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Peter Abayomi Onanuga and Adewale Owodunni Saka

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Article abstract

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Emerging Digital Technologies: Building Competencies of STEM Pre-Service Teachers

Peter Abayomi Onanuga
Olabisi Onabanjo University

Adewale Owodunni Saka
Olabisi Onabanjo University

ABSTRACT

This study investigated the level of emerging digital technologies' competencies of Science, Technology, Engineering, and Mathematics (STEM) pre-service teachers. It employed a descriptive survey research design. A sample of 357 STEM pre-service teachers from a Nigerian university were selected purposively, based on the criteria that they were willing to participate in the online test. The Science, Technology, Engineering and Mathematics Emerging Digital Technologies' Competencies Test (STEM-EDTCT, r=0.84) was used to collect data online, through a Google form. The data collected were analyzed using descriptive mean, standard deviations, simple percentages, and inferential statistics (independent t-test and analysis of variance). The results showed that the level of emerging digital technologies' competencies of STEM pre-service teachers was low, regardless of their mode of entry into the university. The study also found a significant gender difference in the level of digital competencies, with male pre-service teachers scoring higher than their female counterparts. Based on the findings, it is recommended that Nigeria's policy on pre-service teacher-training should focus on acquiring skills and competencies, particularly in digital technologies. STEM pre-service teachers should be equipped with known and emerging technologies to enable them to deliver knowledge and information effectively.

Introduction

Teachers are the implementers of the curriculum, and the delivery of instructions to achieve the curricular objectives depends on their quality. Educating citizens who can contribute to social and national progress depends on teachers (Saka, 2021), as no educational system can surpass the quality of its instructors. It means that competent teachers give students the necessary abilities, knowledge, and attitudes to compete favourably in the digital economy of the twenty-first century.

In Nigeria, emerging technologies for teaching and learning have been recognized through various existing national policies. For instance, The National Science, Technology, and Innovation Roadmap (NSTIR) and the National Science, Technology, and Innovation Policy (NSTIP) recognize the importance of emerging technologies in teaching and learning, and call for their integration into the educational system. Specifically, the NSTIR emphasizes the need to incorporate these tools into all aspects of academia (Federal Ministry of Science and Technology, 2012). Similarly, the NSTIP calls for introducing new and emerging digital-based media into teaching and learning processes (National Office for Technology Acquisition and Promotion, 2012). The Nigerian Education Sector Plan 2018-2022 also recognizes the need to upgrade the curriculum content, pedagogy, and teacher competencies to reflect these new, modern advancements (Federal Ministry of Education, 2018a). The plan further calls for developing a robust technology-enabled learning environment that supports using emerging technologies in teaching and learning.

Furthermore, the Federal Ministry of Education (2018b), through the National Policy on Science and Technology Education (S &T E), states that the essence of the policy direction is to make students and teachers self-adaptable to the knowledge and skills to use emerging technologies for teaching and learning. This policy direction means that as the world increasingly relies on technology, teachers must be equipped with the skills and competencies necessary to effectively incorporate ever-evolving digital tools into their teaching practices and classroom instruction. These strategies can transform how teachers deliver instruction and engage with their students for sustainable learning and improved performance. Accordingly, emerging technologies are viewed as any technologies developed to substantially affect society's social, educational, business, and economic landscape. Examples are artificial intelligence (AI), 5G Technology, cybersecurity, the Internet of Things (IoT), blockchain, FinTech, robotics, virtual, augmented and mixed reality, which already have significant business and societal impacts. Often referred to as the fourth revolution, emerging digital technologies that blend physical and digital innovations play a significant role in the everyday lives of individuals (Belk et al., 2023). This study has concentrated on artificial intelligence (AI), 5G Technology, the Internet of Things (IoT), augmented reality (AR) and virtual reality (VR).

Acquiring the skills, knowledge, and competencies necessary to utilize these digital formats to improve and achieve excellent learning is contingent on the training of teachers. Teacher education in Nigeria emphasizes educational planning and development to train prospective teachers professionally. The entry qualifications for teacher-education programs depend on the type of institution training them. There are those who are prepared by colleges of education, leading to the award of the Nigeria Certificate in Education (NCE) – the minimum qualification for entry into the teaching profession in Nigeria – and those who are educated by universities, leading to the award of a Bachelor of Education (B.Ed.), Bachelor of Science Education (B.Sc. Ed.), or Bachelor of Arts Education (B.A. Ed.). Admission to Colleges of Education requires a Senior Secondary-School Certificate Examination (SSSCE) result from the West African

Examinations Council (WAEC), the National Examination Council (NECO), or an equivalent Ordinary Level (O' Level) qualification, with credit passes in four subjects at not more than two sittings, including English and mathematics. Two of the subjects must be relevant to the course that the candidate wishes to study. Additionally, the candidate must sit for and pass the Unified Tertiary Matriculation Examination (UTME) administered by the Joint Admissions and Matriculation Board (JAMB), as well as screening examinations conducted by individual institutions.

For university admission, candidates must possess an O' Level qualification with credit passes in five subjects at not more than two sittings, including English and mathematics. The remaining three subjects should be relevant to the chosen course of study. Admission can be into Year 1 for those coming directly from senior secondary-schools, or into Year 2, as Direct Entry (DE) for students with intermediate qualifications, such as an NCE, National Diploma, Ordinary Diploma, or Joint Universities Preliminary Examinations Board (JUPEB) certification. Applicants for Year 1 admission must sit for both the JAMB UTME and the post-UTME conducted by the respective institutions, while DE candidates are only required to take the post-UTME.

The teacher-education program is structured to equip teachers to effectively perform their duties with the incorporation of information and communication (ICT) tools. As a result, Aslan and Zhu (2020) recommended that teacher-preparation programs give pre-service teachers opportunities to expand their abilities and knowledge of emerging technologies through coursework and hands-on experiences. Pre-service teachers must also be aware of the significance of incorporating emerging digital technologies into their teaching functions and classroom practices to prepare their students for future technological needs. For instance, Onanuga and Saka (2018) remarked that positive experiences in upper-basic education will facilitate students' future engagement in STEM subjects. STEM skills are some of the 21st-century skills that students need to solve various societal problems. They recommended the stakeholders' efforts to ensure that students are competent in STEM education for competitive advantages. On the strength of this, pre-service teachers need to be suitably skilled to be capable enough to cope with the future relevance of incorporating digital technologies in the educational system at the secondary school level. The researchers also attested that various governments and stakeholders' efforts in promoting STEM education at all tiers of academia are quite encouraging and motivating. These observations would be energizers to prompt implementation and help would-be teachers to step up their skills in digital technologies, which would enhance effective 21st-century classroom practices.

Several studies have examined the skills and competencies necessary for teachers to integrate emerging technologies into their teaching methods effectively. Ertmer and Ottenbreit-Leftwich (2010) observed, for instance, that teachers must comprehensively understand the technological and pedagogical ideas that enable effective teaching and learning. In addition, they stated that teachers must adapt to new technology and be open to experimenting with various instructional methods. Another study by Voogt et al. (2017) identified a set of competencies that teachers must possess to use technology to educate successfully. These abilities include the capacity to design technology-enhanced learning environments, promote student-centred learning, and engage in continuous professional growth. To prepare pre-service teachers to realistically leverage emerging technologies in their future instructional delivery, teacher-education programs must ensure that they provide their students with the necessary skills and competencies. One way to achieve this is through integrating technology into teacher-education programs during training in higher educational institutions. For example, Gao et al. (2019) reported that a technology-integrated teacher-education program improved pre-service teachers' attitudes toward using technology in their teaching, and increased their self-efficacy in using the technology.

The Federal Ministry of Education (FME, 2014) identified that pre-service teacher course contents in university undergraduate programs are inadequate in preparing them for the knowledge-driven economy. The teaching methods predominantly consist of lecture-based learning, and there is a low level of information technology (IT) utilization and penetration. Consequently, pre-service teachers lack digital-competency skills. To address this issue, the National Policy on Science and Technology Education (FME, 2018b) emphasizes upgrading skills in critical areas, including technological utilization and adaptation. This policy emphasizes the importance of preparing STEM teachers to effectively integrate emerging digital technologies into their teaching practices when they eventually assume positions as practicing teachers in schools. Similarly, Ogunkola and Adefuye (2019) reported that pre-service teachers lacked the requisite skills and capabilities in instructional design, technological integration, and student-learning-outcomes assessment. The researchers suggested improving the training of pre-service STEM teachers in emerging technologies to better equip them to integrate these technologies into their teaching activities and tasks, while providing their students with high-quality education that is relevant to the modern world. Meanwhile, Aslan and Zhu (2020) also pointed out that while most pre-service teachers had access to technology and were comfortable using it in their personal lives, they lacked the skills and knowledge needed to integrate it into their teaching effectively. Hence, this study is profoundly essential, as teacher trainers make concerted efforts to promote the deployment of technologies in 21st-century classrooms.

Meanwhile, studies have investigated the influence of gender on the abilities, competencies, and understanding of emerging technologies among pre-service STEM instructors. For instance, Abdullah and Halim (2020) discovered that female pre-service STEM teachers reported poorer self-efficacy in utilizing emerging technologies than their male counterparts. This study revealed a gender disparity in the readiness of pre-service STEM instructors to integrate modern technology into their teaching practices. Another study by Hsu and Wang (2019) reported that male pre-service STEM teachers had higher technological pedagogical content knowledge (TPACK) scores than their female counterparts. Nonetheless, the study indicated that female pre-service STEM teachers with higher TPACK scores employed more technology in their teaching practices than male pre-service STEM teachers with comparable TPACK ratings. It was concluded that although male pre-service STEM teachers may have better TPACK ratings, this does not necessarily indicate that they are more inclined to use technology in the classroom. Hence, this study is expedient and instructive to contribute to the body of knowledge in assessing how pre-service teachers' skills, knowledge, and competencies have been built toward using emerging technologies for teaching and learning in the 21st century. It also determined the extent of knowledge, skills, and competencies' building based on gender, mode of entry, and course of study.

Theoretical Model

The Technological Pedagogical Content Knowledge (TPACK) framework, established by Mishra and Koehler (2006), is a viable theoretical model for discussing the development of pre-service teachers' skills, knowledge, and competencies in developing technologies. The TPACK framework posits that effective technology integration in education requires a mix of three essential categories of knowledge: technical knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK). The connection of these domains leads to the creation of TPACK, the knowledge required to integrate technology into teaching effectively. It is, therefore, essential to

offer pre-service teachers the chance to grow their TK, PK, and CK and to assist them in integrating these domains to form TPACK to enhance their skills, knowledge, and competencies of pre-service teachers in emerging technologies. This can be accomplished through a combination of curriculum, practical experiences, and opportunities for professional growth (Koehler & Mishra, 2009). To increase their skills and knowledge, pre-service teachers must also be encouraged to experiment with digital tools and engage in reflective practice (Almarashdeh, 2019).

Recent research has proved the TPACK framework's efficiency in developing pre-service teachers' skills, knowledge, and abilities in evolving information-age media (Yu et al., 2020). By utilizing the TPACK framework to guide the development of pre-service teachers' skills and knowledge in these areas, teacher educators can ensure that their graduates are adequately prepared to meet the demands of a modern, technology-driven world. The relevance of the model was taken into consideration in the execution of this study, where the researchers used test items that took care of the TK, PK, and CK as frameworks to conform to the concerns of the research focus.

Related Literature

Yu et al.'s (2020) study explored pre-service STEM teachers' technological pedagogical content knowledge (TPACK) to use emerging technologies in teaching. The study found that while most pre-service STEM teachers had a basic understanding of TPACK, they lacked the necessary skills to integrate digital media into their teaching practices. Likewise, the study by Dag and Kılıc-Cakmak (2020) investigated the effect of a STEM-oriented technology-integrated pedagogy course on pre-service teachers' attitudes towards, and knowledge of, emerging technologies. The findings showed that the course positively impacted pre-service teachers' attitudes toward using electronic tools in teaching, and improved their knowledge and skills in technology integration. The outcomes of these studies imply the importance of providing pre-service STEM teachers with extensive training and support in the ever-changing world of software and hardware. Through expanded knowledge, competencies, and abilities, pre-service STEM teachers can successfully integrate technology into their pedagogical practices, and provide their students with a high-quality education that meets the needs of contemporary society.

On gender and the skills, knowledge, and competencies of emerging technologies, Abdullah and Halim's (2020) study examined the self-efficacy and attitudes about using new technologies among female pre-service STEM teachers in Malaysia. One hundred and sixty-nine (169) pre-service female STEM instructors were surveyed at a public university. The questionnaire consisted of three sections: demographic data, self-efficacy and attitudes toward the use of developing technologies, as well as free-form questions. The study indicated that female pre-service STEM teachers had poor self-efficacy in using emerging technologies, and that attitudes toward using digital formats in the classroom was positively correlated with self-efficacy in using such devices. In a separate study, Hsu and Wang (2019) investigated the relationship between gender and pre-service STEM teachers' technological pedagogical content knowledge (TPACK) and its association with self-efficacy, attitudes, and anxiety concerning technology integration. The survey of 310 pre-service STEM instructors at a Taiwanese institution gathered data on demographics, TPACK, self-efficacy, attitudes, and apprehension toward technology integration. The research discovered that male pre-service STEM teachers had higher TPACK scores than their female counterparts. It was also discovered that female pre-service STEM teachers with higher TPACK scores reported employing more technology in their teaching practices than male pre-service STEM instructors with comparable TPACK scores.

Hung and Huang (2021) investigated gender differences in pre-service STEM teachers' digital competence and technology integration self-efficacy. The research comprised 375 pre-service STEM instructors from Taiwanese universities. Compared to female colleagues, men pre-service STEM instructors demonstrated greater digital competence and technology integration self-efficacy. Roig-Vila et al. (2018) also investigated the association between gender and pre-service STEM teachers' TPACK and the usage of digital resources. The participants were 555 pre-service STEM teachers from a Spanish university. The finding demonstrated that male pre-service STEM teachers had higher TPACK scores than female pre-service STEM instructors. Nonetheless, the study identified no significant gender differences in using digital instructional resources. On digital competence and gender, Cabezas-González et al. (2021) researched to verify the existence of significant differences according to gender; both genders were suspended, and male educators showed significantly higher scores than future women educators.

In a study conducted by Zubairu et al. (2019) at Ahmadu Bello University in Nigeria, the digital competencies of 279 pre-service teachers in the Faculty of Education were assessed, based on their department. Results showed a significant difference in digital competencies among the different departments. Milutinović's (2020) study also found that students' perceived usefulness of emerging technologies significantly predicted their digital competencies, indicating that those with higher scores in these areas were more likely to intend to use electronic media in the classroom. The study further revealed that the year in college significantly affected these competencies, suggesting that the longer a student spent in higher education, the greater their proficiency in using technology. Masters' students reported significantly higher levels of digital competency than first-year students and juniors. However, there was no significant difference between the digital competencies of first year and third-year students.

On the mode of entry, Okebukola et al. (2018) examined the use of educational technology among pre-service teachers in Nigeria, based on their method of university admission. The study indicated that pre-service teachers admitted through direct entry were more likely to have prior experience with educational technology and use it in their teaching methods. In a separate study, Yusuf (2017) investigated the attitudes and views of pre-service teachers on the use of technology in teaching and learning. According to the study, there were considerable disparities in the opinions of pre-service teachers based on their university entrance. Specifically, pre-service teachers admitted through direct entry had higher favourable opinions regarding technology use than those admitted through the University Matriculation Examination. Similarly, Adekomi and Adeoye (2017) investigated the level of pre-service teachers' technological ability for teaching and learning. The study indicated that pre-service teachers who obtained admission through direct entry had better competency in using technology for teaching and learning than those who gained admission through the University Matriculation Examination. This finding is corroborated by Osunkunle et al. (2020), who examined the technology competence of pre-service teachers based on their mode of entry to the university, and found that pre-service teachers who gained admission through direct entry had higher levels of technology competence, and were more likely to integrate technology into their teaching practices, than those who gained admission through University Matriculation Examination.

From the literature review, it is evident that in a limited number of studies, all dimensions of digital competence have been considered, and research has often been conducted within specific countries. For this reason, investigations that comprehensively address the digital competencies of pre-service teachers and precisely express their deficiencies, along with which areas are different, according to variables such as gender, branch, and perceived level of digital competence are required. Within this framework, the shortcomings in the scope of comfort with digital educational

resources can be identified, and suggestions can be made on how the training content should address these inadequacies (Cebi & Reisoglu, 2020). This research must be carried out within the scope of different countries, because each of their policies regarding teacher education, or training programs, are different. In this way, every location can undertake necessary activities and initiatives according to its needs.

Previous studies did not examine the level of emerging digital technologies among pre-service STEM teachers, suggesting that these students may not develop what is required for their future careers. It is crucial to foster these skills in science teacher training, especially for STEM teachers, as they are essential for promoting science in schools and entry into professional STEM-related fields. This analysis is, therefore, necessary to assess the current level of emerging digital technological competencies among pre-service STEM teachers, and identify areas where improvements can be made.

In this respect, the research question answered in the study is:

1. What would the pattern level of STEM pre-service teachers look like in emerging digital technological competencies?

In addition, the following hypotheses were formulated and tested at a 0.05 level of significance:

1. There is no significant difference in the level of competence of STEM pre-service teachers in emerging digital technologies according to the mode of entry into the university.
2. There is no significant difference in the level of competence of STEM pre-service teachers in emerging digital technologies according to gender.
3. There is no significant difference in the level of competence of STEM pre-service teachers in emerging digital technologies according to the course of study.

Methodology

The research design is a descriptive survey. The university undergraduates of two state-owned public universities in Ogun State, Nigeria, undergoing teacher-education programs, were the target population from which the sample was drawn. While the students from one of them were the participants, a few students from the second school were used to validate the instruments.

The sample consisted of (357 300-level students (penultimate-year students) in STEM-related courses selected through convenience (using a Google form sent to the students' WhatsApp platform, which provided easy accessibility to the instrument) and purposive sampling techniques to select only the 300-level students on the assumption that they had gained some experience and exposure in pedagogy during professional training (practical training) in their chosen fields.

The respondents' demographic information is shown in Table 1.

Table 1: Distribution of respondents by personal demographic data (N = 357).

Demographic variables	Frequency (f)	Percentage (%)
Gender		
Male	133	37.3
Female	224	62.7
STEM Courses		
Biology Education	84	23.5
Chemistry Education	121	33.9
Health Education	53	14.8
Integrated Science	44	12.3

Demographic variables	Frequency (f)	Percentage (%)
Mathematics/Computer	5	1.4
Physics	8	2.2
Physical Education	42	11.8
Mode of Entry		
University Tertiary Matriculation Examination (UTME)	307	86.0
Direct Entry (DE)	50	14.0

Source: Researchers' field survey, 2023

Table 1 presents the distribution of pre-service teachers by gender, mode of study, and course major. Most participants were female, accounting for 62.7% of the sample, while only 37.3% were male. Although the researchers acknowledged the existence of non-binary gender identities, this study used binary (male and female) categories for the gender variable, because the Nigerian context does not officially recognize any gender identities beyond male and female. The study focused solely on the binary option to avoid data collection constraints. Similarly, most participants (33.9%) were in Chemistry Education, followed by Biology Education (23.5%), Health Education (14.8%), Integrated Science (12.3%), Physical Education (11.8%), Physics Education (2.2%), and Mathematics/Computer Education (1.3%). Additionally, 307 students (86.0% of the total) entered the institution through UTME, while 141 students (14.0%) did so via direct entry (DE).

The research instrument used for data collection was a 25-item multiple choice code-named "STEM Pre-service Teacher Emerging Digital Technologies Competencies Test" (STEM-EDTCT), and was researcher-developed. The STEM-EDTCT was divided into five parts, with five questions in each sub-component: artificial intelligence (AI), 5G Technology, augmented reality, virtual reality, and the internet of things (IoT), to make a total of 25 items. The scoring point regime for the competencies went thus: very low (1 – 9), low (10 -12), high (13 -19) and very high (20 - 25). The test was moulded in Google format for presentation as an online test for the students for 30 minutes. The researchers developed the instrument. The students were informed of the time of the test in advance, and that if anyone missed the time announced, such respondents would not be captured, due to the time limit of the test. It was conducted during a 300-level course coded, EDU 304, and titled "ICT in Education." The course was two-unit and compulsory.

The face and content validities of the instrument were obtained by subjecting it to the critiques of six experts, three of whom are in test constructions, and the other three who were lecturers in Science and Technology Education at Olabisi Onabanjo University, Ago-Iwoye, Ogun State, Nigeria. The adequacy of the competency test was assessed using statistical indexes, item difficulty index, and item discrimination index. For the difficulty index, items ranging from 40-60% were considered, items below 40% were considered too difficult, and items above 60% were taken as too simple. For the discriminating index, the values that ranged from +0.4 to +1.0 were accepted as discriminating. Thus, 25 items that survived the difficulty level after item analysis of the initial 75 items were considered in the study with an appropriate discriminating index, which was considered (see Appendix II). A positive value indicated that the distracter is invalid, since it was chosen by more of the candidates in the high-ability group. A negative index value indicated that the distracter was valid, since candidates in the low-ability group primarily chose it. A zero-distracter index indicated that the distracter did not confuse anybody; therefore, any option with a negative value was avoided. The instrument's reliability was obtained by administering the test to 30 students in STEM-related courses in the second state university, because the students shared

similar characteristics with those in the targeted institution. The responses from the students were subjected to Cronbach Alpha statistics, which yielded a reliability coefficient of .84.

Before data collection via the online Google form, the respondents were addressed through the Olabisi Onabanjo University Learning Management System—Microsoft Teams. They were informed of the purpose of the study, and the need to participate. However, an opportunity was provided for those uninterested to opt out. This explains why only 357 students responded to the instrument out of the 800 students registered for the course EDU 304 (ICT in Education). The data, collected online using Google form, were analyzed using descriptive and inferential statistical tools. Descriptive statistics included frequency counts, percentages, mean, and standard deviation, while the inferential statistics employed were the F-ratio, t-test, and ANOVA.

Results

The data analysis results are provided per the research questions, followed by the testing of hypotheses.

Research question 1: What would the pattern of level of STEM pre-service teachers look like in emerging digital technologies competencies?

Table 2: Descriptive statistics showing level of pattern of STEM pre-service teachers in emerging digital technological competencies.

Level	Frequency (f)	Percentage (%)
Very Low	7	2.0
Low	255	71.4
High	63	17.6
Very High	32	9.0

Table 2 presents the descriptive statistics on the pattern of emerging digital technological competencies among STEM pre-service teachers. The findings reveal that most of those sampled possessed a low level of competency in this area, with 262 students (73.4%) falling into the low-level category. This was followed by 63 students (17.6%) in the high-level category, 32 students (9.0%) in the very high-level category, and only seven students (2.0%) in the very low-level category.

The following null hypotheses were tested at a 0.05 probability level: There is no significant difference in level of competencies of STEM pre-service teachers in emerging digital technologies, according to mode of entry into university.

Table 3: T-test showing differences in the level of STEM pre-service teachers emerging digital technological competencies by mode of entry into university.

Mode of Entry	N	Mean	S.D	Std. Error	Df	T	p
UTME	307	38.485	14.18	.809	355	1.577	0.116
DE	50	35.140	12.11	1.713			

Table 3 presents the results of the independent sample t-test showing differences in the level of emerging digital technological competencies of pre-service teachers by mode of entry into university. The result above indicates a non-significant outcome ($t = 1.637$; $p > 0.05$). This outcome implies that the mean level of STEM pre-service teachers is 38.485 UTME students recorded, and is not significantly different from the mean score of 35.140, recorded by the direct entry mode. In this situation, the difference in the mean was statistically insignificant. Hence, there is no significant difference in the level of emerging digital technological competencies of STEM pre-service teachers according to their entry mode.

Hypothesis 2: There is no significant difference in level of competence of STEM pre-service teachers in emerging digital technologies according to gender.

Table 4: T-test showing gender differences in the level of STEM pre-service teachers emerging digital technological competencies.

Gender	N	Mean	S D	Std. Error	Df	t	p
Male	133	41.669	15.344	1.330	355	3.889	0.0001
Female	224	35.848	12.582	.8410			

Table 4 presents the result of the independent sample t-test showing gender differences in the level of STEM pre-service teachers' emerging digital technological competencies. The result indicates that the mean score of 41.669 recorded by the males, based on their level of this is significantly higher than the mean score of 35.848 of their female counterparts. Also, the t-calculated value of 3.889, whose probability is close to zero percent, indicated that gender significantly influenced the level of emerging digital technological competencies of STEM pre-service teachers. Hence, statistically, it can, thus, be inferred that there is a significant gender difference in the level of emerging digital technological competencies of the pre-service teachers.

Hypothesis 3: There is no significant difference in the level of competencies of STEM pre-service teachers in emerging digital technologies according to course of study.

Table 5: ANOVA showing differences in the level of STEM pre-service teachers' emerging digital technological competencies by course of study.

Course of study	N	Mean	Std. Deviation	Std. Error	F-cal	Sig. of F
Biology Education	84	36.3333	12.87599	1.40489	4.401	0.0001
Chemistry Education	121	40.1983	13.04902	1.18627		
Health Education	53	32.8679	12.42057	1.70610		
Integrated Science	44	43.7955	16.18868	2.44054		
Mathematics/Computer	5	42.2000	20.58397	9.20543		
Physics	8	44.5000	11.48913	4.06202		
Physical Education	42	33.8095	14.18388	2.18862		
Total	357	38.0168	13.94289	0.73794		

Table 5 presents the result of the analysis of variance (ANOVA) showing significant differences in the level of STEM pre-service teachers' emerging digital technological competencies according to the course of study. The findings indicate a significant outcome ($F = 4.401$ $p < 0.05$). The mean score of 36.33 for the level of pre-service teachers' emerging digital technological competencies recorded by those students running biology education was significantly different from the mean score of 40.198 recorded for chemistry education students. Similarly, the mean score of 32.867 for health education students is statistically different from the mean score of 43.7955 that was recorded for integrated science students. Equally, the mean score of 42.20 for mathematics education students significantly differs from the mean score of 44.50 and 33.80 recorded for physics and physical education students, respectively. Hence, the observed mean difference is statistically significant. Hence, it can be concluded that there is a significant difference in the level of pre-service teachers' emerging digital technological competencies based on their course of study.

Discussion

This study identified STEM pre-service teachers' emerging digital technological competencies by performing a descriptive analysis to determine their distribution in terms of demographic variables and their level pattern. The results showed that they generally exhibited a low-level pattern in competencies, and only a few demonstrated a high pattern.

One of the study's findings revealed no significant difference in emerging digital technological competency levels among STEM pre-service teachers, based on their mode of entry, whether through UTME or DE. This result implies that both groups of students lacked sufficient exposure to basic digital skills before admission to the university and during their academic program, despite the global technology invasion. Many secondary schools in Nigeria, particularly public schools, may not have adequate facilities to provide hands-on experience with emerging digital technologies. This lack of exposure to these skills may hinder their ability to incorporate technology into their teaching practices in the future. These findings are different from the results of previous studies conducted by Okebukola et al. (2018) and Adekomi and Adeoye (2017), which reported that pre-service teachers admitted through direct entry were more likely to have prior experience with educational technology and to use it in their teaching methods. The difference in findings might be attributed to the variation in the sample size, methodology, and instrument used for data collection. The Technology Pedagogy and Content Knowledge (TPACK) model can be used to situate the findings of this study. The TPACK model emphasizes the need for teachers to possess technological knowledge, pedagogical knowledge, and content knowledge to effectively integrate technology into their teaching practices. The current study suggests a lack of technological knowledge among UTME and DE students, which could hinder their ability to integrate electronic methods into their teaching practices. Therefore, it is essential to incorporate digital skills into the pre-service teacher training program to bridge the technological knowledge gap and prepare them for the 21st-century classroom.

The findings of the study suggest that there is a significant gender difference in the level of emerging digital technological competencies of STEM pre-service teachers, with male students showing higher levels of these skills compared to their female counterparts. This finding aligns with previous research studies (Abdullah & Halim, 2020; Hsu & Wang, 2019; Hung & Huang, 2021) that have also reported a gender disparity in these areas among pre-service teachers. However, it is important to note that this finding does not necessarily suggest that males are

inherently better at using digital technologies than females. Instead, it could be due to social and cultural factors which influence how males and females are encouraged to engage with technology. For example, despite having better phones than their male counterparts, female students use their phones more for social media, instead of learning with them. This finding can be situated within the TPACK theoretical model, which suggests that effective teaching involves a combination of technological, pedagogical, and content knowledge. In this case, the gender disparity in digital competencies may reflect differences in how male and female pre-service teachers have been exposed to electronic instruments, along with the habits cultivated in the use of technology in the classroom. It is possible that male students have had more opportunities to develop technological knowledge and skills outside of the classroom, while female students have been unwilling to do so. Alternatively, there may be differences in how male and female students use their phones to learn about emerging technologies, which could lead to differences in their level of technological knowledge and skill.

The finding that there is a significant difference in the level of STEM pre-service teachers' emerging digital technological competencies based on their course of study is crucial. This implies that pre-service STEM teachers' digital competence level is affected by the specific courses that they are studying. This finding aligns with the TPACK theoretical model, which suggests that technology integration is subject-specific and that the context in which technology is used affects how effectively it can be integrated into teaching and learning. For instance, a STEM teacher who teaches biology may need different technological competencies than one who teaches mathematics or computer science. The subject-specificity of technology integration highlights the need for targeted interventions in teacher-education programs that consider the needs of STEM teachers in different fields. The finding of this result is similar to that of Zubairu et al. (2019), who found a significant difference in the digital competencies of pre-service teachers, based on their department, further underscores the need for a targeted approach to developing digital skills in pre-service STEM teachers. It is essential to provide direct training to pre-service teachers, focusing on the specific digital technologies relevant to their subjects, to help them acquire the necessary competencies.

Conclusion

In conclusion, the findings of this study have shown that STEM pre-service teachers in Nigerian universities have relatively low levels of emerging digital technological competencies. The results also indicate significant differences in the level of these skills based on the course of study, gender, and mode of entry. However, there were no significant differences in these levels between students admitted through UTME or DE.

Within the TPACK theoretical model, this research recommends the importance of integrating technology, content, and pedagogy in the education of pre-service teachers. It also recommends including emerging digital technologies in the teacher-education curriculum to ensure that pre-service teachers have the necessary skills to meet the demands of the 21st-century classroom. Furthermore, these findings underscore the need for teacher-education institutions to adopt a gender-sensitive approach in training pre-service teachers, to bridge the gender gap in digital technology competencies. Additionally, the results suggest that STEM pre-service teachers' emerging digital technological competencies could be influenced by their course of study, indicating the need for targeted training and support for pre-service teachers in different disciplines.

Limitations and Future Studies

This research targeted only the 300-level students enrolled in a compulsory course (EDU 304). However, out of 800 registered students, only 357 responded to the instrument, far below the average number of the prospective participants. This limited sample size may affect the generalizability of the findings, as survey studies typically benefit from larger samples to improve the reliability and applicability of the results. To this end, future studies should include a larger number of respondents to enhance the generalizability and applicability of the findings. Additionally, further research should collect data from students upon admission in Year 1 (100-level) to assess their initial knowledge, awareness, and skills related to emerging technologies. The same data should then be collected at the end of their programs in Year 4 (400-level) to evaluate the competencies they have developed during their university education.

Author Bio

Dr. Peter Abayomi Onanuga and Dr. Adewale Owodunni Saka are lecturers at Olabisi Onabanjo University, Ago-Iwoye, Nigeria. They hold PhDs in science education. Their research focus has largely been in science education, with research efforts being geared towards teaching strategies, teaching effectiveness, and learning outcomes of school students. Their teaching experience in the university has spanned between sixteen and eight years respectively, while teaching both undergraduates and postgraduates. The duo are active members of Science Teachers Association of Nigeria (STAN), but the first author holds a fellowship status of FSTAN. They both equally belong to Curriculum Organisation of Nigeria (CON). They have published widely in reputable journal outlets of both the local and international coverage and have attended several conferences, both in Nigeria and on the global scene. They are open to collaboration with scholars in the areas of teaching and curriculum studies in any part of the globe.

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