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Assessing the Proficiency level in Digital Competences of Secondary School Science Teachers

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ABSTRACT

This study investigated Nigerian science teachers' perceptions regarding their level of digital competency. A 22-item questionnaire based on the Digital Competence of Educators Framework was administered to 102 science teachers from an education district in Lagos, Nigeria. Descriptive statistics were employed to analyse the data. It was discovered that the majority of sampled teachers demonstrated an integrator–B1 level of digital proficiency. A proficiency level of B1 demonstrates that teachers at this level still need to improve their knowledge of which tools are most effective in which circumstances, and their ability to integrate digital technologies into their pedagogical strategies and methods. Teachers also demonstrated low proficiency levels in the sub-dimension of digital content creation, providing feedback and planning, analyzing evidence of students' problems, and organizational communication. These results highlight the need for ongoing professional development that focuses more on real-classroom examples of how science teachers can use technology to meet the various needs of students, thereby fostering improvements in their level of digital proficiency. This may also help higher education institutions re-evaluate their teacher preparation programs to ensure that incoming teachers are better prepared to use digital technologies in their classrooms.

Keywords: *Digital competencies; DigCompEdu Framework; Science teachers; Technology Integration*

INTRODUCTION

The importance of Information Communication and Technology (ICT) has seen tremendous growth in countries around the world such that the question is no longer whether to use ICT but rather how to improve ICT use. The roles of teachers in the classroom have also become more complex due to ongoing advancements in educational technology. Teachers are now expected to be technologically savvy in order to meet the demands and expectations of modern students, who are known as future-engaged citizens in a digitized and changing society. This necessitates interaction between how a subject is taught (pedagogy), substantive understanding of what is being taught, and the tools used (technology) in order to be effective (Samson et al., 2021). For instance, the fourth industrial revolution has brought about the adoption of highly networked systems like artificial intelligence, the Internet of things, big data, widespread and routine use of sensors and technical assistance systems, machine learning, high-level automation, and the use of cyber-physical systems in our daily lives (Schwab, 2016). These technological advancements provide the tools for conducting different scientific research and investigation. Thus, utilizing modern technologies is essential for developing 21st-century skills like problem-solving and inquiry. As a result, there has been an increasing demand for educational platforms that allow the use of various technological tools and digital media to improve K-12 education (Hoban, Nielsen, & Shepherd, 2016). Government initiatives and training programs worldwide have also begun to support the use of digital technology in education for teaching and learning, so as to aid the digitalization process (Antonietti, Cattaneo, & Amenduni, 2022).

Earlier research has shown that using digital technologies in science education allows students to practice scientific methodologies such as conducting research, designing, and carrying out experiments, analyzing appropriate results for the field, and helping them visualize abstract scientific concepts (Ucar, 2015). The use of digital technologies has also promoted collaborative learning, the development of 21st-century skills, and students' autonomy, responsibility, and capacity for reflection and initiative (van Laar, 2017). Furthermore, using digital technologies in education can assist teachers in leveraging digital tools for assessment, motivating students to study STEM subjects in greater depth, encouraging the replication of real-world problems, and developing students' social and problem-solving skills (Ucar, 2015). Given these opportunities, teachers must have the competencies (knowledge, skills, literacies, and attitudes) required to fully exploit the potential of digital technologies for enhancing teaching and learning and adequately preparing their students for life and work in a digital society (Redecker & Punie, 2017). This implies that teachers must have strong digital competencies in order to incorporate, adapt, and/or apply digital technologies creatively and confidently. In light of this, the European Union defined digital competence as:

> "The safe, critical and responsible use of and interaction with digital technologies for learning, work and social participation. It includes information and data literacy, communication and collaboration, media literacy, digital content creation (including programming), security (including digital wellbeing and cybersecurity-related skills), intellectual property issues, problem-solving and critical thinking." (Council of the European Union, 2018, p. 9)

In order for teachers to effectively use ICT from its many perspectives, including technological, informational, multimedia, communicative, collaborative, and ethical, they must possess a specific set of knowledge, skills, strategies, and attitudes while also adhering to pedagogical-didactic principles for adopting digital technology in their instructional practices (Benali, Kaddouri, & Azzimani, 2018; Santos, Pedro, & Mattar, 2021). In Nigeria, as in many other countries, the government and educational stakeholders place a high value on teachers' ability to bridge digital divides at both the local and international levels if they receive adequate ICT capacity building. As a result, the country has established several ICT policy frameworks and implementation strategies, committed significant resources to ICT infrastructure, and increased teacher's ICT awareness and capacity through ongoing advocacy, training, and novel projects, particularly online programs and activities that allow teachers to practically experience the usefulness of ICT in teaching and learning (Isyaku & Nwokeocha, 2011). For instance, the Teachers Registration Council of Nigeria (TRCN) started an ongoing professional training program for science teachers at the primary, secondary, and tertiary levels in Nigeria to give them the necessary ICT skills, such as using computer software appropriate for teaching and learning, Internet skills, particularly the use of electronic mails and online research and paper publication and using virtual classroom management software (Isyaku & Nwokeocha, 2011). In 2009, the Lagos State Government organized an ICT curriculum workshop for public secondary school teachers to assist them in effectively using ICT facilities in instructional delivery (Lagos Ministry of Information, 2011). Further, the Lagos State Government launched the Lagos Eko Project in 2009 with World Bank assistance in order to strengthen the state's knowledge economy by improving instruction quality through upgrading science laboratories and providing ICT facilities such as computer sets and e-tutor software applications to enhance instructional delivery in secondary schools (Eko, 2010; 2011). The E-tutor software is divided into two modules: virtual classroom learning modules and blended learning modules. As part of the impressive educational policies of the Nigerian Government, the Lagos State Government unveiled Eko Excellence in Child Education and Learning (EKO EXCEL) in 2019 as a transformational initiative to support learning and teaching through cutting-edge technology. One of the objectives of EKO EXCEL is to improve teachers' and students' digital literacy, allowing them to collaborate in real-time using advanced educational technology.

Despite the widespread availability of educational hardware and software, teachers' use of digital technologies in the classroom and the overall digital competency of teachers in many countries, including Nigeria, appear to remain inadequate. For example, research conducted under the

International Computer and Information Literacy Study (ICILS) in 2018 revealed that less than 50% of teachers from participating countries used technology in their classrooms regularly (Fraillon, Ainley, Schulz, Duckworth, & Friedman, 2019). In addition, results of the 2018 Teaching and Learning International Survey (TALIS) conducted by the Organisation for Economic Co-operation and Development (OECD) revealed that teachers from participating countries reported a high need for technology-related skill training, with only 43% feeling prepared to use technology in their classrooms (OECD, 2019). These concerns have prompted many countries, including Nigeria, to investigate teachers' digital competence. Digital competence is an important factor in implementing high-quality educational learning processes, especially in today's changing educational landscape marked by the use of educational technology in teaching and learning. Research has revealed that many teachers lack digital competence (Kartimi, Riyanto, & Winarso, 2023). According to Benali et al., (2018), personal characteristics such as attitudes toward using ICT and the environment (curricula requirements, years of teaching, infrastructure) can impact digital competence. As such, it requires an assessment strategy that considers numerous variables in order to be evaluated objectively.

In light of the above discussion, the current study investigates the perceptions of Nigerian science teachers regarding their level of digital competency. This study utilized the Digital Competence of Teachers (DigcompEdu) Framework as an underlying conceptual framework to investigate the perspectives of Nigerian science teachers on their digital competences and their level of satisfaction with using these competencies. The outcomes of this study have the potential to provide useful insights into the aforementioned elements. Thus, this research was guided by the following question:

> ‘What are the self-perceptions of Nigerian science teachers about the proficiency level of their digital competencies?’

LITERATURE REVIEW

The importance of digital competence in the educational context has grown in significance. It is now acknowledged as one of the crucial skills teachers in today's society must possess for lifelong learning (Yelubay, Seri, Dzhussubaliyeva, & Abdigapbarova, 2020). Janssen, Stoyanov, Ferrari, Punie, Pannekeet, and Sloep (2013) provided a broader perspective on the nature of general digital competence:

> “It entails more than just knowing how to use devices and applications and is intricately linked with information and communication skills. Sensible and healthy ICT use necessitates specific knowledge and attitudes about legal and ethical issues, privacy, and security, as well as an understanding of the role of ICT in society and a balanced attitude toward technology.” (p. 480).

However, the development of teachers' digital competencies should not be limited to general pedagogical digital competencies but should also include subject-specific digital competencies (Thoms, Colberg, Heiniger, & Huwer, 2022). Furthermore, teachers' digital competence must enable them to:

> "facilitate students' learning and acquisition of their digital competence, carry out processes for improving and innovating teaching in accordance with the needs of the digital era, as well as contribute to their professional development in accordance with the changes that occur in society and schools…" (de Catalunya, 2018, p. 11).

Over the years, several models and frameworks have been published to better understand the state of teachers' digital competencies, which is the set of knowledge, skills, and attitudes required for a teacher to use technology effectively. One common framework identified in the literature as frequently used for informing the digital competencies of science teachers and is well-supported by empirical research is Mishra and Koehler's (2006) Technological, Pedagogical and Content Knowledge (TPACK) framework. The TPACK framework was created to assist teachers in planning, selecting, utilizing, and adjusting technology, appropriate for content and pedagogy when carrying out learning activities (Tomczyk & Fedeli, 2021). However, the TPACK framework only addressed teachers' knowledge composition from an epistemological standpoint without considering the practical knowledge or proficiency level of teachers' subject-specific digital competencies (Hsu, Yeh, & Wu, 2015). Even though the concept of digital competence is not explicitly mentioned in TPACK, it is an obvious part of the technology-reserved area (Tomczyk & Fedeli, 2021). Hence, the TPACK concept is considered as a starting point for developing teachers' digital competence. To better understand how the TPACK model can inform teachers' digital competence within actual science teaching contexts, Yhe et al., (2014) developed the Technological, Pedagogical and Content Knowledge-Practical (TPACK-P) framework, which reflects the craft knowledge teachers develop for and from actual science teaching in classrooms with technology. According to Hsu et al., (2015), the TPACK-P scale can assist science teachers in developing their digital competencies through three main domains of knowledge with an ICT focus on learners, curriculum design, and classroom instruction. These three major domains are further subdivided into eight knowledge dimensions: *using ICT to understand students, using ICT to understand subject content, planning ICT-infused curriculum, using ICT representations to present instructional representations, employing ICT-integrated teaching strategies, applying ICT to instructional management, infusing ICT into teaching contexts and using ICT to assess students learning*. The TPACK-P framework also informs science teacher educators about critical technological aspects that should be facilitated in science teacher education programs. It gives novice science teachers ideas about expert science teachers' technology-infused instructional practices. The TPACK-P framework clearly defines fields of application of ICT in science education and allows for a rapid evaluation of teachers' proficiency levels. Each competency domain of the TPACK-P framework is described by competency expectations, which are similar in structure to domains 1 to 5 of the European Framework for the Digital Competence of Educators (DigCompEdu).

Based on the technological pedagogical and content knowledge in the practical context of teaching (TPACK-P), Lin & Hsu (2015) explored the digital competence of 40 in-service science teachers in Taiwan and found that science teachers generally know how to adopt technologies in teaching within each domain of TPACK-P. However, the proficiency level of teachers' digital competencies in terms of the TPACK-P framework was categorized into three groups: technology infusive application, technology transitional, and plan and design emphasis group. According to Lin & Hsu (2015), the infusive application group comprised science teachers with sophisticated levels of TPACK-P across the domains of assessment, planning and designing, and teaching practices; while the transition group comprised science teachers with average levels of knowledge across the three domains; and the plan and design emphasis group comprised science teachers who were more knowledgeable about technology-infused teaching planning and design than the assessment and teaching practice domains. Similarly, Ramnarain, Pieters, & Wu (2021) investigated the TPACK-P of pre-service science teachers at a South African university and discovered that the vast majority of pre-service science teachers had a proficiency level of 3, demonstrating the infusive application, in which the teacher used ICTs to guide learners to self-explore and independently construct their science knowledge.

Research on digital competence in science classrooms suggest that science teachers could develop their digital competence through educational activities that increase digital literacy and the use of technology in science teaching. Samson et al., (2021) investigated the digital literacy and competency of 80 science teachers from public secondary schools in the Philippines and discovered that these teachers were competent in finding, understanding, using, and creating digital information. The teachers were also confident in gathering data through digital technologies. As a result, their level of digital literacy was considered to be high. Another study conducted by Kartimi et al., (2023) used the European Digital Competence Framework for Citizens (DigComp) to assess the digital competence of 105 science teachers in Indonesia. The authors discovered that while sampled science teachers demonstrated high levels of information and data literacy, communication, collaboration, and problem-solving, they lacked digital competence in security and digital content creation. Teachers with strong digital competencies are assumed to be able to use digital technologies to foster communication and collaborative learning among students and colleagues in the same classroom space. Moreover, teachers' ability to troubleshoot technical issues in the classroom can help them become more proficient in the journey toward digitalization of classroom management and organization, as students require competent and confident teachers who can use digital technology (Yhe, Hsu, Wu, Hwang, & Lin, 2014). As stated by Muammar, Hashim, & Panthakkan (2022), teachers can use digital technologies to communicate and interact with colleagues and students, as well as for the collective good and continuous innovation in the organization and teaching profession, allowing them to improve their digital competence in terms of professional engagement.

Considering the effectiveness of ICTs in teaching science subjects, it is evident that there is a global imperative for science teachers to develop specific digital competencies in addition to their general pedagogical use of technology. These digital competencies are especially important in subject-specific instruction.

CONCEPTUAL FRAMEWORK

Teachers require an increasingly broad set of competencies as the teaching profession faces rapidly changing demands that necessitate a new, broader, and more sophisticated set of competencies than previously required. More importantly, the pervasiveness of digital devices and applications and the obligation to assist learners in becoming digitally competent requires teachers to develop their digital competence. Several frameworks and models such as the common Spanish Framework of Digital Competence for Teachers, the British Framework of Digital Teaching, Technological Pedagogical Content Knowledge (TPACK), the Information and Communication Technology Standards for Teachers (NETS-T) proposed by the International Society for Technology in Education (ISTE), and the United Nations Educational, Scientific and Cultural Organization (UNESCO) ICT competence framework for teachers have been developed and adopted to understand the digital competence of teachers (Cabero-Almenara et al., 2020). However, none of these frameworks identified the pedagogical and professional focus areas for integrating technology into teaching and professional practice, nor is it intended to assist teachers in comprehensively assessing and developing the progression level of their digital competence. In light of this, the Joint Research Center of the European Commission developed the Digital Competence of Teachers framework for measuring and supporting the development of teachers-specific digital competencies (Redecker & Punie, 2017). The framework describes how digital technologies can be used to enhance and innovate education and training through 22 professional competencies organized in six areas of teachers' professional activities. According to Redecker & Punie (2017), the DigCompEdu is intended for teachers at all educational levels, including primary and secondary education, higher education, adult education, general and vocational education and training, special needs education, and non-formal learning contexts. In light of this, the framework for the Digital Competence of Teachers (DigcompEdu) is adopted as a conceptual framework for this study. The six domains/areas of the DigCompEdu framework include the following:

- The first domain focuses on professional engagement and commitment, which entails teachers' efficient and appropriate use of digital technologies for communication and collaboration with colleagues, learners, parents and external persons, and professional development.

- The second domain focuses on identifying quality educational digital resources. Teachers must also be able to modify, create and share these resources and to adjust them to their lesson objectives, learners, and teaching styles. Likewise, they must know how to use and administer digital content responsibly, respecting the author's rights and protecting personal data.
- The third domain focuses on managing and orchestrating the use of digital tools in teaching and learning: This has to do with knowing how to design, plan and implement the use of digital technologies in all the phases of the teaching process, promoting learner-centred approaches and methodologies.
- The fourth focuses on using digital tools and strategies for evaluation and feedback: This entails the ability of teachers to use digital technologies to improve the existing evaluation strategies and pave the way for new and better evaluation methods. Moreover, after analyzing a large amount of available data (digital) about the individual interactions of learners, teachers can provide more specific comments and support.
- The fifth domain addresses using digital tools to empower learners: This area acknowledges the potential of digital technologies for learner-centred teaching and learning strategies. One of the key strengths of digital technologies in education is their potential to boost the collaboration of learners in the teaching-learning process and their autonomy in it. Moreover, digital technologies can be used to provide learning activities adapted to the competence level, interests and learning needs of each learner. Thus, this area is transversal to areas 2, 3 and 4 because it contains a set of guiding principles relevant and complementary to the competencies specified in these areas.
- The sixth domain is learners' digital competence, which involves the ability of teachers to support learners' digital competence, enabling learners to use digital technologies for information, communication, content creation, wellbeing, and problem-solving creatively and responsibly. It is regarded as an integral part of teacher competence in ICT and the main theme of this competence area.

Ghomi & Redecker (2019) specified that domains 2 to 5 of the DigCompEdu Framework form the pedagogic core of the framework because they detail the competencies teachers need to foster effective, inclusive, and innovative learning strategies and use of digital tools. The focus of DigCompEdu on the pedagogical dimension enables it to provide details on how digital technologies can be effectively integrated into teaching and learning, how they can be used to improve teaching and learning strategies, what key objectives should guide their implementation, and how their use can lead to educational innovation as experience and competence grow (Roblyer & Doering, 2014). Similarly, Tomczyk & Fedeli (2021) stated that each domain has distinct indicators related to learning and teaching activities, their development, and the broader contexts occurring at the intersection of information society development and pedagogy. An overview of the DigCompEdu Framework is shown in Figure 1.

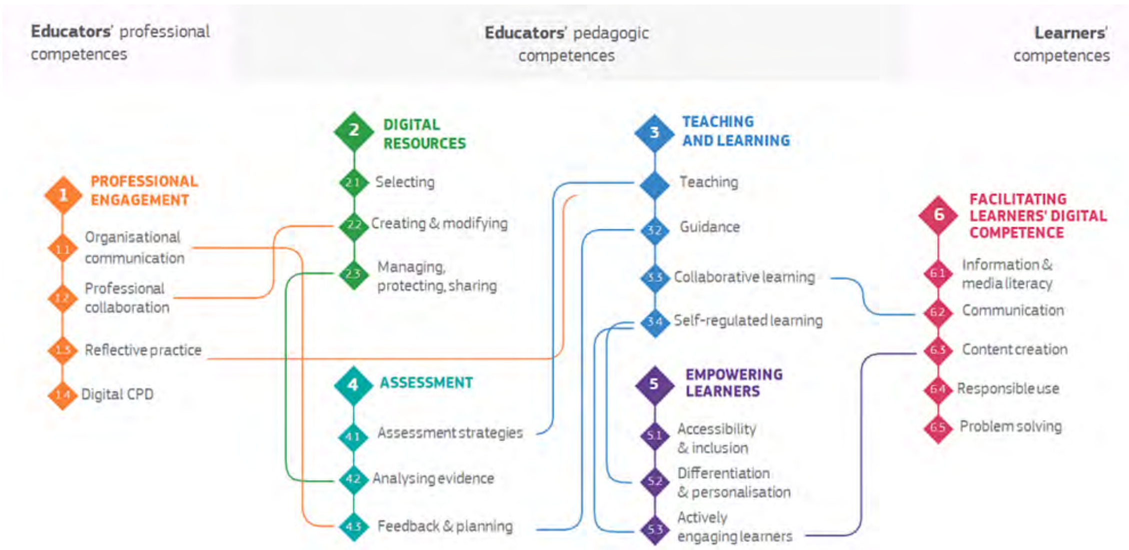

Figure 1: An overview of the framework for Digital Competence of Teachers (European Commission)

In addition to the six competence areas/domains of teachers' professional activities presented in Figure 1, the DigCompEdu Framework also proposes six progressive levels of proficiency. According to Ghomi & Redecker (2019), the proficiency level of a teacher's digital competence is identified using the Common European Framework of Reference for Languages (CEFR), ranging from the Newcomer (A1) or Novice level or those with very little experience and contact with educational technology to Pioneer (C2), or those who innovate with ICT, as explained below.

- Newcomer (A1): Teachers at the Newcomers' level are aware of the potential of digital technologies for enhancing pedagogical and professional practices. However, they have had very little contact with digital technologies and use them mainly for lesson preparation, administration, or organizational communication. As such, Newcomers need guidance and encouragement to expand their repertoire and apply their existing digital competence in the pedagogical realm.
- Explorer (A2): Teachers at this level are aware of the potential of digital technologies and are interested in exploring them to enhance pedagogical and professional practices. They have started using digital technologies in some areas of digital competence without following a comprehensive or consistent approach. Explorers need encouragement, insight, and inspiration, e.g. through the example and guidance of colleagues embedded in a collaborative exchange of practices.
- Integrator (B1): Teachers at the Integrator level experiment with digital technologies in various contexts and for various purposes, integrating them into many of their practices. They creatively use them to enhance diverse aspects of their professional engagements. They are eager to expand their repertoire of practices. They are however still working on understanding which tools work best in which situations and on fitting digital technologies to pedagogic strategies and methods. Integrators need more time for experimentation and reflection, complemented by collaborative encouragement and knowledge.
- Expert (B2): Experts use various digital technologies confidently, creatively, and critically to enhance their professional activities. They purposefully select digital technologies for particular situations and try to understand the benefits and drawbacks of different digital strategies. They are curious and open to new ideas, knowing that there are many things they have not tried out yet. They use experimentation to expand, structure and consolidate

their repertoire of strategies. Experts are the backbone of any educational organization when it comes to innovative practices.

- Leader (C1): Leaders have a consistent and comprehensive approach to using digital technologies to enhance pedagogic and professional practices. They rely on a broad repertoire of digital strategies from which they know how to choose the most appropriate for any situation. They continuously reflect on and further develop their practices. Exchanging with peers, they keep updated on new developments and ideas. They are a source of inspiration for others to whom they pass on their expertise.
- Pioneer (C2): Pioneers question the adequacy of contemporary digital and pedagogical practices of which they are leaders. They are concerned about the constraints or drawbacks of these practices and are driven by the impulse to innovate education even further. Pioneers experiment with highly innovative and complex digital technologies and/or develop novel pedagogical approaches. Pioneers are a unique and rare species. They lead innovation and are a role model for younger teachers (Redecker & Punie, 2017, p. 30).

The rule of thumb for assessing the overall result of teachers' digital competencies based on the six proficiency levels is presented in Table 1

Table 1: *Digital Competence levels and score per area of the DigCompEdu Check-In Questionnaire*

Proficiency level	**Newcomer (A1)**	**Explorer (A2)**	**Integrator (B1)**	**Expert (B2)**	**Leader (C1)**	**Pioneer (C2)**
General scores	Below 20 points	Between 20 and 33 points	Between 34 and 49 points	Between 50 and 65 points	Between 66 and 80 points	Above 80 points
Area/Domain						
Domains 1 and 3	4	5 -7	8 - 10	11 - 13	14 - 15	16
Domain 2, 4, 5	3	4 - 5	6 - 7	8 - 9	10 - 11	12
Domain 6	5 - 6	7 - 8	9 - 12	13 - 16	17 - 19	20

Source: Redecker (2019).

METHODOLOGY

A descriptive survey research design was employed in this study. This type of design is ideal for this study because it allows for the investigation of relationships between variables (Maree & Pietersen, 2014). The study sample consists of one hundred and two science teachers from schools within an Education District in Lagos, Nigeria. Data was collected through a closed-ended questionnaire that allowed teachers to self-reflect and assess their digital competence. The questionnaire contained three sections. Section A consisted of demographic information, Section B consisted of 22 items, with each item representing the 22 competencies in the DigCompEdu Framework, while Section C consisted of 10 items that explored teachers' private use of digital technology and their digital environment. Each of the 22 items in Section B consisted of a statement describing the core of the competence in concrete, practical terms, as well as five possible answers with points/scores ranging from 0 to 4, and the total score for the feedback report (ranging from 0 to 88 points) was cumulatively structured and mapped onto the six proficiency levels of the framework. Questions (items) one to four focused on the professional engagement dimension of the science teachers. Questions five to seven focused on the digital resources dimension. Questions eight to eleven focused on the teaching and learning dimension, and questions 12 to 14 focused on the assessment dimension. Questions 15 to 17 focused on empowering learners, and lastly, questions 18 to 22 focused on facilitating learners' digital competence dimension. Figure 1 above illustrates how the 22 items of the questionnaire were clustered according to the six different knowledge domains of DigCompEdu. The teachers were asked to select the answer that best reflected their practice. The survey questions were re-examined for face and content validity by a panel of subject matter experts composed of 8 professionals: secondary school science teachers, district curriculum coordinator, and University educators with science education backgrounds. A measure of internal consistency of the items was assessed using Cronbach's alpha.

Data collection and Ethics

The data collection for this study took place between July and August 2022, during a marking coordination program for science teachers registered as examiners at one of the marking centres within the education district. Participants were required to read the information about the research objectives in the introductory section before filling out the questionnaire. Since the study emphasized the importance of voluntary participation and assurance of complete anonymity, participants were required to give their consent for willing participation by ticking a box. As a result, the information gathered through questionnaires was kept private and anonymous. Furthermore, approval to carry out the study was obtained from the Centre Coordinator. The data collected were analysed using frequency counts, percentages, means and standard deviation. The analysis was conducted using the SPSS Software.

Participant characteristics

In determining the sample for the study, random sampling was used and a total of one hundred and two (102) respondents comprising 56 (54.9%) females and 46 (45.1%) males took part in the survey. Analysis of participants' responses shows that 23.5% of the teachers were under 25 years, as well as between 25 and 29 years respectively, while 19.6% were between 30 to 39 years, and 33.3% were above the age of 40 years. According to their teaching experience, 36.3% of the teachers have been teaching for less than five years, 22.5% have been teaching between 6 to 10 years, 33.3% have been teaching between 11 to 15 years, whereas 7.9% have been teaching science or mathematics for more than 15 years. The division of participants into subject taught show that 18 (17.6 %) of the participants teach Physics, 35 (34.3%) teach Chemistry, 39 (38.2%) teach Biology, and 10 (9.8%) teach Integrated Science.

RESULTS

After examining the properties of the items, various analyses were performed to test the internal consistency of the instrument and to determine how closely related a set of items are as a group. The data analysis revealed that the adapted questionnaire had an excellent internal consistency and reliability, with an overall Cronbach alpha of .872 for all 22 items. As a robustness check, the corrected item-total correlation and squared multiple correlation tests revealed that the instrument has the required internal consistency, despite some weaker values indicating that some of the instrument's items could be refined. The levels of item-total correlation reliability for each item were higher than 0.30, indicating an acceptable level of internal reliability (Cristobal et al., 2007).

Proficiency level of Teachers' digital competences

The proficiency level in digital competencies is scaled by points, which vary according to the area/domain by the number of competencies. The overall results show an average mean of 47.72 points, with a standard deviation of 13.021 and a variance of 169.552. Thus allowing the researcher to consider teachers' proficiency level as Integrator – B1, as shown in Table 1. When analyzed in a stratified manner, findings reveal that most of the respondents (64.8%) were located at the proficiency level B1–Integrator, 13.7% have a proficiency level B2–Expert, and 18.50%

demonstrated a proficiency level C1–Leader as shown in Figure 2. However, about 3.0% of the respondents are still at proficiency level A2 –Explorer.

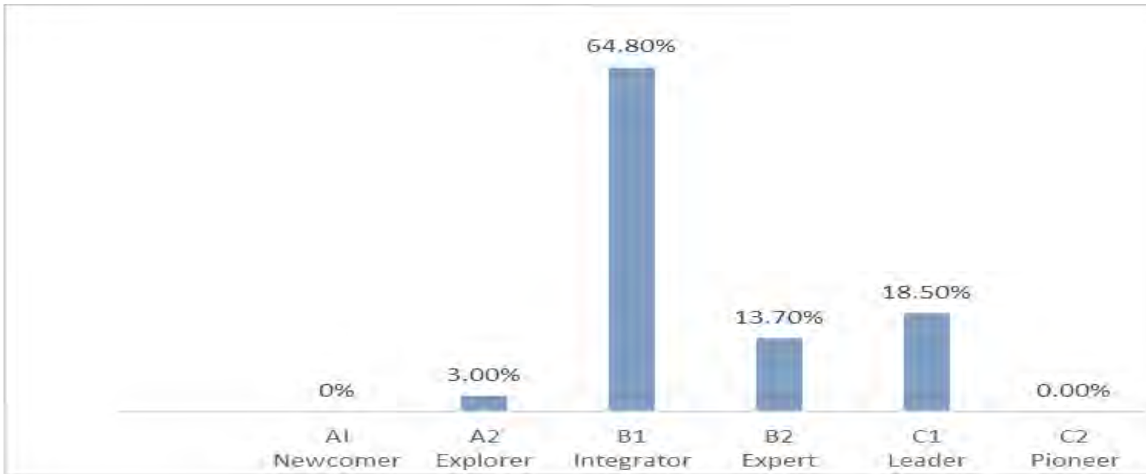

Figure 2: Overall proficiency levels

Analysis by area/domain showed that sampled science teachers are classified as integrators (B1) in the area of digital resources, teaching and learning based empowering learners and facilitating learners' digital competence. This implies that most of these teachers can creatively use digital technologies to enhance diverse aspects of their professional engagement and are eager to expand their repertoire of practices. However, teachers were rated as explorers (A2) in the area of professional engagement and assessment on their points, which falls within the range of scores from 20% to 33%, implying that they have started using digital technologies in some areas and will benefit from more consistent practice, as can be seen in Table 2.

Table 2: *Area/Domain based proficiency levels*

Areas/Domain	**Cronbach alpha**	**Number of items**	**Mean**	**SD**	**Proficiency level**
1. Professional Engagement	.836	4	7.83	2.743	Explorer (A2)
2. Digital Resources	.830	3	7.54	2.578	Integrator (B1)
3. Teaching and Learning	.392	4	10.64	2.259	Integrator (B1)
4. Assessment	.705	3	5.70	3.008	Explorer (A2)
5. Empowering Learners	.777	3	6.48	2.910	Integrator (B1)
6. Facilitating learners' digital competence	.640	5	10.62	4.076	Integrator (B1)

In order to have a better understanding of the level of digital competencies of science teachers in Nigeria, participants' responses to each question listed under the six main digital competencies were analysed. The results shown in Figure 3 below are interesting as they concern participants' competence levels and allow us to get a first idea of which of the 22 DigCompEdu competencies are more difficult, and which are easier to obtain. Since each item allows for five different scores, ranging from 0 to 4, the natural average, if all answer options were equally likely, would be the value 2. When the average scores of the various items were compared, it was discovered that the overall average value across all 22 competencies was 2.37, with average values ranging from 1.38 to 3.09.

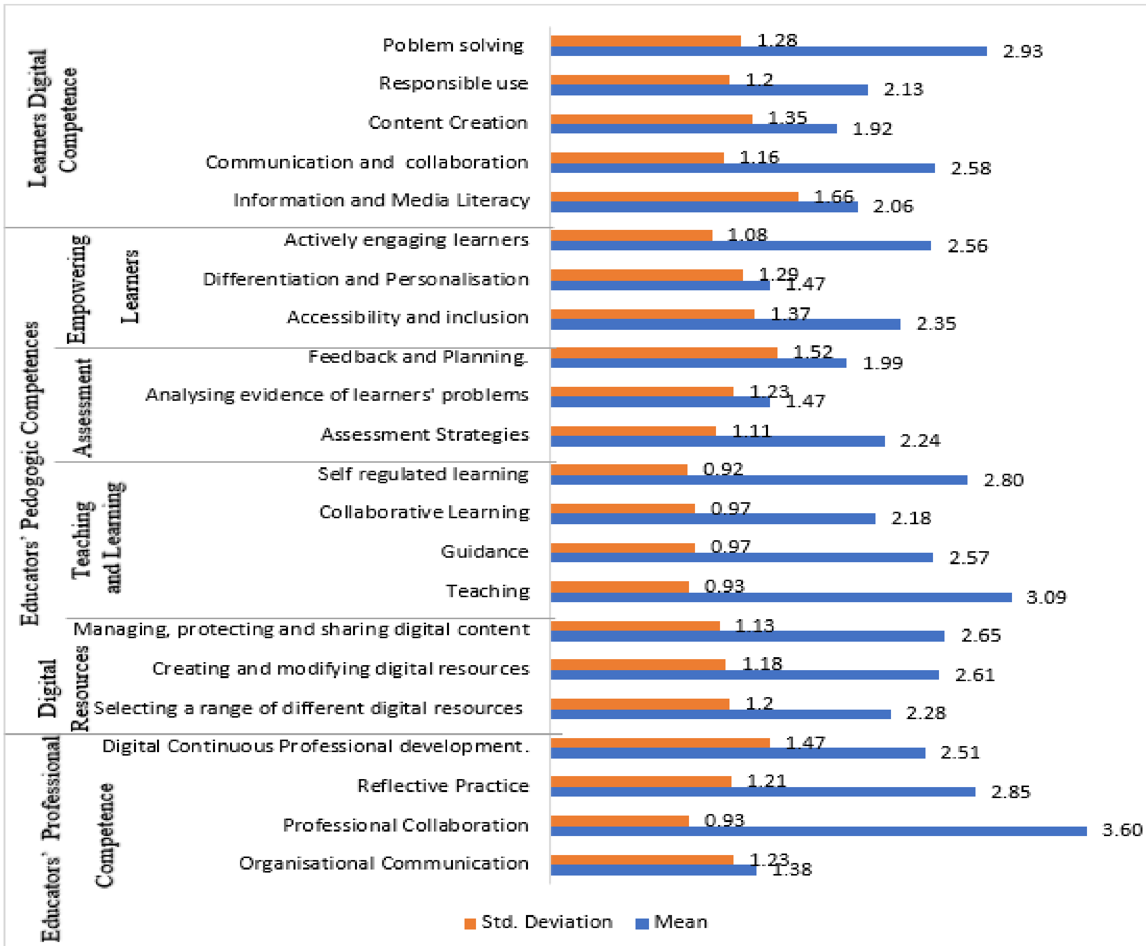

Figure 3: Average scores of participants' digital competence

Educators' professional competence

The answer options in the four questions representing professional engagement were ordered in increasing degrees of engagement with digital technologies. The data in Figure 3 shows that teachers have a high level of knowledge in using digital technologies to collaborate with colleagues inside and outside their educational organization (item 2, M = 3.60), with 52.90% indicating that they jointly create materials with other teachers in an online network. Teachers also demonstrated an intermediate level of knowledge on how to actively develop their digital teaching skills (item 3, M=2.85), with 40.20% indicating that they discuss and participate in discussions with peers about how to use digital technologies to innovate and improve educational practices. Furthermore, results show that teachers have a moderately high level of proficiency in their ability to use technology in online training opportunities such as online courses, MOOCs, and webinars (item 4, M = 2.51), with 41.20% indicating that they regularly participate in all types of online training. However, in terms of organizational communication, participants' response to item 1 "I systematically use different digital channels to enhance communication with students, parents, and colleagues, e.g. emails, blogs, the school's website, Apps" yielded a mean value of 1.38, with 40.20% indicating that they rarely use digital communication channels. 33.0% of the participants indicated that they combine different communication channels, e.g. email and class blog or school website; 22.50% systematically select, adjust, and combine different digital solutions to communicate effectively, and 4.30% use basic digital communication channels like mail.

Digital Resources

Based on the data in Table 2, the average score for teachers' ability to identify good educational resources and to modify, create and share digital resources that fit their learning objectives, student group and teaching style (digital resources) is 7.54. Based on the DigCompEdu checklist, this domain contains three questions (items). Responses from participants are depicted in Figure 3 for the following statements: "I use various internet sites and search strategies to find and select a variety of different digital resources" (Item 5, M = 2.28), "I create my own digital resources and modify existing ones to adapt them to my needs" (Item 6, M = 2.61), and "I effectively protect sensitive content, e.g. exams, students' grades, and personal data" (Item 7, M = 2.65). In terms of item 5 (selecting a range of different digital resources), findings show that 13.70% of respondents strategically select among the many different repositories they know, 38.20% frequently use different repositories with educational resources, and 20.60% know different websites with educational resources and use them occasionally. When asked about their ability to create and modify digital resources (item 6), 34.30% of respondents said they somewhat create worksheets and digital presentations but not much more, 28.40% create and modify different types of resources, and 26.50% indicated it as part of their daily practice to create and modify different types of digital resources.

Teaching and Learning

The teaching and learning domain is made up of four questions (items) that examine teachers' ability to design, plan and implement the use of digital technologies at various stages of the teaching and learning process, with the goal of shifting the emphasis of the lesson from teacher-led to student-centred processes. The data in Figure 3 reveal that teachers have a high level of knowledge on how to use technology for teaching (item 8, M = 3.09), with 41.20% indicating that they carefully consider how, when, and why to use digital technologies in planning fun activity for each phase of the lesson, ensuring that they are used with added value. Teachers also have a fairly high level of knowledge on how to use technology for monitoring interaction (item 9, M = 2.57), with 42.20% indicating that they occasionally monitor learners' behaviour and engagement in their collaborative digital environments. The use of technology for documentation and planning (self-regulated learning) was also fairly acknowledged by participants (item 11, M = 2.80), with 34.30% indicating that they use various digital tools to allow students to plan, document, or monitor their learning. However, their proficiency in the use of digital technologies for collaborative learning was low on average (item 10, M = 2.18), with 36.30% requiring students working in groups or teams to frequently use digital technologies (Internet) to find information and present their results in digital format.

Assessment

As shown in Figure 3, the assessment domain of teachers' digital competence contains three indicators, with the highest mean obtained by item 12 "I use digital assessment formats to monitor student progress", at the mean value of 2.24 and the lowest mean is reached by item 13 "I analyze all data available to me to timely identify students who need additional support" at the mean value of 1.47. However, the results of teachers' competence in using digital technologies for assessment strategies show that 31.40% claim to use various digital tools to monitor student progress regularly. Regarding using technology to analyze available data to identify students who require additional support in a timely manner, the same percentage of respondents say the data are either unavailable to them or it is not their responsibility to analyze the data. Similarly, 31.40% claim to regularly screen all available evidence to identify students who require additional assistance, and 24.50% use a variety of digital approaches to provide feedback.

Empowering Learners

The DigCompEdu Framework domain of empowering learners focuses on understanding how teachers use technology to promote student autonomy and active participation in class, based on three questions (items), as shown in Figure 3. For items in this domain, the highest mean is presented by teachers' use of digital technologies for students to actively participate in class (item 17, M=2.56) and the lowest mean is obtained by teachers' ability to use digital technologies to offer students personalized learning opportunities (item 16, M=1.47). Findings further reveal that 10.80% of the respondents use digital technologies to systematically adapt their teaching to meet each student's unique learning needs, preferences, and interests. When designing digital assignments for students, 29.40% of the respondents claim they adapt the assignments, discuss the solutions, and provide alternative ways to complete the assignment. In contrast, 36.30% of the respondents use digital technologies (e.g. videos, animations, and cartoons) to motivate students to actively participate in class during instruction.

Facilitating Learners' Digital Competence

An integral part of teachers' digital competence is their ability to facilitate learners' digital competence, which is examined through five questions (items). The data in Figure 3 shows that the average score for item 18 was 2.06, with 51.0% of respondents indicating that they teach students how to assess the reliability of information and identify misinformation and bias. The mean score for teachers setting up assignments which require students to use digital means to communicate and collaborate within and outside the class (item 19) was 2.58. 25.50% occasionally require their students to communicate or collaborate online, while 36.30% allow their students to use digital ways to communicate and collaborate internally and externally. In addition, 22.50% set up assignments in a structured way that allows students to slowly expand their skills. With a mean score of 1.92 for teachers' responses to item 20, "I set up assignments that require learners to create digital content (e.g., videos, audios, photos, digital presentations, blogs, wikis)," 46.1% allow their students to create digital content as an important component of their studies and purposefully increase the level of difficulty to help students advance their skills. The statement on item 21 "I teach students how to behave safely and responsibly online", received a mean score of 2.13, with 11.80% indicating that it is not their responsibility to teach this, 18.60% stated that if at all, students only use safe environments, 26.50% explain the basic rules for safely and responsibly acting in an online environment, 31.40% discuss and agree on rules of conduct, and 11.70% allow their students to practically apply existing rules in the different digital environments they use. Furthermore, the survey results show that teachers' responses to the statement "I encourage students to use digital technologies creatively to solve concrete problems such as overcoming obstacles or challenges that arise during the learning process" had the highest average scores in this domain (Item 22, M= 2.93). While 15.70% rarely have the opportunity to foster students' digital problem-solving, 33.30% occasionally encourage students to use digital technologies for problem-solving when the opportunity arises. However, 32.40% stated that they frequently experiment with technological solutions to problems and intentionally incorporate opportunities for creatively using digital technologies to solve problems in the subject they teach.

DISCUSSION AND CONCLUSION

The DigCompEdu CheckIn, a European framework that describes competencies centred on supporting and encouraging the use of digital tools to improve and innovate education, considers all educators from preschool to higher education (Santos et al., 2021). With the widespread implementation of technology-supported initiatives and professional development training in Nigerian schools, understanding the level of digital proficiency attained by in-service teachers becomes critical. This will help identify areas where teachers are vulnerable and provide them with the training they need to progress toward digital fluency. Results indicate that 18.50% of the sampled science teachers demonstrated their proficiency levels as a leader – C1, while 13.70% demonstrated a proficiency level B2 – Experts. However, a higher percentage of the sampled teachers (64.80%) scored between 34 and 49 points on the assessment of their overall digital competence level, indicating an integrator– B1 level of proficiency. This implies that many of these teachers are still developing their skills in the types of pedagogies that make the most of technology. Given that this score includes teachers who use digital technologies on a semi-regular basis, it falls within the expected levels, suggesting that more research is needed to determine which tools are most effective in various contexts and how teachers can adapt them to suit pedagogical methods and strategies. Though teachers report opportunities for using digital technologies, many of them seem to struggle because they do not have time to become sufficiently familiar with technologies (Benali et al., 2018).

Analyzing participants' responses based on the six areas of the framework made it possible to identify the domains of science teachers' ability to use digital technologies with the lowest value. According to the findings, the domains with the lowest score are in the areas of educators' professional competence (7.83 with a threshold of 7) and assessment (5.70 with a threshold of 5) at a competence level close to A2 – Explorer, while the digital competence level of B1 - Integrator was identified in the other areas. According to what has been defined for these levels, teachers at the explorer level "need encouragement, insight and inspiration through the example and guidance of colleagues, embedded in a collaborative exchange of practices." In contrast, teachers at the integrator level need "a little more time for experimentation and reflection, complemented by collaborative support and knowledge sharing, to become Expert". The assessment domain includes teachers' ability to use technology to support assessment strategy competencies, evidence analysis of student problems, feedback, and planning. Other evidence along these lines has already been identified in studies of teachers' digital competence using the TPACK-P model in the Taiwan context, which found that 45% of science teachers were considered to be at the infusive application level of using technology for assessment, planning and designing, and practical teaching because they tended to think about teaching practice with technologies with greater consideration of students' needs and clearly defined the manner to manage interactions with students (Hsu et al., 2015). Santos et al., (2021) argued that assessment can be both a facilitator and a hindrance to educational innovation because it necessitates a wide range of available data about each learner's learning behaviour and can help to directly monitor their progress, facilitate feedback, and allow educators to evaluate and adapt their teaching strategies.

A detailed analysis of the twenty-two competencies on the instrument reveals that competencies related to the use of technology for professional collaboration, reflective practice, teaching, self-regulated learning, and students' problem-solving have higher average scores, implying that the sampled teachers have a relatively high level of digital proficiency in these competencies. However, competencies related to using technology to assist learners in creating digital content, providing feedback and planning, analyzing evidence of students' problems, and organizational communication had lower average scores, indicating greater difficulty to achieve. These are critical competencies that teachers do not take seriously or consider when they first begin to explore digital teaching independently (Benali et al., 2018).

The results of this study show that sampled teachers still have a long way to go before they achieve the desired digital fluency, level C2 — Pioneer, defined as the maximum level by the instrument used. The findings of this study confirm the need to train and re-train teachers on the practical use of technology to improve the teaching and learning process, as well as professional interactions within and outside the classroom. However, the training of teachers should focus more on practical situations of how they can use technology to adapt to the various needs of learners. More so, teacher education programs in the country must provide appropriate experiences for pre-service teachers to improve their digital competencies for planning and designing instruction, assessment, teaching, and learning in science. This will assist them in developing the necessary skills and application practices for technology integration in a real-world classroom setting. The appropriateness of pedagogical representation selections and planned learning activity designs involving digital technologies are determined by teachers' technological pedagogical content knowledge. Only when teachers gain and learn from the practical usage of technology to support science education can their digital competence be further developed and strengthened. It is, therefore, necessary to initiate educational processes aimed at improving and developing the professional quality of Nigerian science teachers, using training models consistent with the pedagogical dynamics of the social web, such as the TPACK model (Koehler & Mishra, 2008) and TPACK-P model (Yhe et al., 2014). This model is not only a frame of reference for the knowledge teachers are required to have when teaching using technology, but also a training model that could benefit the definition of a 'new' didactics for digital teaching in Nigeria based on the scientific and pedagogical knowledge of technology. By identifying the type of knowledge needed to integrate technology in teaching, this model can be quite an effective response to address the digital competence shortcomings identified in this research.

A limitation of this study is that data collected in the questionnaire reflect respondents' self-report, so their perceived level of digital competence may not correspond to their actual level. Though the use of self-report measures is often prone to social desirability bias, as well as respondents' subjectivity regarding their knowledge and level of proficiency (Ramnarain et al., 2021), self-reports remain a useful and indispensable assessment tool for measuring how teachers perceive their competence levels and for identifying their strengths and weaknesses (Pekruna, 2020). Therefore, future research should also include lesson observations to determine how science teachers actually implement the DigCompEdu CheckIn indicators in their classroom practices. The current study was also limited to selected teachers within an education district in Lagos, Nigeria. Therefore, a larger-scale study involving other science and possibly non-science teachers across various education districts and states in Nigeria should be planned. In this way, the status of teachers' digital competence in the country can be more broadly established. Further to this, research could be planned to compare the proficiency level of teachers' digital competence based on years of experience, gender, age, and academic qualification. A study conducted in Morocco using the same 22-item questionnaire found that the competence levels of male and female participants have the same range. Furthermore, the authors found that the digital competence levels of teachers increase with teaching experience (Benali et al., 2018). It would be interesting to establish whether similar results would be found for Nigeria.

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Data Availability

The datasets generated during this study are available from the author on reasonable request.

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