisya and Makokha (2016), who highlighted that poor internet connectivity was a key limitation to ICT implementation in public elementary schools in Kenya.

The findings also showed that only 44.6 % of the respondents reported that uninterrupted power supply and solar systems were available in at least 40% of the schools. However, utilization was low, with an average of 8.0% of the respondents reporting actual utilization of the uninterrupted power supply and solar systems. This finding illustrates that digital learning integration into STEM subjects is being impacted by power supply issues. This poor access to a reliable source of electricity has been stated as a reason why many schools do not have consistent access to computers, projectors, smart boards, and internet service during instruction. In some areas of Kitui County where electricity connectivity is unreliable, the lack of solar backup systems also restricts practical STEM implementation. Thus, this finding indicates that poor power infrastructure is a significant limiting factor in integrating digital resources into junior schools. Results agree with Omito and Kembo (2022) in a study regarding the preparedness of school heads and tutors to incorporate the Digital Literacy Programme (DLP) in classroom activities in public primary schools in Mombasa, revealing that 85.8% of these schools were linked to dependable power sources that facilitated efficient use of technology devices

The use of LCD screens and smart boards was the least available digital infrastructure at 10% of the respondents. Their pedagogy utilization was very low, with less than 2% of respondents reporting their use in teaching. This indicates that many public junior schools in Kitui County have not adopted advanced interactive technologies such as LCD screens and SMART boards which are critical for engaging learners, demonstrating visually, and facilitating STEM learning. Therefore, the lack of these technologies indicates that many schools continue to rely on traditional teacher-centered instructional techniques, rather than learner-centered instructional methods that are supported by technology, as supported by the Competency-Based Education (CBE). Likewise, low availability was reported for interactive boards at 13.6% of the respondents confirmed availability of interactive boards in schools, where their use was almost negligible at 2%.

The results suggested that schools had limited access to modern instructional technologies that would allow for practical and collaborative experiences in the STEM areas. This might be linked to inadequate teachers' training, lack of technical skills, and maintenance support. Thus, students may not be able to make optimal use of digital visualization and simulation strategies that are needed for good STEM teaching. The study also revealed that the ICT laboratories were very constrained, with only 5.4% of the respondents reporting having an ICT laboratory in their school. Nearly none of the respondents indicated that they used them in the teaching process. This result indicated that there was lack of ICT laboratories in the school, which restricts learners' opportunities to develop hands-on technological skills, computer literacy, and digital competencies needed for STEM subjects. The results thus suggested that digital-based STEM learning is greatly restricted by the lack of institutional infrastructure which agrees with Khoso (2022) that students' learning experiences can be enhanced by technological and infrastructure amenities such as laboratories.

The availability of science laboratories was also reported to be inadequate, with only 10.1% of the respondents stating that their schools had science laboratories that were hardly used in teaching. This result indicates that there is still a space for the improvement of the practical science learning in many public junior schools. The absence of working laboratories reduces the applicability of theoretical knowledge, scientific investigation, and experimental learning which may result in weak competencies in science subjects as the learners are mainly exposed to theoretical knowledge without practical. The results agree Ansari et al. (2022) in a study that, the digital infrastructure in school include hardware devices like computers, tablets, smartboards, projectors, science lab devices, connectivity such as reliable internet, networking systems, bandwidth, Software's and platforms such as learning management systems (LMS), virtual labs, simulation software and the support systems such as ICT policies, technical support staff, electricity and data storage.

The findings from Table 3 showed that majority of the headteachers and teachers at 59.5% indicated that they rescheduled STEM instruction to periods when they had access to the resources. This was a clear manifestation that many schools were not able to conduct STEM subjects as per their school timetable due to lack digital infrastructure and laboratories. Such rescheduling impairs the logical flow of learning, instructional time, and the intent of continuity and depth of the STEM concepts. Additionally, 39.1% of the respondents reported sharing of ICT laboratories and science laboratories with other schools. This showed resourcefulness and working together, but it poses significant logistical issues like wasted time travelling, disruption of other lessons, and reduced access time for practical lessons. Relatively few schools had connections to another well-equipped schools and TVET centres at 15.3%. This implied that there is a relatively small level of co-operation between schools and TVETs, although this was beneficial to schools with no resources. Very few zonal or sub-county level ICT hubs were established at 5.6%, showing that there was little systemic support from education authorities. These findings are in agreement with Cheloti (2026) on the policy brief that junior schools need to come up with better resource sharing strategy among institutions to fill the gap of limited resources.

Generally, the results suggested that digital infrastructure in the public junior schools in Kitui County was a major challenge that hindered the effective implementation of the STEM subjects. Teachers were unable to deliver STEM learning in suitable school environments and schools had to find ways to cope, such as rescheduling lessons, sharing facilities and using external institutions to provide STEM learning. Thus, the results imply the need to invest more in the digital infrastructure of schools such as ICT laboratories, internet access, a reliable power supply and modern science laboratories that would facilitate the implementation of the STEM curriculum. These findings are in agreement with Tondeur et al. (2017) that limited access to infrastructure remains a main challenge to effective ICT integration in third-world countries, such as Kenya.

Results from Table 4 indicated a mean of 1.64, which showed that the respondents concurred that the digital infrastructure in junior schools was inadequate. The results showed that most of the public junior schools in Kitui County had faced notable challenges regarding the digital infrastructure required for the successful implementation of STEM subjects. The overall mean scores from both the head teachers and teachers indicated that most schools did not have good digital and technological facilities to effectively support the teaching and learning processes in STEM education. The findings further showed that the availability of science laboratories was low in most of the schools, with a mean of 1.62 and 1.70 from headteachers and teachers, respectively. The head teachers and teachers, in general, expressed a negative opinion that their schools had sufficient science laboratories for science teaching, suggesting that many students may not have access to opportunities to perform hands-on scientific activities and practical experiments, which are important aspects of STEM curriculum implementation. The lack of adequate laboratories might thus lead to the overemphasis on theoretical teaching, which may adversely impact on the students' understanding of scientific concepts and the development of practical skills.

The study also found that instructional computer equipment and software were limited at the schools with means of 1.70 and 1.60. The low mean scores indicated a shortage of computers, laptops, and educational software on relevant topics available to enable digital learning in many schools. This shortage made it difficult to incorporate technology into teaching, narrow the range of digital knowledge that students are exposed to, and restrict teachers from providing interactive STEM lessons. The results suggested that insufficient digital devices still remain a significant barrier to technology-supported teaching in most junior schools of Kitui

County. The results also showed that internet access and Wi-Fi in a majority of schools were not adequate. Head teachers had even higher levels of perceived reliability regarding internet access at 2.10 than the teachers at 1.60 indicating limited internet access at the classroom level. Internet connectivity was unreliable for accessing online learning materials and resources, virtual laboratories, videos, and digital content necessary for effective STEM instruction. The results agree with Nyongesa and Otieno (2020) who showed that the provision of ICT infrastructure such as ICT laboratories and accessible internet, enabled teachers to use technology in teaching effectively in schools.

For electricity and solar power supplies, the results indicated fairly moderate results with respect to the other infrastructure variables. The scores still indicated inadequate levels of availability. This meant that some schools had electricity, other schools had solar power, but the electricity or solar power could not have been reliable enough to be used for digital learning activities. Electrical power failures may cause lessons disruption, damage digital equipment and deter the regular use of ICT tools in STEM teaching. The study also revealed that standby power supply systems, including generators or Uninterruptible Power Supply (UPS) devices were generally not available in most junior schools. The low mean scores suggested that schools were underprepared to manage power outages and blackouts and this led to regular disruptions in digital lessons, loss of data and a lack of confidence amongst teachers in the use of digital technologies in classroom practices.

The overall findings indicated that the digital infrastructures in public junior schools in Kitui County was inadequate to enable the effective implementation of STEM subjects. The lack of laboratory equipment, computer hardware, internet access, steady power supplies, and backup generators suggested that schools continue to have significant infrastructural obstacles that must be overcome when using digital learning in STEM education. The results thus highlighted the need to invest more in the provision of ICT infrastructure, Science laboratories, Internet facilities and energy systems in rural schools to improve the implementation of STEM curriculum in the Junior schools. These findings are in consistent with Khumalo et al. (2025) that there was lack of technological tools like computers, smartphones and inconsistent electricity which hindered effective implementation of the new education curriculum. They further identified key barriers such as time wastage in using e-resources, poor motivation, and inadequate power supply in the state.

In terms of the challenges faced while utilizing digital infrastructures, results from Table 5 showed a strong consensus among head teachers and teachers on the main challenges of using digital infrastructure effectively in STEM Education. The main challenge (29.7%) was inadequate digital devices. This implied that most schools didn't have enough computers, laptops and tablets for hands-on and student-centered STEM education. Due to the shortages teachers had to use ineffective strategies like rescheduling lessons, or demonstrations only during teaching and learning of STEM subjects. Poor internet/network connectivity (24.5%) was identified as the second dominant challenge which significantly hampered the ability to provide access to online educational resources, virtual labs, interactive simulations or digital content necessary for effective STEM delivery in the CBE. Unreliable power supply was cited by 22.6% of the respondents as basic infrastructural barrier. With no electricity or solar power, these devices are not usable, and hence the high "Never Used" percentages in Table 4.

The availability of dedicated ICT and Science Laboratories was yet another challenge (12.7%). Lack of adequate practical spaces makes it very difficult to perform experiments, project work or hands-on activities, which are central to STEM learning. Financial issues, inadequate maintenance/technical support, and low teachers' digital skills are some of the other challenges mentioned. The data clearly showed that in Kitui County there were identified system and interconnected challenges to infrastructural development which have a direct impact to the implementation of STEM subjects in schools. The goal of teaching competent, practically skilled students in STEM education will not be achieved unless there is intentional and urgent action in the county. Results are in support of Khumalo et al. (2025) that there was lack of technological tools like computers, smartphones and inconsistent electricity which hindered effective implementation of the new education curriculum. The results further showed the cope with which the digital infrastructure challenges, junior schools in Kitui County are mainly using short term coping strategies which are survival related as opposed to sustainable long-term strategies to cope with the poor digital infrastructure and ICT laboratories. Improvisation and use of personal devices was the most common measure at (45.1%). This meant that teachers taught using their personal smart phones, laptop and Mi-Fi devices which showed that teacher resiliency and commitment but has serious implications for equity, consistency and teacher load.

The level of participation of school administrators in infrastructure and funding such as construction of labs, look for CDF support were mentioned by a higher number of head teachers at (12.3%) than by teachers, indicating that school administrators are more active in long term infrastructure solutions, while classroom teachers are more active in short term survival strategies. Moderately adopted (14%) were external support and sourcing which included borrowing facilities from the nearby schools, seeking assistance from the NGO and well-wishers. The reliance on outside support had increased with reduced capacity or capability. Interestingly, virtual laboratories were not widely adopted, with only 9.1% of teachers mentioning them. Digital alternatives were rarely mentioned, suggesting that technologies such as virtual laboratories are not widely adopted even though they have the potential to fill the infrastructure gap. Some of the measures adopted by the headteachers and teachers to resolve digital infrastructures were sought. The data from Table 6 showed that schools are mostly implementing reactive and individualized approaches, instead of systemic solution at the institutional level. Lack of infrastructure and the little support from the government and county authorities was evident in the high reliance on personal devices and improvisation. These measures helped schools survive the short-term, but not help to implement STEM subjects in meaningful and practical way as envisioned in the Competency Based Curriculum. The situation indicated a systemic problem in the provision of appropriate digital infrastructure in junior secondary schools in Kitui County.

The qualitative findings on digital infrastructure from the SCQASOs presented in Table 7, showed a high percentage of 39.8% on improvisation, in particular, teachers relying on personal smartphones and improvised setup, suggested that schools were dependent on individual efforts for survival, and not on systems support. This has led to the cancellation of some lessons, sharing of school facilities with senior schools, and even some schools dropping out of the practical STEM science altogether. The findings suggested a systemic implementation gap. Digital resource integration has not proven to be effective because of continued issues with electricity, network coverage and limited government-provided devices. The infrastructure gaps hinder the provision of interactive and hands-on STEM lessons, and may exacerbate inequities especially in remote and semi-arid sub-counties. The future of quality STEM education in Kitui County junior schools is likely to be far from being realized if the necessary and urgent interventions of infrastructure, teacher support and sustainable funding are not made.

The qualitative results of the SCQASOs confirmed the quantitative results from teachers and head teachers on the digital infrastructure was inadequate in public Junior schools in Kitui County. Teachers and head teachers indicated shortage of availability of science laboratories, computer hardware, internet access and standby power supply indicating that the digital infrastructure in most schools was insufficient for effective STEM implementation. These findings were supported by the SCQASOs who affirmed that there were still many schools with underdeveloped laboratories and some stakeholders called the situation a “nightmare”. Further, the officers shared that some schools about 12.3 % had to use secondary schools for science and ICT facilities, confirming the quantitative findings that there is a shortage of science and ICT facilities in junior schools to support STEM learning.

All the three respondents reported limited computer laboratories and limited digital devices. Head teachers and teachers reported that, computers, projectors and ICT laboratories were not easily available and rarely used in the teaching of STEM subjects. Likewise, the SCQASOs reported that many schools improvised and converted ordinary classrooms into multi-purpose digital classrooms or small storage areas for storage of the small number of devices that were available. The officers also mentioned that the numbers of gadgets provided by the government were inadequate and distributed unequally and that the student to gadget ratio was too high. This is corroborated by the quantitative findings where access to computer hardware and ICT labs was still low in many schools. The qualitative results also corroborated quantitative results in regards to dependence on personal digital devices. Mobile phones and tablets were also available in moderate numbers in schools with head teachers and teachers indicating that they were among the most accessible digital resources. The SCQASOs noted that a significant amount of digital learning was reliant on teachers' personal devices, such as smartphones and laptops, because of the limited availability of official devices. The triangulation suggested that while schools tried to carry on with STEM instruction via personal devices, this was not sustainable, and therefore was also indicative of a larger problem of infrastructure in the education system.

The quantitative results from the headteachers and teachers also indicated that there was a shortage of electricity, solar power and standby electricity in most school. These were echoed by a SCQASO who said that there was a tremendous challenge to implement the digital curriculum due to power outages and the lack of electricity in some schools, leading to very low uptake of the STEM subjects. The officer also stressed the freshness and need to have solar backups and stand-by batteries to maintain digital learning continuity. The results showed that power supply is a major obstacle for effective digital incorporation and STEM implementation in junior schools. The results for the internet connectivity also showed very good agreement between quantitative and qualitative data. Availability and utilization of internet connectivity and Wi-fi in schools were also reported to be limited. The SCQASO also noted that network coverage was weak or non-existent in the remote areas of the sub-county, supporting these findings. They also noted that when internet services were available, schools and teachers frequently relied on personal data bundles or Mi-fi devices to connect to the internet. The officers further emphasized the lack of affordable and government-sponsored internet access and the burden it placed on teachers to pay for their own internet access to facilitate digital pedagogy. This triangulation indicated that the problem of poor internet infrastructure and high internet connectivity fees remain to be a challenge in the implementation of STEM education in public junior schools in Kitui County.

The results from the cross tabulation on availability of digital infrastructure and implementation of STEM subjects in Table 8 revealed that majority of the respondents who answered "very high" to the question of having the digital infrastructure were also more likely to report high implementation of STEM subjects. This indicated that the schools with a good digital infrastructure were more capable to effectively introduce and implement STEM subjects. The results also showed that the schools with medium digital infrastructures had a medium to high level of implementation of the STEM subjects. This suggested that partial access to the digital infrastructure had a positive impact on STEM implementation, but this impact may have been hindered by a lack of digital infrastructure sustainability or effectiveness. This type of school may have used digital technologies occasionally but not in an adequate way for the programs to be fully implemented.

On the contrary, the schools with low availability of digital infrastructure had mostly low levels of STEM implementation. This implied that lack of infrastructure limited the delivery of STEM education. Schools without any laboratory, internet access, computers or regular power supply may be depending on teaching theories with little practical exposure. As a result, students in these schools may not have had adequate experiences in acquiring problem-solving, technological, and scientific skills within the STEM curriculum. The results also revealed that very few respondents reported STEM implementation did not exist at any level, indicating that while the school infrastructure issues hampered the implementation of STEM, most schools were implementing some level of STEM teaching. The implementation of the digital infrastructure, however, seemed to differ in quality and effectiveness based on the digital infrastructure present in the schools. The results were in support of Bileti et al. (2024) that didactic infrastructure management was significant for curriculum implementation and Kibera (2021) who also found that the use of ICT in schools, led to educational and pedagogical outcomes which was useful to both the facilitators, teachers and students. The use of ICT across educational institutions promoted collective, zealous and long-life learning, enhancing students' enthusiasm, provided better convenience to information, enhance shared working resources, generating and deepen comprehension, and help learners reason and express communication creatively.

The study further tested the first hypothesis that stated, **$H_0$1**: There is no statistically significant influence between adequacy of digital infrastructure and the implementation of STEM subjects in public junior schools in Kitui County, Kenya. From the results of Table 9, the F-test statistic (F = 92.574, p = .000) showed the fitness of the regression model, which meant that digital infrastructure was a significant predictor of the implementation of STEM subjects. On individual significance, digital infrastructure was significant since p-values was less than 0.05 giving the predictive model as: implementation of STEM subjects = 1.207 + 0.720 on digital infrastructure. This meant that if digital infrastructure was increased by one unit, implementation of STEM subjects would on average, increase by 0.720 units making it a very significant variable in

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implementation of STEM subjects. Therefore, the hypothesis H_01 was rejected and an alternative accepted that states there is statistically significant between adequacy of digital infrastructure and the implementation of STEM subjects in public junior schools in Kitui County, Kenya. Results are in support of Wang and Wang (2023) that having more ICT resources boosts learner engagement. Based on these inferential results the researcher concluded that poor implementation of STEM curriculum in junior schools in Kitui county was caused by lack of digital infrastructure as shown by the descriptive results.

From the Regression Coefficients results for digital resource integration and implementation of STEM Subjects, digital infrastructure is the second most influential factor ($\beta = 0.568$). This shows that the availability and adequacy of ICT facilities such as computers, internet connectivity, and digital learning devices significantly boosted the implementation of STEM subjects. Schools with robust infrastructure are more likely to effectively incorporate digital tools into STEM instruction than schools without digital infrastructure, which is in agreement with Bileti et al. (2024) that didactic infrastructure management is significant for curriculum implementation and that poor infrastructure correlates with weaker preparation, delivery, and assessment during teaching and learning.

CONCLUSIONS

The study concluded that the level of digital infrastructure directly influences the implementation of STEM subjects in junior public schools in Kitui County. While some schools had access to basic digital tools, such as mobile devices and tablets, the general state of these infrastructures in the majority of the public junior schools was inadequate compared to what is required for the successful implementation of STEM subjects (Science laboratories, ICT lab, internet accessibility, smart tools, and reliable electrical power supplies). From inferential statistics, there is a high positive correlation between digital infrastructure and the implementation of STEM subjects. Similarly, descriptive data showed that there is a lack of digital infrastructure such as science laboratories, computer hardware, software, internet connectivity, and standby power supply, signifying inadequate preparedness of the institutions in implementing digital STEM. The study, therefore, concludes that the lack of digital infrastructure has greatly affected the ability of schools to effectively implement STEM subjects in most of the junior public schools and could be the course of poor performance in STEM in Kitui County.

RECOMMENDATIONS

Based on the study findings and conclusions, the study recommends as follows: -

i. The Ministry of Education should prioritize the construction of key STEM infrastructure that includes laboratories, ICT labs, and technology workshops in schools to facilitate proper CBE curriculum implementation.

ii. The government should develop a policy on school resource sharing so that schools can use labs and workshops in other institutions to solve the existing infrastructure gaps in their schools.

iii. The schools should seek assistance from donors, well-wishers, and supporters to provide computers and laptops to the junior schools, particularly in rural and underserved regions where governmental assistance might be insufficient or slow.

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