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Emerging Technologies in STEM Education: Examining Availability, Utilization, and Gender Differences among Teachers in Nigeria

Teknologi Baru dalam Pendidikan STEM: Kajian Ketersediaan, Pemanfaatan, dan Perbedaan Gender di Kalangan Guru di Nigeria

BOLAJI Hameed Olalekan, IBRAHIM Abdulmuhsin*, ABDULAZEEZ Bolanle Tawakalt-Anu & SALIU Omotosho Jimoh
Department of Science Education, Faculty of Education, Al-Hikmah University, Ilorin, Nigeria
*Corresponding Email: abdulmuhsinibrahim72@gmail.com

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ABSTRAK

Latar Belakang : *Pendidikan sains, teknologi, rekayasa, dan matematika (STEM) berperan penting dalam mendorong inovasi dan kemajuan teknologi. Namun, banyak lembaga pendidikan masih menghadapi kendala dalam mengintegrasikan teknologi baru ke dalam pembelajaran STEM.* ***Tujuan :*** *Penelitian ini bertujuan menganalisis ketersediaan dan pemanfaatan teknologi baru dalam pembelajaran STEM serta menguji perbedaan pemanfaatannya antara guru laki-laki dan perempuan di sekolah menengah di wilayah barat daya Nigeria.* ***Metode :*** *Penelitian ini menggunakan desain survei deskriptif. Dari populasi 10.310 guru STEM, sebanyak 384 responden dipilih melalui pengambilan sampel bertahap. Ukuran sampel ditentukan berdasarkan tabel Cohen et al. (2018). Data dikumpulkan menggunakan kuesioner terstruktur Emerging Technologies in STEM Education Teachers' Availability and Utilization Questionnaire (ETSETUQ) yang telah divalidasi oleh para ahli. Koefisien reliabilitas untuk aspek ketersediaan, aspek pemanfaatan, dan instrumen secara keseluruhan masing-masing sebesar 0,79, 0,84, dan 0,81. Data dianalisis menggunakan rerata, simpangan baku, persentase, dan uji t dua sampel independen.* ***Hasil:*** *Sebagian besar teknologi baru memiliki ketersediaan yang terbatas dan jarang digunakan dalam pembelajaran STEM. Perangkat seluler merupakan pengecualian dalam hal ketersediaan karena dapat diakses secara luas. Pemanfaatan teknologi baru oleh guru laki-laki dan perempuan tidak berbeda secara signifikan (t(382) = 0,56, p = 0,58).* ***Kesimpulan :*** *Ketersediaan dan pemanfaatan teknologi baru dalam pembelajaran STEM di sekolah menengah di wilayah barat daya Nigeria masih terbatas. Pemerintah dan pemangku kepentingan terkait perlu meningkatkan penyediaan infrastruktur, menyelenggarakan pelatihan berkelanjutan bagi guru, dan memastikan akses yang merata terhadap sumber daya digital bagi seluruh guru.*

ABSTRACT

Background: *Science, technology, engineering, and mathematics (STEM) education plays an important role in fostering innovation and technological advancement. However, many educational institutions face challenges in integrating emerging technologies into STEM instruction.* ***Objective :*** *This study examined the availability and use of emerging technologies among secondary school STEM teachers in South-West Nigeria and assessed whether their use differed by gender.* ***Methods:*** *A descriptive survey was conducted among 384 respondents selected from a population of 10,310 STEM teachers using a multistage sampling procedure. The sample size was determined using Cohen et al.'s (2018) sample size table. Data were collected using the Emerging Technologies in STEM Education Teachers' Availability and Utilization Questionnaire (ETSETUQ), which was validated by experts. The reliability coefficients were 0.79 for availability, 0.84 for utilization, and 0.81 for the overall instrument. Data were analyzed using means, standard deviations, percentages, and an independent-samples t test.* ***Results:*** *Most emerging technologies were largely unavailable and rarely used in STEM instruction. Mobile devices were widely accessible. There was no statistically significant difference in the use of emerging technologies between male and female teachers (t(382) = 0.56, p = .58).* ***Conclusion:*** *The availability and use of emerging technologies in secondary school STEM instruction in South-West Nigeria remain limited. The government and relevant stakeholders should improve infrastructure, provide ongoing professional development for teachers, and ensure equitable access to digital resources.*

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INTRODUCTION

Science, Technology, Engineering, and Mathematics (STEM) education has become increasingly recognized as a major driver of innovation, economic competitiveness, technological advancement, and sustainable national development across the world. In contemporary knowledge-based societies, STEM education equips learners with critical thinking, creativity, collaboration, communication, and problem-solving competencies needed to function effectively in rapidly evolving technological environments (Tijani & Adeduyigbe, 2026). As digital transformation continues to reshape educational systems globally, the integration of emerging technologies into STEM instruction has attracted considerable attention among researchers, policymakers, and educational stakeholders. Emerging technologies such as artificial intelligence (AI), virtual laboratories, augmented reality (AR), virtual reality (VR), simulations, robotics, learning management systems (LMS), Internet of Things (IoT), cloud computing, and multimedia instructional platforms are increasingly being adopted to improve instructional effectiveness, learner engagement, conceptual understanding, and inquiry-based learning in STEM classrooms (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2023). These technologies support interactive and student-centered learning experiences capable of enhancing scientific reasoning and practical skills development among learners.

The growing importance of emerging technologies in education is closely associated with the transition from traditional teacher-centered pedagogies to more innovative and technology-enhanced instructional approaches. According to Organization for Economic Co-operation and Development, digital technologies have become essential tools for promoting flexible, inclusive, and collaborative learning environments that foster higher-order thinking skills and creativity among students (Organization for Economic Co-operation and Development [OECD], 2023). Similarly, United Nations Educational, Scientific and Cultural Organization emphasized that technology-enhanced education has the potential to bridge learning gaps, improve access to quality education, and prepare learners for future digital economies (UNESCO, 2023). Within STEM education specifically, emerging technologies help simplify abstract scientific concepts through visualization, simulations, animations, virtual experimentation, and real-time data analysis, thereby improving students' conceptual understanding and academic performance.

Despite the educational benefits associated with emerging technologies, their successful integration into STEM instruction depends largely on their availability and effective utilization by teachers. Availability refers to the extent to which technological resources, digital infrastructure, and instructional technologies are accessible within schools for teaching and learning purposes (Yizengaw & Nigussie, 2023). The mere presence of technological tools in schools does not necessarily guarantee their effective use in classroom instruction. Effective utilization involves teachers' ability and willingness to integrate these technologies meaningfully into pedagogical practices to facilitate active learning, collaboration, experimentation, and problem-solving. Research has consistently shown that the successful implementation of technology-enhanced education depends on factors such as teachers' technological competence, institutional support, infrastructure, professional development opportunities, and positive attitudes toward technology integration (Petko et al., 2021). Consequently, schools with inadequate technological resources or insufficient teacher preparedness may struggle to fully realize the educational potential of emerging technologies in STEM education.

Globally, governments and educational institutions have intensified efforts to promote digital transformation in education following the disruptions caused by the COVID-19 pandemic. The pandemic exposed significant inequalities in access to digital learning technologies and highlighted the urgent need for teachers to possess adequate digital competencies for remote and blended learning environments. According to the World Bank, many developing countries continue to experience challenges related to inadequate ICT infrastructure, poor internet connectivity, insufficient teacher training, and unequal access to digital resources, all of which hinder effective technology integration in schools (Mathebula et al., 2025). In Sub-Saharan Africa, these challenges remain particularly pronounced due to infrastructural deficits, unstable electricity supply, inadequate funding, and limited access to modern educational technologies.

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In Nigeria, educational reforms increasingly emphasize the integration of digital technologies into teaching and learning processes to improve instructional quality and align the education system with global technological trends. The Federal Ministry of Education and several educational agencies have introduced policies aimed at strengthening ICT integration and promoting digital literacy among teachers and students. However, evidence from existing studies suggests that many secondary schools in Nigeria still experience inadequate access to technological infrastructure and limited utilization of emerging technologies in classroom instruction (Adebayo & Soykan, 2023). In many STEM classrooms, traditional lecture-based teaching methods continue to dominate despite the growing availability of digital technologies capable of supporting inquiry-based and experiential learning approaches. This situation raises concerns about the preparedness of schools and teachers to implement technology-enhanced STEM education effectively.

Within South-West Nigeria, variations in infrastructural development, institutional support, teacher preparedness, and access to digital resources may significantly influence the availability and utilization of emerging technologies in STEM classrooms. Urban schools may possess relatively better technological facilities compared to rural schools, while disparities in teacher training and digital competence may further affect instructional technology integration. In addition, gender-related factors may also influence teachers' utilization of emerging technologies. Previous studies on gender and technology integration have produced inconsistent findings. Some studies suggest that male teachers demonstrate higher confidence and greater utilization of digital technologies compared to female teachers, whereas other studies report no significant gender differences in technology adoption and instructional use (Scherer et al., 2021). These inconsistent findings indicate the need for more context-specific empirical investigations, particularly within STEM education in Nigeria.

Although several studies have examined ICT integration and digital technology use in education, many previous studies have focused broadly on general ICT utilization without specifically examining emerging technologies within STEM instructional contexts. Furthermore, limited empirical attention has been given to understanding how availability and utilization of emerging technologies vary across gender among STEM teachers in South-West Nigeria. The scarcity of localized empirical evidence creates a significant knowledge gap that limits evidence-based policymaking, strategic planning, and effective implementation of technology-enhanced STEM education. Against this background, the present study seeks to examine the availability and utilization of emerging technologies for teaching STEM subjects and investigate gender differences in teachers' utilization of these technologies in South-West Nigeria. The findings of the study are expected to provide empirical evidence that will support educational policy development, teacher professional development initiatives, infrastructural improvement, and the advancement of technology-enhanced STEM education in Nigeria.

Literature

The integration of emerging technologies into STEM education has attracted growing global attention because of its potential to enhance instructional effectiveness, improve learner engagement, and promote critical thinking and problem-solving skills among students. Emerging technologies in education include innovative digital tools and platforms such as artificial intelligence (AI), virtual laboratories, augmented reality (AR), virtual reality (VR), robotics, simulation software, learning management systems (LMS), cloud-based applications, and collaborative digital platforms that support teaching and learning processes. The adoption of these technologies has gradually transformed STEM education from conventional teacher-centered approaches to more interactive, inquiry-based, and learner-centered instructional practices. Scholars have consistently emphasized that the success of twenty-first-century STEM education depends largely on teachers' ability to access, utilize, and integrate these technological resources effectively within classroom instruction (Xu & Ouyang, 2022).

Available literature suggests that the availability of emerging technologies is a crucial determinant of the quality and effectiveness of STEM instruction. Xu and Ouyang (2022), in a systematic review of artificial intelligence applications in STEM education, reported that technologies such as intelligent tutoring systems, robotics, simulations, and AI-driven instructional tools significantly improve students' conceptual understanding and collaborative learning experiences when adequately accessible in educational settings. Their findings further revealed that access to digital technologies promotes instructional innovation and strengthens STEM learning environments. Similarly, Nedungadi et al. (2023) observed that technologies such as robotics, artificial intelligence, and extended reality positively influence students' creativity, cognitive development, and technical competencies in STEM education.

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Despite the recognized benefits of emerging technologies, evidence from developing countries indicates that many schools continue to experience inadequate technological infrastructure and limited digital instructional resources. In Nigeria, factors such as inadequate funding, unstable electricity supply, poor internet connectivity, and insufficient institutional support remain major barriers to the availability of emerging technologies in schools. Onyebuchi et al. (2024) noted that although STEM education is increasingly acknowledged as essential for technological advancement and national development in Nigeria, many schools still lack the digital facilities required for effective STEM instruction. The authors further explained that inadequate technological infrastructure significantly limits teachers' capacity to implement technology-enhanced instructional practices effectively.

Beyond availability, the utilization of emerging technologies among STEM teachers remains an important issue in educational research. Existing studies indicate that although many teachers demonstrate basic technological awareness, their practical competence in integrating advanced digital tools into instructional activities remains relatively limited. Onanuga and Saka (2025) found that STEM teachers and pre-service teachers demonstrated moderate competence in the use of emerging technologies such as augmented reality and virtual reality; however, their classroom integration was constrained by inadequate professional training and limited institutional support. Similarly, studies on technology-enhanced learning in Nigeria reveal that while teachers commonly utilize basic digital devices such as smartphones, computers, and multimedia tools, the use of advanced instructional technologies including simulations, virtual laboratories, artificial intelligence applications, and collaborative digital platforms remains relatively low (Ohanu et al., 2024).

Gender differences in the utilization of emerging technologies have also received considerable scholarly attention. Several studies have shown that male teachers often demonstrate slightly higher confidence and competence in the use of digital technologies compared to female teachers, especially in technology-intensive educational environments. These differences have been associated with disparities in digital exposure, self-efficacy, institutional support, and access to professional development opportunities. Samuel et al. (2020) argued that educational exposure and confidence levels significantly influence women's participation and engagement in emerging technological environments. However, other studies have reported little or no significant gender differences in technology integration when equal access to technological resources and training opportunities is provided. These inconsistent findings highlight the need for further empirical studies, particularly within localized contexts such as South-West Nigeria.

Furthermore, current educational reforms continue to emphasize the integration of emerging technologies into STEM classrooms as a strategy for preparing learners for digital economies and future workforce demands. International organizations such as the United Nations Educational, Scientific and Cultural Organization and the Organization for Economic Co-operation and Development consistently advocate technology-driven STEM education that promotes innovation, creativity, collaboration, and problem-solving skills among learners. Nevertheless, the extent to which these technologies are available and effectively utilized by STEM teachers in developing countries remains insufficiently explored. Existing literature has focused largely on general ICT integration and higher education contexts, with limited emphasis on secondary school STEM teachers and demographic variables such as gender. Consequently, there is a strong need for context-specific empirical studies examining the availability and utilization of emerging technologies among STEM teachers within the Nigerian educational system.

The main purpose of the study is to examine the availability and utilization of emerging technologies for teaching STEM subjects and investigate gender differences in teachers' utilization of these technologies in secondary schools in South-West Nigeria. Specifically, the study aimed to: examined the availability of emerging technologies for teaching STEM subjects; Determine the utilization of emerging technologies for teaching STEM subjects; Examine the difference between male and female secondary school STEM teachers' utilization of emerging technologies for teaching STEM subjects.

Research Questions : What is the availability of emerging technologies for teaching STEM subjects?, What is the utilization of emerging technologies for teaching STEM subjects?,

Research Hypothesis H0: There is no significant difference between male and female secondary school STEM teachers' utilization of emerging technologies for teaching STEM subjects.

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RESEARCH METHOD

This study adopted a quantitative research approach using a descriptive survey design of the cross-sectional type. The design was considered appropriate because it enabled the researcher to collect data from a representative sample of STEM teachers at a single point in time in order to examine the availability and utilization of emerging technologies for teaching STEM subjects, as well as to investigate gender differences in teachers' utilization of these technologies in secondary schools in South-West Nigeria. The cross-sectional survey design is suitable for describing existing conditions without manipulating variables, thereby allowing the study to capture a realistic snapshot of teachers' access to and use of emerging technologies such as artificial intelligence tools, virtual laboratories, augmented reality, virtual reality, simulation software, robotics, and learning management systems. It also facilitates the generalization of findings from the sampled respondents to the wider population of STEM teachers within the region.

The population of the study comprised all senior secondary school STEM teachers (Mathematics, Physics, Chemistry, Biology, and Computer Science/ICT) in South-West Nigeria. The target population of STEM teachers is estimated at 10,310 in South-West, Nigeria. The sample size for the study was determined using the sample size determination table developed by Cohen et al. (2018) at a 95% confidence level and 5% margin of error. Based on this standard table, a sample size of 384 STEM teachers was deemed adequate for a population of this magnitude. This sample size was considered appropriate to ensure statistical representativeness, reduce sampling error, and enhance the reliability and generalizability of the study findings.

A multi-stage sampling procedure was employed to select participants for the study. At the first stage, proportionate sampling technique was used to allocate the sample across the six South-West states (Ekiti, Lagos, Ogun, Ondo, Osun, and Oyo) based on their relative population sizes. At the second stage, stratified sampling technique was used to categorize respondents according to subject area (Mathematics, Sciences, and Computer Science/ICT) and gender (male and female), ensuring adequate representation of all relevant subgroups. At the final stage, simple random sampling technique was used to select individual respondents from each stratum, giving every STEM teacher an equal chance of participation and minimizing selection bias.

Data for the study were collected using researchers' constructed questionnaire titled Emerging Technologies in STEM Education Teachers' Availability and Utilization Questionnaire (ETSETUQ). The instrument was divided into two sections: Section A obtained demographic information such as gender, subject area, qualification, and teaching experience, while Section B assessed the availability and utilization of emerging technologies. Responses were measured using a four-point Likert scale adapted to each construct.

To ensure validity, the instrument was reviewed by experts in Science Education, Educational Technology, and Measurement and Evaluation to establish content, construct, and face validity. The internal consistency reliability method was adopted and the Cronbach Alpha was used to determine the reliability of the instrument. The reliability scores of 0.79 for availability, 0.84 for utilization and the overall reliability scores of 0.81 was ascertained which adjudged the instrument reliable, yielding acceptable coefficients across the constructs and confirming internal consistency.

Data collection was conducted through direct administration and online distribution using Google Forms to ensure wide coverage across the South-West states. Ethical standards were strictly observed, including informed consent, voluntary participation, confidentiality, and anonymity of respondents. Data were analyzed using SPSS version 25. Descriptive statistics such as frequency counts, percentages, means, and standard deviations were used to answer the research questions, while an independent samples t-test was used to test gender differences in utilization of emerging technologies at a 0.05 level of significance.

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RESULTS AND DISCUSSION

Research Question One: What is the availability of emerging technologies for teaching STEM subjects?

Table 1. Availability of emerging technologies for teaching STEM subjects

S/N	Items	Available	Not Available	Mean	St.D
1	Artificial Intelligence (AI) tools	143 (37.2%)	241 (62.8%)	1.37	0.48
2	Virtual Laboratories (Virtual Labs)	16 (4.2%)	368 (95.8%)	1.04	0.19
3	Augmented Reality (AR)	10 (2.6%)	374 (97.4%)	1.02	0.16
4	Virtual Reality (VR)	12 (3.1%)	372 (96.9%)	1.03	0.17
5	Simulation Software	10 (2.6%)	374 (97.4%)	1.02	0.16
6	Learning Management Systems (LMS)	16 (4.2%)	368 (95.8%)	1.04	0.19
7	Interactive Whiteboards (Smart Boards)	16 (4.2%)	368 (95.8%)	1.04	0.19
8	Mobile Learning Devices (Smartphones/Tablets)	372 (96.9%)	12 (3.1%)	1.97	0.17
9	Online Collaboration Tools	16 (4.2%)	368 (95.8%)	1.04	0.19
10	Multimedia Instructional Tools	53 (13.8%)	331 (86.2%)	1.13	0.34

The results presented in Table 1 provide an overview of the availability of emerging technologies for teaching STEM subjects among secondary school teachers in South-West Nigeria, based on responses from 384 participants. Overall, the findings indicate a generally low level of availability of most advanced digital instructional tools across schools in the region, suggesting limited institutional readiness for technology-enhanced STEM education. Specifically, Artificial Intelligence (AI) tools were reported as available by 37.2% of respondents (M = 1.37, SD = 0.48), indicating a relatively higher presence compared to other emerging technologies, although still insufficient for effective and widespread instructional application. In contrast, most of the core technologies required for modern STEM pedagogy were reported as largely unavailable. These include virtual laboratories (M = 1.04, SD = 0.19), augmented reality (M = 1.03, SD = 0.16), virtual reality (M = 1.03, SD = 0.17), simulation software (M = 1.03, SD = 0.16), learning management systems (M = 1.04, SD = 0.19), interactive whiteboards (M = 1.04, SD = 0.19), and online collaboration tools (M = 1.04, SD = 0.19), with over 90% of respondents indicating non-availability. This pattern reflects a substantial deficit in essential digital infrastructure needed to support interactive, inquiry-based, and learner-centered STEM instruction.

In addition, multimedia instructional tools recorded low availability at 13.8% (M = 1.13, SD = 0.34), further indicating limited institutional provision of structured digital teaching resources. On the other hand, mobile learning devices such as smartphones and tablets were widely reported as available, with 96.9% of respondents confirming their presence (M = 1.97, SD = 0.17). This suggests that while personal digital devices are commonly accessible, their instructional integration within formal STEM teaching practices remains largely unstructured and underutilized. The findings suggest that the availability of emerging technologies for STEM education in South-West Nigerian secondary schools is generally very low, with the exception of mobile devices and limited access to AI tools. This persistent infrastructural gap presents a significant barrier to the effective implementation of technology-driven STEM instruction in the region.

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Research Question Two: What is the utilization of emerging technologies for teaching STEM subjects?

Table 2. Utilization of emerging technologies for teaching STEM subjects

S/N	Items	HU (%)	MU (%)	SU (%)	NU (%)	Mean	St.D
1	Artificial Intelligence (AI) tools: e.g., adaptive learning platforms and AI tutors that personalize STEM instruction.	18 (4.7%)	96 (25.0%)	72 (18.8%)	198 (51.6%)	1.83	0.91
2	Virtual Laboratories (Virtual Labs): Software that allows students to perform simulated STEM experiments.	9 (2.3%)	54 (14.1%)	48 (12.5%)	273 (71.1%)	1.48	0.79
3	Augmented Reality (AR): Mobile applications that overlay STEM models and concepts onto real-world environments.	6 (1.6%)	39 (10.2%)	42 (10.9%)	297 (77.3%)	1.36	0.68
4	Virtual Reality (VR): Immersive environments for exploring scientific and engineering concepts.	5 (1.3%)	31 (8.1%)	40 (10.4%)	308 (80.2%)	1.30	0.62
5	Simulation Software: Interactive programs for teaching scientific and mathematical processes.	11 (2.9%)	68 (17.7%)	53 (13.8%)	252 (65.6%)	1.58	0.83
6	Learning Management Systems (LMS): Platforms for delivering STEM content, assignments, and assessments.	22 (5.7%)	104 (27.1%)	76 (19.8%)	182 (47.4%)	1.91	0.96
7	Interactive Whiteboards (Smart Boards): Digital boards that enhance STEM teaching and classroom interaction.	14 (3.6%)	89 (23.2%)	67 (17.4%)	214 (55.7%)	1.75	0.88
8	Mobile Learning Devices (Smartphones/Tablets): Used for accessing STEM applications, videos, and e-books.	71 (18.5%)	187 (48.7%)	89 (23.2%)	37 (9.6%)	2.76	0.87
9	Online Collaboration Tools: Platforms such as Zoom, Google Meet, or Microsoft Teams for virtual STEM lessons.	16 (4.2%)	82 (21.4%)	61 (15.9%)	225 (58.6%)	1.71	0.89
10	Multimedia Instructional Tools: Educational videos, animations, and digital presentations for STEM instruction.	28 (7.3%)	121 (31.5%)	74 (19.3%)	161 (41.9%)	2.04	1.01

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The data presented in Table 2 provide insight into the extent to which emerging technologies are employed in the teaching of STEM subjects. The analysis was carried out using the mean ratings and percentage distribution of respondents across the categories of Highly Utilized (HU), Moderately Utilized (MU), Slightly Utilized (SU), and Not Utilized (NU). Among the technologies examined, Mobile Learning Devices such as smartphones and tablets recorded the highest level of usage, with a mean score of 2.76 and a standard deviation of 0.87. This suggests that these devices are commonly integrated into STEM instruction for accessing educational applications, instructional videos, and electronic learning materials. The substantial proportion of respondents who rated them as highly or moderately utilized further indicates that mobile technologies have become the most accessible and widely adopted digital tools in STEM classrooms.

Multimedia instructional tools also demonstrated a comparatively higher level of utilization, as reflected by a mean score of 2.04 and a standard deviation of 1.01. This finding implies that resources such as animations, educational videos, and digital presentations are fairly incorporated into teaching practices, likely because they enhance students' understanding of complex scientific and mathematical concepts through visual representation. In addition, Learning Management Systems (LMS) showed a moderate degree of utilization, with a mean score of 1.91 and a standard deviation of 0.96. This indicates that digital platforms designed for content delivery, assignment management, and assessment administration are gradually gaining acceptance in STEM education, although their adoption remains limited in many schools.

Conversely, the study revealed low utilization levels for technologies such as Artificial Intelligence tools, Interactive Whiteboards, Online Collaboration Tools, and Simulation Software, with mean scores of 1.83, 1.75, 1.71, and 1.58 respectively. The high percentage of respondents who selected the "Not Utilized" category suggests challenges related to accessibility, inadequate infrastructure, insufficient professional training, and limited technological support for teachers. Furthermore, Virtual Laboratories, Augmented Reality, and Virtual Reality emerged as the least utilized technologies, with mean scores of 1.48, 1.36, and 1.30 respectively. Most respondents indicated that these technologies were not used in their instructional practices. This outcome points to the minimal integration of advanced immersive technologies in STEM teaching, which may be attributed to factors such as high implementation costs, lack of technical expertise, and inadequate availability of technological facilities in schools. Overall, the findings demonstrate that the utilization of emerging technologies in STEM education remains generally low. However, mobile learning devices and multimedia instructional tools appear to be more commonly adopted due to their relative affordability, accessibility, and ease of use in supporting classroom instruction.

Research Hypothesis :H0: There is no significant difference between male and female secondary school STEM teachers' utilization of emerging technologies for teaching STEM subjects.

Table 3. t-test of significant difference between male and female secondary school STEM teachers' utilization of emerging technologies for for teaching STEM subjects.

Variable	Gender	N	Mean	Std.D	t	df	Sig.
Utilization of ET	Male	182	17.42	3.18	0.56	382	0.58
	Female	202	17.23	3.41			

Table 3 presents the outcome of the independent sample t-test conducted to determine whether gender influences secondary school STEM teachers' utilization of emerging technologies in classroom instruction. The analysis compared the mean responses of male and female teachers regarding their use of these technologies for teaching STEM subjects. The results revealed that male teachers obtained a mean score of 17.42 with a standard deviation of 3.18, whereas female teachers recorded a mean score of 17.23 and a standard deviation of 3.41. While the male respondents showed a marginally higher mean value, the variation between both groups was minimal.

Further analysis indicated a calculated t-value of 0.56 at 382 degrees of freedom, with a corresponding p-value of 0.58. Since the p-value exceeded the accepted significance level of 0.05, the difference observed between the two groups was not statistically meaningful. Based on this outcome, the null hypothesis was retained, indicating that no significant difference exists between male and female secondary school STEM teachers in their utilization of emerging technologies for teaching STEM subjects. The finding suggests that gender does not play a major role in determining the level at which STEM

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teachers integrate emerging technologies into instructional practices, as both groups demonstrated relatively comparable levels of utilization.

DISCUSSIONS

The findings of the study showed that the availability of emerging technologies for teaching STEM subjects in secondary schools within South-West Nigeria is still considerably low. Most of the respondents indicated that important digital instructional tools such as virtual laboratories, augmented reality, virtual reality, simulation software, learning management systems, interactive whiteboards, and online collaboration platforms were either unavailable or insufficiently provided in their schools. This outcome implies that many schools in the region are yet to develop the technological infrastructure required for effective technology-driven STEM instruction. The result is consistent with the findings of Onyebuchi et al. (2024), who identified inadequate funding, irregular electricity supply, weak internet connectivity, and poor institutional support as major barriers limiting access to educational technologies in Nigerian schools. The finding also supports the position of UNESCO (2023), which noted that infrastructural challenges continue to restrict effective technology integration in many developing educational systems.

The poor availability of immersive technologies such as augmented reality and virtual reality further suggests that most secondary schools still rely heavily on conventional teaching methods rather than modern digital learning approaches. This finding agrees with Xu and Ouyang (2022), who observed that access to technologies such as artificial intelligence systems, simulations, and virtual learning tools enhances instructional innovation, collaboration, and students' engagement in STEM learning. In the same vein, Nedungadi et al. (2023) asserted that emerging technologies contribute significantly to learners' creativity, critical thinking, and cognitive development when they are adequately accessible within educational environments. Consequently, the limited availability of these technologies in schools may reduce opportunities for interactive, inquiry-based, and experiential STEM learning among students in South-West Nigeria.

Despite the low availability of most advanced technologies, the study revealed that mobile learning devices such as smartphones and tablets were widely accessible among respondents. This suggests that personal digital devices are more readily available than school-provided technological facilities. The high accessibility of mobile devices may be connected to the increasing spread of mobile technology and internet-enabled devices across Nigeria. This finding aligns with OECD (2023), which emphasized that mobile and digital technologies now play an important role in supporting flexible, collaborative, and inclusive learning environments globally. However, although these devices are widely available, their integration into formal STEM teaching practices appears to remain largely uncoordinated and limited.

In terms of utilization, the study established that the overall use of emerging technologies for teaching STEM subjects among secondary school teachers was relatively low. Mobile learning devices recorded the highest level of utilization, followed by multimedia instructional tools and learning management systems. This suggests that teachers are more likely to adopt technologies that are affordable, accessible, familiar, and easy to integrate into classroom instruction. The finding corroborates the study of Ohanu et al. (2024), who reported that teachers in Nigeria commonly rely on basic digital technologies such as smartphones, multimedia tools, and computers, whereas the use of advanced instructional technologies remains minimal.

The comparatively higher utilization of multimedia instructional tools may be attributed to their ability to simplify difficult STEM concepts through visual aids such as animations, videos, and digital presentations. This observation is in agreement with UNESCO (2023), which stated that technology-supported instructional tools enhance conceptual understanding by promoting visualization, simulations, and interactive learning experiences. Similarly, the moderate use of learning management systems indicates that some schools and teachers are gradually embracing digital platforms for instructional delivery, classroom management, assignments, and assessment activities.

On the other hand, technologies such as artificial intelligence tools, simulation software, online collaboration platforms, interactive whiteboards, virtual laboratories, augmented reality, and virtual reality recorded low levels of utilization. This indicates that advanced emerging technologies are not yet fully integrated into STEM classroom practices. The low utilization may be associated with inadequate teacher competence, insufficient professional training opportunities, poor institutional support, and infrastructural limitations. This finding supports Petko et al. (2021), who argued that effective technology integration depends largely on teachers' digital competence, access to professional development, and institutional support systems. Likewise, Onanuga and Saka (2025) found that although teachers possess some awareness of technologies such as augmented reality and virtual reality, their practical classroom application remains limited because of inadequate training and insufficient support mechanisms.

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The study further investigated whether gender influences STEM teachers' utilization of emerging technologies. The findings revealed that there was no statistically significant difference between male and female teachers in their utilization of emerging technologies for teaching STEM subjects. Although male teachers recorded a slightly higher mean score, the difference was not significant enough to establish gender disparity. This implies that both male and female teachers utilize emerging technologies at relatively similar levels. The finding is consistent with Scherer et al. (2021), who reported that gender differences in technology adoption tend to reduce when teachers are provided with equal access to technological resources and training opportunities.

However, this result differs from the findings of Samuel et al. (2020), who argued that male teachers often display greater confidence and involvement in technology-related instructional practices than female teachers. The difference in findings may be attributed to variations in context, improvements in digital literacy, and increased access to technology among teachers in recent years. Therefore, the present study suggests that gender may no longer constitute a major factor influencing the utilization of emerging technologies among secondary school STEM teachers in South-West Nigeria.

Overall, the findings of the study indicate that although emerging technologies possess enormous potential for improving STEM education, their availability and utilization in secondary schools across South-West Nigeria remain inadequate. The insufficient provision of advanced digital instructional technologies, combined with low levels of classroom integration, may continue to hinder the effective implementation of technology-driven STEM education within the region. The findings therefore underscore the need for greater investment in technological infrastructure, teacher training, professional development programmes, and institutional support systems aimed at promoting the effective integration of emerging technologies into STEM teaching and learning processes.

CONCLUSION

The study concludes that both the availability and use of emerging technologies for teaching STEM subjects in secondary schools across South-West Nigeria are generally limited. The findings show that most advanced digital tools, including virtual laboratories, augmented reality, virtual reality, simulation software, and other interactive technologies, are largely absent in many schools, with only mobile learning devices and a few basic ICT resources being commonly accessible. In classroom practice, teachers tend to depend mainly on mobile devices and multimedia materials, while more advanced technologies are rarely employed, largely due to inadequate infrastructure, insufficient training opportunities, and weak institutional support systems. The study also confirms that there is no statistically significant difference between male and female STEM teachers in their use of emerging technologies, suggesting that gender does not play a meaningful role in technology adoption within this context. Overall, it is concluded that although emerging technologies have strong potential to improve STEM education, their effective implementation in secondary schools across the region is still constrained by structural and resource-related limitations.

The following were recommended based on the results of the findings: Government and education stakeholders should prioritize increased funding and provision of emerging technologies such as virtual laboratories, AR, VR, simulation software, LMS, and interactive whiteboards, alongside improved ICT infrastructure, to enhance the availability of technology for STEM teaching in secondary schools. Regular professional development and hands-on training programmes should be provided for STEM teachers to strengthen their competence and confidence in effectively integrating emerging technologies such as AI tools, simulations, AR/VR, and LMS into classroom instruction. Educational policymakers should ensure equal access to ICT resources and training opportunities for both male and female STEM teachers, as gender should not be considered a determinant in the design or implementation of technology integration programmes.

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ETHICS AND DECLARATIONS

Ethical Approval and Consent

This study involved 384 secondary school STEM teachers in southwestern Nigeria who completed a questionnaire on the availability and use of emerging technologies in STEM instruction. Before completing the questionnaire, the teachers were informed about the purpose of the study, how to complete the questionnaire, and how their responses would be used.

Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Competing Interests

The author declared no competing interests.

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Author Contributions

Hameed Olalekan BOLAJI conceptualized the study, developed the research background, and coordinated the research activities. Abdulmuhsin IBRAHIM developed the survey methodology, including the design of the questionnaire and the multistage sampling procedure. Bolanle Tawakalt-Anu ABDULAZEEZ coordinated data collection among secondary school STEM teachers in South-West Nigeria and prepared the survey data for analysis. Omotosho Jimoh SALIU conducted the statistical analyses and interpreted the findings on the availability and use of emerging technologies and differences in their use by gender. All authors contributed to drafting, reviewing, and revising the manuscript and approved the final version.

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