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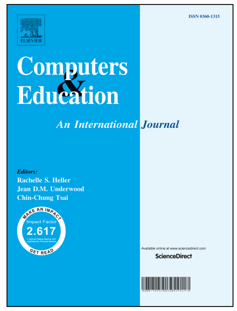

Factors affecting Nigerian teacher educators' technology integration: Considering characteristics, knowledge constructs, ICT practices and beliefs

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Declaration of Interest and Funding

The authors have no conflict of interest to declare. The research incorporated ethical principles involving informed consent and guidelines according to the Finnish National Board on Research Integrity (TENK). This included informing participants on the research purpose, voluntary involvement and no identifiers are used in the data analysis.

Abstract

To provide a diverse comprehension of teachers' *TPACK* (Technological, Pedagogical, and Content Knowledge) and how TPACK is reflected in practice, this study examined teacher educators' (TEs') conceptions of technology integration. Specifically, the main objective of the study was to investigate the factors influencing Nigerian teacher educators' technology integration using a self-completion survey administered to Nigerian teacher educators from three schools in the southern region of Nigeria. We utilized the partial least squares structural equation modeling (PLS-SEM) approach for the data analysis. Two frameworks—TPACK and Second Information Technology in Education Study (*SITES*)—guided the scale development. The results indicated that three constructs (perceived technological knowledge, teachers' knowledge [excluding technology] and perceived knowledge for integrating technology) directly influenced the TEs' technology integration, while two others (information and communication technology [ICT] pedagogical practices and perceived effect on students) did not. Among the teachers' characteristics, teaching experience, and class size were found statistically associated with their technology integration. The results of this study are beneficial for developing professional training to help teachers integrate technology specifically by developing their ICT pedagogical practices. Through such training, teachers could be enlightened on how to align their perceived effect of teaching with technology.

Keywords: ICT in education; technology integration; teacher educators; partial least square – sequential equation modelling (PLS-SEM)

Factors affecting Nigerian teacher educators' technology integration: Considering characteristics, knowledge constructs, ICT practices, and beliefs

Introduction

Both educators and policymakers have high expectations that ICT will support educational reforms and better teaching and learning practices (Elstad, 2016). In addition, ICT literacy and twenty-first century skills have been recognized as essential for productivity in an information society (Groff, 2013). Accordingly, what happens inside the classroom is crucial (OECD, 2016) and questions concerning how teacher trainees learn to integrate technology into their teaching practices should be considered. Nevertheless, it behooves TEs to help teacher trainees to become digitally literate individuals who can teach the necessary skills to their future students (Binkley et al., 2012; Howells, 2018); hence, TEs are recognized as “gatekeepers” (Tondeur et al., 2019), because of the role they play in the preparation of the future generation of teachers.

Research over decades has shown that technology integration in the classroom depends on several connected factors relating to teachers' characteristics, schools, and educational systems (Bingimlas, 2009; Buabeng-Andoh, 2012a; Inan & Lowther, 2010; Joo, Lim, & Kim, 2016; Petko, Prasse, & Cantieni, 2018; Plomp, Pelgrum, & Carstens, 2009; Tay, Lim, & Lim, 2013; Taimalu & Luik, 2019). A recent systematic review of the literature by Lai and Bower (2019) examined the intricacy of this technology integration process, and discussions on educational technology integration have continued with regard to the different factors influencing the integration process (Howard, Chan, Mozejko, & Caputi, 2015). Bower (2019), for instance, argued that it is crucial to understand the ways in which beliefs, knowledge, practices, and the environment mutually influence each other in relation to educational technology usage; therefore, in the current study, we developed our scales based on two well-known frameworks—TPACK and SITES—to probe more deeply into the factors influencing teachers’ technology integration.

Koehler and Mishra (2006) proposed the TPACK framework for clarifying the knowledge necessary for the successful integration of ICT into teaching and learning; however, many researchers have argued that the TPACK framework oversimplifies the factors surrounding technology integration by excluding teachers' beliefs and various contextual barriers, such as access to resources, training, and support (Angeli & Valanides, 2009; Brantley-Dias & Ertmer, 2013; Yurdakul et al., 2012). As a result, to provide broad insight into teachers’ technology integration, we adopted constructs from the SITES framework, which was introduced by the International Association for the Evaluation of Educational Achievement (IEA). The IEA has long been interested in the use of ICT in education. In the 1990s, the IEA initiated the SITES. The third module of the SITES project, asserted that system and school factors have a significant effect on teachers' pedagogical use of ICT (Law & Chow, 2008). The SITES 2006 conceptual framework emphasized that school-level and system-level factors, and teachers' characteristics, determine the teachers' pedagogical practices, which in turn influence students' learning outcomes (see Plomp et al., 2009, pp. 12-13). It therefore inferred that the SITES 2006 framework mainly concerns the application of ICT in classroom activities. The phenomena examined in the current study included the teachers' ICT practices that contribute to their technology integration. In particular, we paid attention to understanding the technical competencies and behaviors of TEs as they prepare future generations of teachers. This is particularly important for understanding TEs' influence on future teachers' technology integration.

The main objective of this study was to investigate the factors influencing Nigerian TEs' technology integration. Among the African countries, Nigeria is listed as the highest internet consumer (Edo, Okodua, & Odebiyi, 2019), and the ownership and use of information technologies, such as mobile phones, laptops, tablets, and personal computers, have become popular among Nigerian students, teachers, and schools (Ifinedo, Saarela, & Hämäläinen, 2019; Ifinedo, Kankaanranta, Neittaanmäki, & Hämäläinen, 2017; Oluwafeyikemi, Ajayi, & Gata, 2018; Utulu & Alonge, 2012). Despite these developments, the Nigerian education system is threatened by problems such as the large number of out-of-school children, high dropout rates, and low literacy rates (Ifinedo & Kankaanranta, 2018). Technology integration may be one solution for addressing these educational challenges; therefore, the Federal Ministry of Education (2014) has emphasized ICT's integration in the delivery of education in Nigeria. Onyia and Onyia (2011) indicated that many Nigerian faculties fail to integrate technology into classrooms, and Ameen, Adeniji, and Abdullahi (2019) observed this low level of ICT integration among Nigerian teachers and students. Olokooba, Okunloye, Abdulsalam, and Balogun (2018), in turn, identified challenges such as the unavailability of computers, the lack of instructional software, the inadequacy of teachers' technical knowledge, the irregular power supply, and the deficient maintenance of computer systems as the main barriers to the use of ICT in Nigerian schools. Findings from a literature review relating to ICT integration in education revealed that TEs in Nigerian colleges of education and other institutions did not use digital technology in their pedagogical practices (Garba, Singh, Yusuf, & Ziden, 2013); hence, our study specifically focused on Nigerian TEs' perceived technological knowledge, perceived knowledge for integrating technology, ICT pedagogical practices, the perceived effect of teaching with technology on students, teaching knowledge that excludes technology, and technology integration. The research questions were as follows:

- **Research question 1:** What characteristics influence TEs' technological knowledge and their teaching knowledge (excluding technology)?

- **Research question 2:** What relationships exist among TEs' teaching knowledge (excluding technology), perceived technological knowledge, perceived knowledge for integrating technology, ICT pedagogical practices and perceived effect on students?

Theoretical Foundations

Researchers have been trying to explain the foundations of successful educational technology integration for over 30 years (Petko, Prasse, & Cantieni, 2018). These studies have had a common interest in recognizing the interrelationship of factors arising from the technology and the users within the school context and beyond (e.g., Ertmer, 1999; Drent & Meelissen, 2008; Tay, Lim, & Lim, 2013). To deal with a world consisting of both social and technical factors, teachers should be equipped with the relevant competencies to enable them to recognize and perform tasks with the appropriate technological tools in the classroom (Meyers, Erickson, & Small, 2013); for example, the teachers' characteristics that are associated with ICT use in the classroom include the teacher's age, years of teaching experience, the subject taught, and the class size (Gil-Flores, Rodríguez-Santero, & Torres-Gordillo, 2017; Law & Chow, 2009). A teacher's teaching knowledge, perceptions, access, and characteristics, as well as the subject culture, all have an appreciable effect on the teacher's decisions regarding technology integration (Burke, Schuck, Aubusson, Kearney, & Frischknecht, 2018; Ertmer & Ottenbreit-Leftwich, 2010). Prestridge's (2012) study showed an existing association between teachers' ICT skills, confidence, and practice; thus, in this study, we aimed to understand how these factors (i.e., teachers' characteristics, perceived technological knowledge, teaching knowledge, belief and ICT pedagogical practices) together affect technology integration among Nigerian TEs.

In this study, we adopted the knowledge constructs of the TPACK framework. Previous research suggested that technologically and pedagogically competent teachers are more willing to use ICT in the classroom (Chai, Koh, Tsai, & Tan, 2011; Darling-Aduana &

Heinrich, 2018; Maican, Cazan, Lixandroiu, & Dovleac, 2019; Sang, Valcke, van Braak, & Tondeur, 2010; Suárez-Rodríguez, Almerich, Orellana, & Díaz-García, 2018; Vongskulluksn, Xie, & Bowman, 2018); hence, a teacher should be a specialist in both the subject and pedagogy, as well as a competent user of technology (Adams & Ivanov, 2015; Groff, 2013; Luik, Taimalu, & Suviste, 2018). The core of effective teaching with technology consists of three components—content, pedagogy, and technology—and their interconnection (Koehler & Mishra, 2009). This framework, known as TPACK, was based on pedagogical content knowledge (PCK) constructs modeled by Shulman (1986). Koehler and Mishra (2006) modified the PCK framework by adding knowledge of technology integration (i.e., understanding how technology is applied in the teaching of a particular subject). As a result, the TPACK framework includes seven types of knowledge: technological knowledge (TK), pedagogical knowledge (PK), content knowledge (CK), pedagogical content knowledge (PCK), technological pedagogical knowledge (TPK), technological content knowledge (TCK), and technological pedagogical content knowledge (TPACK).

In addition, we utilized the SITES 2006 framework, which views ICT-using pedagogical practices as part of the overall pedagogical practices of the teacher, so that the reasons why and how teachers use ICT in the classroom are underpinned by their overall pedagogical vision and competence (see Carstens & Pelgrum, 2009, pp.13). The SITES 2006 framework also emphasizes that pedagogical practices are not determined solely by the characteristics of the teachers, but also by school- and system-level factors; thus, SITES 2006 recognized that teacher-, school-, and system-level factors often have to change to accommodate the expected or actual impact of pedagogical practices on students (Plomp et al., 2009). SITES 2006 included a teacher survey to assess the perceived impact of pedagogical ICT use on teachers and their students. Indicators derived from the questions relating to personal and contextual factors provided explanatory indicators for the SITES study (Law & Chow, 2009). Personal factors included: demographic background (e.g., age, gender, and professional experience), technical competence, competence in using ICT for pedagogical purposes, pedagogical beliefs, and the rationale for using ICT. Contextual factors included: teacher's participation in ICT-related professional development activities, their perceptions of obstacles, and the presence of a community of practice in their schools. The teacher questionnaire also included questions concerning the target class (e.g., the number of students in the class and the gender mix). In particular, this study adopted constructs such as teachers' demographics, ICT pedagogical practices, and the perceived impact of these practices on students from the SITES framework.

Material and Methods

Research Purpose, Model, and Hypotheses

A previous study focused on Nigerian teachers' preparedness to integrate technology and investigated their seven knowledge constructs according to the TPACK framework (see Ifinedo, Saarela, & Hämäläinen, 2019). Unlike that study, the main objective of this study was to investigate the factors influencing Nigerian TEs' technology integration. Specifically, the study examined their characteristics, perceived knowledge of technology, perceived knowledge for integrating technology, ICT pedagogical practices, and their perceived impact on the students, teaching knowledge (excluding technology), and technology integration.

This study applied a PLS-SEM technique to develop a model representing the relationships between the factors underpinning teacher educators' technology integration. We considered the fact that schools and school districts are complex, but dynamic, systems affected by numerous factors (Mital, Moore, & Llewellyn, 2014) and that, consequently, several attributes affect technology integration success. Based on the complex interrelationships of factors that support technology integration, in this study we opted for a complex yet realistic model (Hirsch, Michaels, & Friedman, 1987). According to our hypothesized model, presented in Figure 1, two research questions and eighteen hypotheses were formed.

The first research question aimed to understand "*what characteristics influence TEs' technological knowledge and their knowledge that does not involve teaching with technology?*"

Age is a potential source of variation in ICT integration (Siddiq, Scherer, Tondeur, 2016); for example, previous research suggested that older teachers' low computer skills and self-confidence influenced their tendency and ability to use and integrate technology (Buabeng-Andoh, 2012b; Fraillon, Ainley, Schulz, Friedman, & Gebhardt, 2014; Inan & Lowther, 2010; Peeraer & van Petegem, 2011). Some weak relationships between technological, pedagogical, and content knowledge perceptions and age have also been found in other studies (e.g., Lee & Tsai, 2010; Koh, Chai, & Tsai, 2010). In addition, Luik et al. (2018) found that the connection between the age of teachers and their primary knowledge constructs (TK, PK, and CK) varied. It correlated negatively with TK, but positively with CK; however, there was no significant association between age and PK. In a study by Liu, Zhang, and Wang (2015), younger teachers had higher perceptions of their TK, but lower perceptions of their PK and PCK, while older teachers had lower perceptions of their TK, but higher perceptions of their PK and PCK. Younger teachers tend to be more open to the use of ICT in education (Inan & Lowther, 2010; Yilmaz & Bayraktar, 2014); accordingly, we postulated the following hypotheses:

- H1: Teacher educators' ages negatively influence their perceived knowledge of technology (PerTechK)
- H2: Teacher educators' ages positively influence their perceived teaching knowledge (excluding technology) (TeKnXict)

The subject taught also influences the use of ICT in the classroom (Howard et al., 2015). Siddiq et al. (2016), for instance, argued that teachers of humanities, languages, and arts tend to place greater emphasis on students' digital and ICT skills than do teachers of mathematics, science, or other subjects. Many mathematics teachers are under pressure to use ICT, but find it difficult to see how ICT can support learning without being restrictive (Tay, Lim, & Lim, 2015; Wikan & Molster, 2011; Xie, Kim, Cheng & Luthy, 2017). Subject practices and cultures may be barriers that hinder the use of technology in the classroom and may also have different effects on usage patterns (Hennessy, Ruthven, & Brindley, 2005; Hew & Brush, 2007; Nelson et al., 2019; Padmavathi, 2013). To this end, we postulated the following hypotheses:

- H3: The subject taught influences the teacher educators' perceived knowledge of technology (PerTechK)
- H4: The subject taught influences the teacher educators' perceived teaching knowledge (excluding technology) (TeKnXict)

Years of teaching experience has an influence on the teachers' knowledge and skill. Jang and Tsai (2012) stated that TPACK is influenced by the years of teaching experience; while experienced teachers may not be as technology-minded as their less-experienced younger peers, they feel more comfortable with their teaching responsibilities and know where to find support (Nelson, Voithofer, & Cheng, 2019). Experienced teachers, therefore, demonstrate higher CK and PK (Jang & Chang, 2016). Qualified teachers use teaching methods and strategies more effectively, because of their extensive knowledge of different content and teaching strategies (Jang & Tsai, 2012; Meskill, Mossop, DiAngelo, & Pasquale, 2002; Saltan & Arslan, 2017), and they are more adept at using new tools to help facilitate teaching and learning (Smarkola, 2007). However, Saltan and Arslan (2017) pointed out that teachers with more than 20 years of experience may not have the proper training to use modern technology or pedagogical approaches, so experience has an indirect influence through knowledge and skill (Farjon, Smiths, & Voogth, 2019). To this end, we postulated the following hypotheses:

- H5: Years of teaching experience (TeachExp) positively influences the teacher educators' perceived knowledge of technology (PerTechK)
- H6: Years of teaching experience (TeachExp) positively influences the teacher educators' perceived teaching knowledge (excluding technology) (TeKnXict)

Class size has an influence on classroom practices. Teachers' experiences of class size are connected to their emotional involvement in teaching (Blatchford, Moriarty, Edmonds, & Martin, 2002), and teachers' decisions regarding ICT integration depend, not only on the subject taught, but also on students' characteristics, such as the number of students in the class, the gender mix, and students' languages (Law, 2009). Although Gibbone, Rukavina, and Silverman (2010) emphasized that class size is not a limiting factor for technology use, class size may be a barrier to using technology, since teachers may be concerned about the amount of technical equipment needed in the classroom (McCulloch et al., 2018). Leendertz, Blignaut, Nieuwoudt, Els, and Ellis (2013) asserted that overpopulated classrooms lead to an increase in work pressure for teachers, which in turn results in less likelihood of integrating technology. Similarly, Hennessy, Harrison, and Wamakote (2010) listed large class size as a critical factor underpinning the lack of ICT competence among teachers within an African education context. Overall, classroom quality is associated with small class size (Marti, Melvin, Noble, & Duch, 2018). Small classes are better environments for learner-centered activities (Wright, Bergom, & Bartholomew, 2019), because students are more engaged and can interact with each other and their teachers in positive and enriching ways (Deutsch, 2003). Consequently, this research proposed the following hypotheses:

- H7: Class size (ClasSize) influences the teacher educators' perceived knowledge of technology (PerTechK)
- H8: Class size influences the teacher educator's perceived teaching knowledge (excluding technology) (TeKnXict)

Technological device ownership is linked to computer experience. Owning ICT is just as important as a person's confidence in using technology and the degree to which technology is utilized pedagogically (Yerdelen-Damar, Boz, & Aydın-Günbatar, 2017). Yurdakul (2017) emphasized that digital nativity is a significant predictor of TPACK competence, since teachers' daily ICT use is also reflected in their professional lives. The availability of technology at home, for instance, affects attitudes towards, and perceptions of, ICT use in the classroom (Islahi & Nasrin, 2019; Padmavathi, 2013). Kahveci, Şahin, and Genç (2011) asserted that ownership of personal computers is a significant predictor of teachers' high-level computer experience and, consequently, more positive attitudes and greater confidence and comfort. Kearney, Burden, and Rai (2015), in turn, noted that students' ownership of mobile devices positively influenced teachers' consideration of practical ways to apply such tools in their subject areas. Building personal ownership, and training teachers to be comfortable and creative users of technology, can help teachers to make innovative transformations in their classrooms (Barak, 2006; Riel, Schwarz, Peterson, & Henricks, 2000); therefore, we hypothesized the following:

- H9: Technological device ownership (TDevOwn) positively influences teacher educators' perceived knowledge of technology (PerTechK)
- H10: Technological device ownership (TDevOwn) positively influences teacher educators' perceived teaching knowledge (excluding technology) (TeKnXict)

The second research question was wider in scope and focused on how TEs' perceived technological knowledge, perceived knowledge for integrating technology, perceived teaching knowledge excluding technology, ICT pedagogical practices, and the perceived effect on students are related to TEs' use of educational technology. The second research question investigated "*what relationships exist among TEs' perceived teaching knowledge, knowledge for technology use, perceptions, and ICT pedagogical practices.*"

Teacher's perceived teaching knowledge influences technology integration, and several researchers have highlighted the relationships between the TPACK constructs. TK, for instance, has been found to have a direct positive influence on teachers' TPACK (Koh, Chai, & Tsai, 2013). Researchers have also found high correlations between PK and PCK, and between TPK and TCK (Çetin & Erdoğan, 2018). CK, in turn, directly and positively influences TCK and PCK (Kiray, Çelik, & Çolakoğlu, 2018). Kiray et al. (2018) further pointed out that PCK critically affects teachers' technology integration, since it has the greatest effect on the teachers' TPACK self-efficacy. Pedagogical competence is as significant as technological competence for successfully integrating technology in teaching (Li, Garza, Keicher, & Popov, 2018). Similarly, ICT integration practices (i.e., the selection of the ICT tools and how often the tools are used) influence teachers' technology integration knowledge (Chuang, Weng, & Huang, 2015), so perceived knowledge can lead to feelings of self-efficacy. Perceived TPACK positively affects teachers' self-efficacy, which means that teachers with TPACK find the technology accessible and useful (Joo, Park, & Lim, 2018). There is a positive relationship between TPACK confidence, TPACK level, and teachers' intention to teach with ICT (Güneş & Bahçivan, 2016; Joo et al., 2016; Joo et al., 2018; Koh & Chai, 2014). Teachers, however, do not usually think of their knowledge as a separate domain (Heitink et al., 2016); for instance, Luik et al. (2018) merged all items relating to technological knowledge (TCK, TPK) into one factor representing technology. Similarly, Boschman, McKenney, and Voogt (2015) highlighted that, in the teachers' narratives, pedagogy was usually addressed in conjunction with other knowledge domains. An interesting observation, however, was that, in general, teachers seemed to be orientated towards PCK, rather than technological knowledge constructs (Tseng, Cheng, & Yeh, 2019; Heitink, Voogt, Verplanken, van Braak, & Fisser, 2016). The current study attempted to investigate the following hypotheses:

- H11: TEs' perceived technological knowledge (PerTechK) positively influences their perceived knowledge for integrating technology (PKn4INgT)
- H12: TEs' perceived technological knowledge (PerTechK) positively influences their technology integration (TechINtn)
- H13: TEs' perceived knowledge for integrating technology (PKn4INgT) positively influences their technology integration (TechINtn)
- H14: TEs' perceived knowledge for integrating technology (PKn4INgT) positively influences their ICT pedagogical practices (ICTPedPr)
- H15: TEs' perceived teaching knowledge, excluding technology (TeKnXict), positively influences their technology integration (TechINtn)

Teachers' ICT pedagogical practices are linked to student outcomes and teachers' knowledge. Teachers' pedagogical practices, such as teaching techniques and strategies, enable learning to take place and provide opportunities for interaction between teachers, learners, and the learning environment (Bottino, 2004). ICT offers several ways to alter and enhance pedagogy and to customize and expand teaching repertoires, strategies, and methods for adapting different learning paths (Bitner & Bitner, 2002; Sutherland et al., 2004). However, the effectiveness of ICT depends on the teachers' actual practices and their ability to integrate ICT into teaching and learning (Comi, Argentin, Gui, Origo, & Pagani, 2017; Drent & Meelissen, 2008). It is therefore vital to consider the whole learning situation; not only the technological tools, but also the teachers who use them, the curriculum objectives, the assessment methods, the social context, and the pedagogical practices (i.e., the ways in which learning is organized and tools are used) (Adams & Ivanov, 2015; Bottino, 2004; Law & Chow, 2008; Okojie, Olinzock, & Okojie-Boulder, 2006). Technology can provide students with deeper understanding of subjects, and learning should, therefore, be the driving factor behind the use of technology in the classroom. Teachers' pedagogical viewpoints extend to what the teachers may consider to be valuable in terms of achieving student outcomes, so knowledge practices may be linked to student outcomes (Hudson, English, Dawes, King, & Baker, 2015). Similarly, teachers' attitudes towards ICT and their motivation for using it in their teaching are influenced by their pedagogies (Cox, 2003). Researchers have highlighted that the use of ICT can transform teachers' knowledge of the subject area, teaching repertoires, and pedagogical skills (Sutherland et al., 2004; Heitink et al., 2016). Hence, we propose the following hypotheses:

- H16: TEs' ICT pedagogical practices (ICTPedPr) positively influence perceived effect of teaching with technology on students (PEffStud)
- H17: TEs' ICT pedagogical practices (ICTPedPr) positively influence their perceived teaching knowledge that excludes technology (TeKnXict)

Teachers' perceptions of technology gains for their students affect classroom practices. Perception is closely related to attitudes, and attitudes, in turn, arise from beliefs and values; therefore, teachers' attitudes and beliefs significantly influence their actions and practices in the classroom (Burke, Schuck, Aubusson, Kearney, & Frischknecht, 2018; Gil-Flores, Rodríguez-Santero, & Torres-Gordillo, 2017; Willis, Lynch, Fradale, & Yeigh, 2019). Previous research has suggested that teachers' negative attitudes and beliefs about technology may prevent them from utilizing technology and, therefore, teachers' positive perceptions (i.e., beliefs and attitudes) are critical for increasing levels of ICT integration (Blackwell, Lauricella, Wartella, Robb, & Schomburg, 2013; Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, & Sendurur, 2012; Hutchison & Reinking, 2011; Islahi & Nasrin, 2019; Joo et al., 2016; Liu, 2011; Miranda & Russell, 2012; Peng & Wong, 2018 Vongkulluksn et al., 2018; Willis et al., 2019). Positive perceptions of ICT also explain high self-efficacy in TPACK and vice versa (Scherer, Tondeur, Siddiq, & Baran, 2018); therefore, a teacher's mindset plays an essential role in the choice of that teacher's teaching approach (Li et al., 2018).

Different factors impact teachers' perceptions, including their prior experience (Khlaif, 2018). When teachers use ICT frequently, they begin to appreciate ICT and understand the benefits and importance of ICT in teaching, eventually guiding their students to use ICT (Chew, Cheng, Kinshuk, & Chen, 2018; Miranda & Russell, 2012). Teachers who have sound experience of technology tend to be more confident users of technology (Miranda & Russel, 2012; Claro et al., 2018). Furthermore, teachers who see ICT as consistent with their educational goals, teaching philosophy, pedagogical beliefs, and practices are more likely to perceive ICT as valuable and adopt ICT (Hamari & Nousiainen, 2015; Las & Chow, 2009; McCulloch, Hollebrands, Lee, Harrison, & Mutlu, 2018; Taimalu & Kuin, 2019). In other words, teachers’ characteristics, such as subject matter and teaching experience, also strongly influence teachers’ perceptions (Jimoyiannis & Komis, 2007). To this end, we postulated the following hypothesis:

- H18: TEs' perceived effect of teaching with technology on students (PEffStud) positively influence their technology integration (TechINtn)

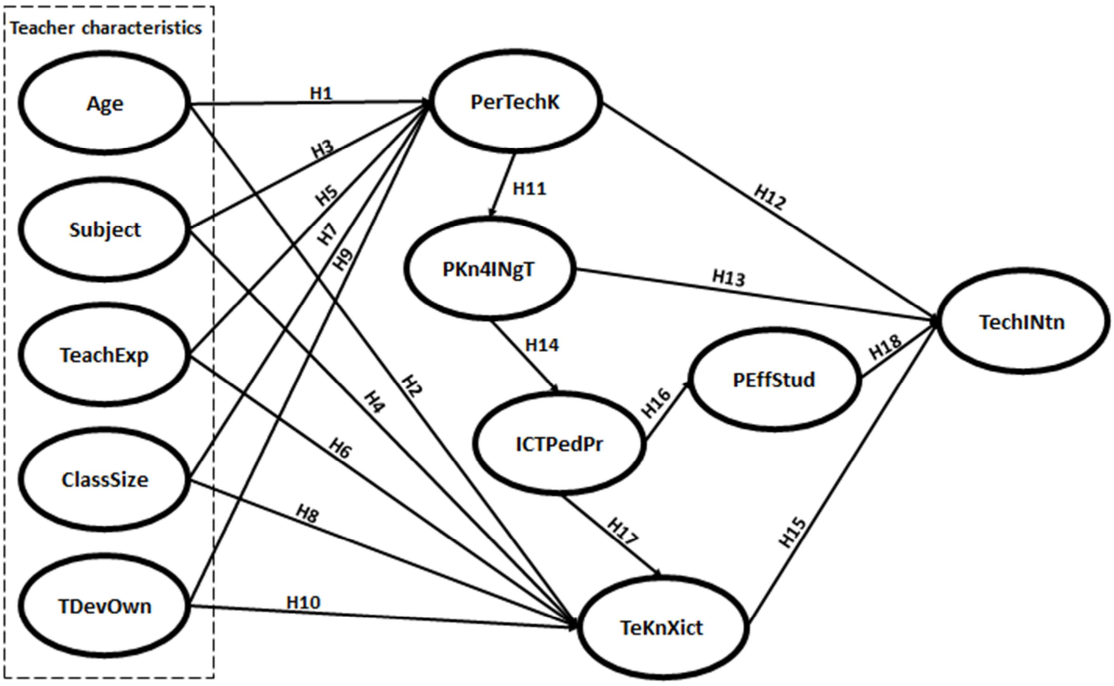

Fig. 1. The hypothesized model

Sample

Data was collected from 148 teacher educators in various departments. Some of the responses were poorly completed; therefore, listwise deletion was applied and, ultimately, 136 responses were found to be useful. Thereafter, the departments were condensed into three categories for ease of analysis—arts, sciences, and social sciences. Departments such as languages or religious studies were assigned to arts (8%), chemistry or database management were assigned to the sciences (35.5%), and geography or agriculture were assigned to the social sciences (50%). Sixty percent of the participants were male and 35% were female. The predominant age group was over 40 years of age (75%). Table 1 shows the remaining demographic information of the respondents.

Table 1: Demographic profile of participants

Variable	Content	Frequency	Percentage
Gender	Male	81	59.6
	Female	48	35.3
	Missing	7	5.1
Age group	25–29	3	2.2
	30–39	25	18.4
	40–49	60	44.1
	50–59	42	30.9
	Over 59	5	3.7
	Missing	1	0.7
Categorized department	Arts	11	8.1
	Sciences	48	35.3
	Social sciences	68	50
	Missing	9	6.6
Teaching experience	Under 2 years	2	1.5
	2–4 years	8	5.9
	5–9 years	36	26.5
	10–19 years	52	38.2
	Over 19 years	38	27.9
Average class size	0–50	60	44.1
	51–100	23	16.9
	101–150	13	9.6
	151–200	1	0.7
	201–500	19	14
	Over 500	5	3.7
	Missing	15	11
Device ownership: (phone, laptop, tablet, desktop computer)	Only one	10	7.4
	Combination of two	70	51.5
	Combination of three	43	31.6
	Combination of four	12	8.8
	Others	1	0.7

Data Collection Instrument

Previously designed and validated questionnaires were used in this study, as recommended for quantitative research (Bryman, Bell, Mills, & Yue, 2011). To improve the content validity, the design of the initial survey was subjected to the scrutiny of a professional in the field of teacher education and ICT use. The demographic information of the respondents, consisting of school name, age group, gender, subject currently taught, job title, years of teaching experience, class size, and ownership of devices, was collected. The demographic characteristics showed that the sample employed for our study was heterogeneous, improving the external validity of the study. Measures for reducing the effects of common method bias (CMB) were followed according to recommendations (Podsako, MacKenzie, Lee, & Podsako, 2003). The occurrence of CMB is attributed to the measurement approach that is used for structural equation modeling (SEM) (Kock, 2015a). Examples of actions taken to control CMB were ensuring the anonymity of respondents, the use of clear instructions at the top of the questionnaire, and clear wording in the overall design of the items. Specifically, in the survey, digital technologies were described as computers, laptops, mobile phones, interactive whiteboards, or software. In addition, respondents were given the option to list other items that they considered to be digital technologies. Furthermore, the full variance inflation factors (VIF) for the data analysis were assessed using WarpPLS software (Kock, 2015a; Kock & Lynn, 2012). The VIFs of the constructs ranged from 1.17 to 2.04, except for TechINtn and PKn4INg, which had higher VIFs of 3.81 and 3.38, respectively. VIFs above 5 indicate that significant collinearity problems exist (Hair, Risher, Sarstedt, & Ringle, 2019), so CMB was not considered to be a concern in this instance.

Measures for perceived technology knowledge (PerTechK), teachers' knowledge (excluding ICT) (TeKnXict), perceived knowledge of technology integration (PKn4INgT), and technology integration (TechINtn) were adapted from the TPACK instrument designed by Schmidt et al. (2009), using a five point Likert scale (strongly disagree, disagree, neutral, agree, and strongly agree). The TPACK questions were adapted for the in-service teaching context, in contrast to the original design, which was designed for a preservice teaching context; for instance, participants were selected from several departments of the college of education. The taught subjects were generalized during the analysis. In addition, items intended for use in teacher education programs in the original design were excluded. In addition, "I can adapt the use of the technologies that I am learning about to different teaching activities" was revised to "I can adapt the use of the technologies that I know to different teaching activities." Eventually, some of the items from the original instrument relating to TeKnXict were found to be poorly loaded and were removed (e.g., CK1, CK2, and PCKI).

Measures for ICT pedagogical practices (ICTPedPr) and perceived effect of teaching with technology on students (PEffStud) were adapted from a SITES-based study conducted in Finland (see Kenttala, Kankaanranta, & Neittaanmaki, 2016). The ICTPedPr construct used a four-point scale Likert (never, rarely, usually, and almost always) to assess how often the participants used ICT and for which activities. While the PEffStud construct used a three-point scale—disadvantage, no effect, advantage. The descriptive statistics for the items used in the questionnaire are shown in Table 2.

Table 2: The descriptive statistics and item loadings for the items in the questionnaire

Construct	Item description	Mean	Standard deviation	Item loading
Teachers' characteristics	Age	4.16	0.845	1.000
	Subject	2.45	0.651	1.000
	Years of teaching	3.85	0.947	1.000
	Average class size	2.26	1.632	1.000
	Technological devices owned	2.44	0.787	1.000
Perceived technological knowledge (PerTechK)	I know about many different technologies	3.80	1.010	0.658
	I have the technical skills I need to use technology	3.82	0.913	0.828
	I know how to solve my own technical problems	3.34	1.027	0.709
	I learn technology easily	4.04	0.888	0.659
	I frequently play with technology	3.58	1.054	0.737
	I have had sufficient opportunities to work with different technologies	3.27	1.119	0.742
Perceived knowledge for integrating technology (PKn4INgT)	I know about technologies that I can use for understanding and teaching my subject.	4.00	0.834	0.774
	I have the technical skills I need to use technology appropriately in teaching	3.74	1.018	0.843
	I can adapt the use of the technologies that I know to different teaching activities	3.80	0.921	0.853
	I think critically about how to use technology in my classes	3.76	0.996	0.763
	I choose technologies that enhance my teaching approaches for a lesson	3.94	0.865	0.912
	I choose technologies that enhance students' learning during a lesson	3.93	0.869	0.887
ICT pedagogical practices (ICTPedPr)	Presenting of information, demonstration, and/or giving instructions to students	2.49	0.891	0.718
	Providing support or extra lessons for individual students or small groups	2.49	0.840	0.717
	Helping or advising students regarding information retrieval	2.75	0.888	0.781

	Organizing or observing of student-led class discussions, demonstrations, and presentations	2.67	0.821	0.750
	Evaluating students learning through experiments, tests, and interviews	2.83	0.843	0.754
	Giving feedback to individuals or small groups	2.72	0.884	0.746
	Organizing, monitoring, and supporting the formation of students' groups and cooperation	2.46	0.922	0.735
Perceived effect of teaching with technology on students	Knowledge of the subject	2.93	0.431	0.899
	ICT skills	2.92	0.427	0.771
	Learning motivation	2.95	0.397	0.790
	Messaging skills	2.83	0.580	0.718
	Information processing skills	2.86	0.523	0.760
(PEffStud)	Cooperation skills	2.89	0.467	0.705
	Student self-direction	2.82	0.590	0.747
	Problem solving skills	2.87	0.514	0.803
	Confidence	2.88	0.496	0.686
Teachers' knowledge (**excluding technology**)	I can use different teaching methods in the classroom	4.26	0.779	0.829
	I can adapt my teaching style to different learners	4.23	0.730	0.855
	I know how to assess students' performance and learning in different ways.	4.27	0.683	0.801
(TeKnXict)	I am familiar with common student understandings and misconceptions of the subject.	4.10	0.822	0.812
	I can adapt my teaching based on what students currently understand or do not understand	4.18	0.732	0.808
	I know how to select effective teaching approaches to guide students' thinking and learning in the subject I teach	4.13	0.814	0.776
Technology integration	I can teach lessons that appropriately combine my subject, technologies, and teaching approaches.	3.79	0.890	0.906
(TechINtn)	I can select technologies to use in my classroom that enhance what I teach, how I teach, and what students learn.	3.82	0.950	0.879
	I can provide leadership in helping others to coordinate the use of content, technologies, and teaching approaches at my school	3.83	1.008	0.890

Data Collection and Data Analysis

The hypotheses were tested using a paper-based self-completed survey, which was administered to Nigerian TEs from three government-owned schools in the southern part of Nigeria, and participation was voluntary. Convenience sampling was used to select these schools, in addition to the fact that they all had ICT laboratories in which ICT tools for teaching were stored.

In this study, the PLS-SEM procedure was used (Hair, Ringle, & Sarstedt, 2011; Lowry & Gaskin, 2014) to explore the relationships between the Nigerian TEs' characteristics, their knowledge constructs, their ICT practices, and their belief in, and perceptions of, technology integration. PLS allows the testing of complex models, relationships between constructs, which are represented by observed variables (Henseler, Hubona, & Ray, 2016), and places fewer constraints on sample size. Data analysis was conducted using WarpPLS 6.0 software (Kock, 2017) and, thereafter, information concerning the structural and measurement model was obtained.

Results

The Measurement Model

The reliability and validity of the constructs in the measurement model, along with their measures, were examined. For reliability, the internal consistency and indicators of the constructs were assessed (see appendix for Table 3 and 4). The values of their Cronbach’s alpha coe□cients (CACs, α) and composite reliability coe□cients (CRC) depicted the model's internal consistency and reliability, while the indicator loadings depicted the reliability of the items to load on their theoretically assigned constructs (Hair et al., 2011; Lowry & Gaskin, 2014), stipulating that values higher than 0.70 attested to satisfactory reliability. For the validity of the model, convergent validity and discriminant validity were evaluated. The average variance extracted (AVE) determined the convergent validity of the constructs. AVE values of 0.50 or greater were recommended by Hair et al. (2011). The conditions for discriminant validity are attained if an indicator loads more strongly on its own construct than on its cross-loadings. The information on our measurement model results are provided in Tables 3 and 4 (see appendix) and they show that the model satisfied all of the reliability and validity requirements. In addition, the heterotrait-monotrait (HTMT) ratio, which is said to be more efficient than the Fornell-Larker criterion for instance, for determining the discriminant validity of a model (see Hair et al., 2019), was examined. For our model, the HTMT ratio of the constructs ranged from 0.13 to 0.69. According to Henseler et al. (2016), HTMT ratio values greater than 0.90 suggest constructs that have discriminant validity problems; therefore, the discriminant validity of our model was established.

The Structural Model

The performance of a structural and measurement model can be described using the goodness of fit measure (Tenenhaus, Vinzi, Chatelin, & Lauro, 2005). For the model in this study, the goodness of fit value was 0.47, which is considered to be large in terms of the effect size (Akter, D'Ambra, & Ray, 2011). Essentially, regression coefficients are used to assess the variance among the endogenous constructs of the structural model. These coefficients include the R-squared measures (R^2), the path significance (p-value), and the path coefficient (β). Figure 2 provides the results for the hypothesized model. Since the R^2 of the model was greater than the 0.02 benchmark, a revision was not considered necessary (Kock, 2017). In addition, the Q-squared coefficient (Q^2), which evaluates the model's capacity to predict the endogenous constructs (Hair et al., 2011; Kock, 2015b), was assessed. The Q^2 coefficients of PerTech, PKn4INg, ICTPedP, TeKnXict, PEffStud, and TechINtn were 0.16, 0.38, 0.07, 0.21, 0.10, and 0.72 respectively. The results of the research model showed that fifteen of the eighteen formulated hypotheses were significantly supported (see Table 5). In summary, the amount of variance in the teacher educators' technology integration, explained by the independent constructs of the hypothesized model, was 72%.

Table 5: Summary of results of the hypothesis testing

Hypotheses	Path coefficient	p-value
H1: Age → PerTechK	-0.06	p < 0.1 (Not supported)
H2: Age → TeKnXict	0.08	p < 0.1 (Not supported)
H3: Subject → PerTechK	-0.12+	p < 0.1 (Supported)
H4: Subject → TeKnXict	0.14*	p < 0.05 (Supported)
H5: TeachExp → PerTechK	0.22**	p < 0.01 (Supported)
H6: TeachExp → TeKnXict	0.25**	p < 0.01 (Supported)
H7: ClassSize → PerTechK	0.20**	p < 0.01 (Supported)
H8: ClassSize → TeKnXict	0.17*	p < 0.05 (Supported)
H9: TDevOwn → PerTechK	0.16*	p < 0.05 (Supported)
H10: TDevOwn → TeKnXict	-0.15*	p < 0.05 (Supported)
H11: PerTechK → PKn4INgT	0.61***	p < 0.001 (Supported)
H12: PerTechK → TechINtn	0.17*	p < 0.05 (Supported)
H13: PKn4INgT → TechINtn	0.55***	p < 0.001 (Supported)
H14: PKn4INgT → ICTPedPr	0.27***	p < 0.001 (Supported)
H15: TeKnXict → TechINtn	0.21**	p < 0.01 (Supported)
H16: ICTPedPr → PEffStud	0.39***	p < 0.001 (Supported)
H17: ICTPedPr → TeKnXict	0.21**	p < 0.01 (Supported)
H18: PEffStud → TechINtn	0.10	p < 0.1 (Not supported)

Note: *** = significant at p < 0.001, ** = significant at p < 0.01, * = significant at p<0.05, + =significant at p= 0.1.

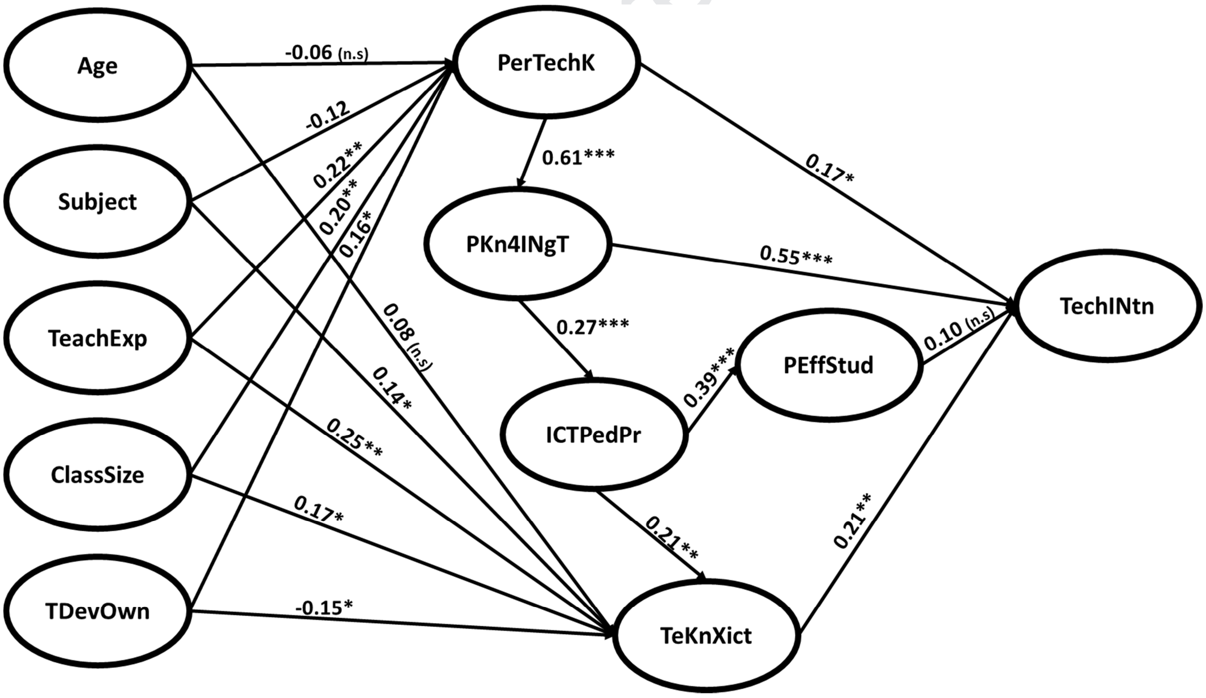

Figure 2: The results of the PLS analysis for the suggested model
Note: *** = significant at p < 0.001, ** = significant at p < 0.01, * = significant at p < 0.05, + = significant at p = 0.1, n. s = not significant.

Discussion

The main objective of this study was to investigate the factors influencing Nigerian teacher educators' technology integration. Specifically, by drawing from the TPACK and SITES frameworks, the study examined the TEs' knowledge (excluding technology), characteristics, perceived technological knowledge, perceived knowledge for integrating technology, ICT pedagogical practices, perceived effect of teaching with technology on the students, and technology integration. Hypothetically, the model held for the teachers in this study, since 72% of the variances of their technology integration were accounted for. Of the eighteen hypotheses formulated, thirteen were significantly supported by the data. Next, we discuss the hypotheses in relation to the research questions.

RQ1

The results for H1 (TEs' age negatively influences their perceived technological knowledge) was not supported. Although the predicted direction (b = -0.06) was consistent with the expectation, the p-value was not significant. Nevertheless, previous research outcomes have shown that age is negatively associated with teachers' computer proficiency (Buabeng-Andoh, 2012b; Claro et al., 2018; Inan & Lowther, 2010; Lee & Tsai, 2010; Luik et al., 2018; Koh et al., 2010). Our study's sample consisted mainly of TEs over 40 years of age, and it is possible that the training they received was not aligned with recent developments in technology, resulting in skepticism with regard to their technological skills; thus, their beliefs and attitudes regarding technology integration may not be as positive as those of younger TEs. H2, which predicted that TEs' age positively influences their perceived teaching knowledge, excluding technology, was also not supported. Surprisingly, this path coefficient also indicated a negative value, implying that as TEs grow older, their other knowledge, which does not involve knowledge of technology, decreases. Contrary to this result, Liu, Zhang, and Wang (2015) indicated that older teachers had higher perceptions of their PK and PCK. For a preservice teacher sample, age was not statistically associated with PK (Luik et al., 2018).

In the case of H3, the results supported the expectation that the taught subject would influence the teacher educators' perceived technological knowledge, albeit negatively. In comparison, TEs in the study showed that the subject they taught significantly and positively influenced their perceived teaching knowledge when the knowledge of technology was excluded (H4). In relation to our study sample, which consisted of 50% social science teachers, 11% art teachers, and the rest science, it is likely that the majority of the teachers (being social science teachers) did not perceive knowledge of technology as relevant for teaching their subjects. While Jang and Tsai (2012) maintained that the subject matter influences teachers' technology integration, other studies showed that, specifically, science teachers have greater digital competence, are more favorably disposed towards ICT use, and use computers more frequently than other subject teachers (Claro et al., 2018; Hennessy et al., 2005; Padmavathi, 2013).

The data supported both H5 and H6, which predicted that the years of teaching experience would influence the TEs' perceived technological knowledge and their teaching knowledge (excluding technology), respectively. As the teachers' experience increased yearly, they perceived an increase in their knowledge of technology as well as their teaching knowledge (excluding technology). Similar results were found in previous studies (Chew et al., 2018; Meskill et al., 2002; Miranda & Russel, 2012; Saltan & Arslan, 2017; Smarkola, 2007), while a negative relationship between teaching experience and teachers' ICT skill was found in prior studies (Buabeng-Andoh, 2012b; Inan & Lowther, 2010). Claro et al. (2018) demonstrated that, as teachers' tested digital competence moved from basic to more demanding tasks, their years of teaching experience became significantly associated with their digital competence. Similarly, other literature has demonstrated positive relationships between teacher's knowledge (excluding technology) (PCK, PK, CK) and teaching experience (Connor & Shultz, 2018; Hanuscin, Cisterna, & Lipsitz, 2018). In our results, however, there was little difference between the influence of teaching experience on either construct when considering their path coefficients and levels of significance; both were significant at the 0.01 level (see Table 5).

With respect to H7 and H8, the assumptions that class size would influence the TEs' perceived technological knowledge and their teaching knowledge (excluding technology) were individually confirmed. Class size more significantly influenced the TEs' perceived technological knowledge (H7 at level 0.01) than their teaching knowledge (excluding technology) (H8 at level 0.05). Consistent with our results were the observations of other studies (Hennessy et al., 2010; Leendertz et al., 2013) that suggested the influence of class size on teachers' technology competence.

The relationship between technology device ownership and both constructs (perceived technological knowledge and teachers' knowledge [excluding technology]) was corroborated by the data (H9 and H10**)**. Other studies offered similar insight (e.g., Kahveci et al., 2011; Padmavathi, 2013). Nevertheless, this result was inconsistent with Claro et al.'s study (2018), in which no statistical significance was found between access to digital devices at home and teachers' digital competence. There was a significant difference between the impact of personal device ownership on these constructs, respectively (i.e., both were significant at the 0.05 level with β= 16 and -15, respectively), implying that, while the ownership of technological devices negatively influenced their professional teaching knowledge, there was a positive relationship between the former and their perceived technological knowledge. Mama and Hennessy (2013) suggested that TEs' ownership of technological devices does not necessarily translate into an increase in their perceived technological knowledge. Yerdelen-Damar et al. (2017), on the other hand, illustrated the insignificant association between preservice teachers' ownership of technology and their TPACK perception, but when mediated by both technical competence and experience, the association became significant. However, Bitner and Bitner (2002) pointed out that teachers' personal development through ICT use promoted their engagement in ICT-based classroom practices.

Among the TEs’ characteristics, subject, class size, teaching experience, and device ownership influenced both TEs’ technological knowledge and knowledge that did not include technology. Although TEs’ age negatively influenced both their technical knowledge and knowledge that did not include technology, the relationships were not statistically significant. Moreover, teaching experience and device ownership influenced both constructs almost equally.

In considering all the paths between these five TE characteristics and their technology integration, the total indirect effect was statistically significant for only teaching experience and class size ($p < 0.05$); however, their effect sizes were not practically relevant. Consistent with other studies (e.g., Farjon et al., 2019; Peeraer & van Petegem, 2011), similar characteristics among these five characteristics did not influence either pre-service or in-service teachers' technology integration when mediated by other factors.

RQ2

The results for H11 (TEs’ perceived technological knowledge positively influences their perceived knowledge for integrating technology) was confirmed by the data. Previous studies supported this result (Koh, Chai, & Tsai, 2013; Taimalu & Luik, 2019).

Both TEs’ perceived technological knowledge and perceived knowledge for integrating technology influenced their technology integration (H12 and H13). Previous studies agreed with this result (Nelson et al., 2019; Taimalu & Luik, 2019).

The data supported the expectation that TEs’ perceived knowledge for integrating technology would influence their ICT pedagogical practices (H14). Prestridge (2012) illustrated the relationship between ICT competence and a similar effect on ICT usage in classrooms.

H15, which predicted that TEs' perceived teaching knowledge, excluding technology, would positively influence their technology integration was confirmed. This result, following the TPACK framework (Koehler & Mishra, 2006), in which path predictions in earlier studies (Kiray et al., 2018; Koh et al., 2013) were among the primary and secondary knowledge constructs, found that PK and PCK could be expected to influence the teachers' technology integration.

The relationship between TEs' ICT pedagogical practices and the perceived effect of teaching with technology on their students (H16) was confirmed. The extant literature posited a reverse relationship, in which the teacher is likely to increase the use of technology in the classroom if such usage is perceived to enhance students' learning (Blackwell et al., 2013; Ertmer et al., 2012; Liu, 2011; Miranda & Russell, 2012; Vongkulluksn et al., 2018; Willis et al., 2019). Scott and Mouza (2007) reported a relationship shift in teacher's pedagogical practices, which occurred when teachers began to see the benefits of technology for both their students and themselves, thus signifying an association between teachers' beliefs and practices.

For H17, the TEs' ICT pedagogical practices positively influenced their perceived teaching knowledge that excluded technology. Other studies gave credence to this result; for instance, Scott and Mouza (2007) asserted that the introduction of ICT tools in teaching influenced teachers' thinking and consideration of their pedagogical beliefs. Sutherland et al. (2004), in turn, emphasized that the use of ICT transformed teachers' knowledge of their subject areas and teaching repertoires, and Heitink et al. (2016) indicated that ICT use is relevant for improving teachers' pedagogical skills. Among the assessed teacher ICT practices, evaluation of students through experiments, tests, and interviews had the highest mean (2.83), and organizing students had the lowest (2.46).

No support was evident for the prediction that TEs' perceived effect of teaching with technology on their students would positively influence their technology integration (H18). This outcome paralleled that of Peeraer and van Petegem (2011). Conversely, however, the study by Leendertz et al. (2013) indicated that teachers with who taught mathematics using ICT had higher TPACK, and also involved their students in the use of ICT, leading to improved students' skills and knowledge of the subject. Similarly, Heitink et al. (2016) suggested that teachers can achieve their educational goals when they use technology. If teachers believe that integrating technology into teaching will benefit the learning goals of the students, then the technology integration skills of the teachers themselves should increase; therefore, the perceptions of teachers should align with those that enable technology integration to succeed (Chikasanda et al., 2013). Notably, in the study, the TEs' perceived effect of teaching with technology on their students was generally positive, with the highest means for learning motivation, ICT skills, and subject knowledge (Table 2). Such perceptions suggested that the TEs understood teaching with ICT to be learner-focused.

Overall, three constructs (teachers' knowledge [excluding technology], perceived technological knowledge, and perceived knowledge for integrating technology) directly influenced the TEs' technology integration, while the other two (ICT pedagogical practices and perceived technology gains for their students) did not. Further examination, using the indirect effect of the constructs on TEs' technology integration, showed only perceived technological knowledge to be statistically significant ($p < 0.001$), with an effect size of 0.20. Considering that over 90% of the TEs in our study personally owned at least two technological devices, this could be the reason for their perceived technological knowledge influencing their technology integration in this way. Notably, the TEs' ICT pedagogical practices did not indirectly influence their technology integration, which contrasted with a prior study demonstrating that teachers' pedagogical practices both directly and indirectly positively influenced their technology integration (Chuang et al., 2015; Drent & Meelissen, 2008). In addition, although their sample comprised preservice teachers, Farjon et al. (2019) indicated that such practices had little impact on their technology integration.

Limitations and Future Work

This study's results should be explained in relation to the following limitations. First, the research sample consisted of teacher educators; therefore, the findings may not apply to teachers within university, primary, or secondary school contexts. Second, we used convenience sampling, and the data was gathered using a cross-sectional survey; therefore, the results may not be applicable to a randomized experiment, and the use of data from longitudinal, observation, and interview studies would enrich the study. Third, the sample size was 136, and the respondents were drawn from only three colleges of education within the southern part of Nigeria; consequently, generalizing to the entire country should be done carefully. Fourth, social desirability bias may have applied in this instance, since a self-completed questionnaire was used to collect the responses from the participants. Although, as we mentioned earlier, PLS-SEM is beneficial for investigating complex models and relatively small sample sizes, a second study cycle with additional data would further strengthen and sharpen the study results.

Similar studies comparing younger TEs and TEs who teach specific subjects (rather than our three broad subject categories) could be conducted in order to explain the influence of subject or age. Further insight, as evident in the disassociation between TEs’ technology integration and both ICT pedagogical practices and the perceived benefits for students, is necessary; for instance, Liu (2011) recognized that contextual factors are responsible for the discrepancies between teachers' beliefs and their teaching activities. Given that our study focused only on the teacher-level factors of technology integration, further research that considers the mediation of other contextual factors, such as the impact of the school-level and system-level on TEs, is needed, as reiterated by other studies (e.g., Buabeng-Andoh, 2012a; Nelson et al., 2019). Further studies could analyze the combined impact of school-level characteristics, teacher characteristics, and their experiences; for example, teachers who have TPACK in one setting might adjust their knowledge in a different way in another setting.

Conclusion

The usefulness of the TPACK framework for investigating teachers' technology integration continues to generate discussion of the factors that affect the complex process and the adequacy of the framework. As a result, in addition to the teachers' knowledge constructs in the TPACK framework, we included in this study other relevant constructs (such as teachers' demographics, ICT pedagogical practices, and the perceived effect of these practices on students), which were inspired by the SITES framework. In this way, we have contributed to the literature, in terms of theory development, by presenting the factors influencing the technology integration of teacher educators within a Nigerian college of education context. As Howard et al. (2015) explained, understanding technology integration requires the knowledge that the process consists of manifold relationships between and among the specific factors considered. In other words, no factor should be considered in isolation, since its influence can become significant when other factors mediate. Our study provides support for previous studies (e.g., Buabeng-Andoh, 2012b; Inan & Lowther, 2010; Nelson et al., 2019) that showed the impact of teacher characteristics on technology integration. It differs from these prior studies, however, because we went further and added factors other than age, subject area, and teaching experience to our model. Moreover, we included the antecedents of class size and device ownership, as well as other constructs—technological knowledge, knowledge for integrating technology, ICT pedagogical practices, perceived effects of these practices on students, and professional teaching knowledge—on teachers' technology integration. Claro et al. (2018) presented quite similar findings to ours, although they applied a different theoretical lens and focused mainly on the digital competencies of teachers within a Chilean context. Highlighted in our study context was the fact that teachers' access to ICT tools should no longer be a barrier to technology integration, due to the TEs' ownership of various technological devices. The information revealed in this study is relevant for developing teachers' technology integration strategies, the policies of the governing bodies of the learning institutions where the research was conducted, school environments in other regions of Nigeria, and other African countries.

Essentially, TEs should take the lead in matters concerning technology integration within the sphere of their classrooms, especially for shaping future professionals who will be competent in the future working environment. One major finding from our study, which raises concern, was that indicated by the lowest contributors of the study's constructs (e.g., ICT pedagogical practices and the perceived effect of teaching students using ICT tools) to the TEs' technology integration. Accordingly, the implication for administrators of educational institutions is the need for practical training, with examples that show how older TEs can align their ICT pedagogical practices and the perceived benefits that students gain through their technology integration. School administrators can encourage TEs to use their ICT devices for teaching. The study by Heitink et al. (2016) emphasized the benefits of supporting teachers' technology integration processes using such "authentic" scenarios. Moreover, such professional development training should provide interactive environments for teachers' reflection and their recounting of experiences and practices that foster or inhibit effective ICT integration processes. This study therefore concludes with a widely-accepted view that more professional development is needed. By adopting a bottom-up approach, more information concerning how our model's constructs can better influence teachers' technology integration can be uncovered.

Educational technology integration is difficult. Although it has been studied for over 30 years, there still is no explanation, theory, model, or framework that can explain the foundations for successful educational technology integration and how it can be achieved. This study has highlighted that technology integration can be understood as a combination of individual teacher-level factors (i.e., knowledge, perceptions, characteristics, and practices); thus, we have provided an understanding of some of a complex series of interconnected factors. Understanding the challenges of technology integration into classroom practice calls for perspectives that situate technology integration within everyday classroom routines. Consequently, we suggest that research on educational technology integration could benefit from taking a broad view, recognizing that technology integration must be considered critically and that many of the challenges have, indeed, already been identified in existing research.

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APPENDIX

Table 3: Composite Reliability, Cronbach Alphas, Average Variance Extracted and Inter-construct correlations

	CRC	CRA	AVE	Age	Subj	Teach Exp	Clas Size	TDev Own	Per TechK	PKn 4INg	ICT PedPr	TeKn Xict	PEff Stud	Tech INtn
Age	1.000	1.000	1.000	1.000	0.167	0.586	0.008	0.088	-0.041	-0.058	-0.054	-0.022	0.008	-0.158
Subject	1.000	1.000	1.000	0.167	1.000	-0.038	0.271	0.041	-0.043	-0.072	0.017	0.070	-0.002	-0.011
TeachExp	1.000	1.000	1.000	0.586	-0.038	1.000	-0.091	0.068	0.076	0.047	0.055	0.031	0.113	-0.000
ClasSize	1.000	1.000	1.000	0.008	0.271	-0.091	1.000	-0.077	0.018	0.041	-0.058	0.180	0.102	0.025
TDevOwn	1.000	1.000	1.000	0.088	0.041	0.068	-0.077	1.000	0.172	0.138	0.205	-0.045	0.302	0.201
PerTechK	0.868	0.817	0.525	-0.041	-0.043	0.076	0.018	0.172	0.724	0.603	0.162	0.403	0.207	0.588
PKn4INg	0.935	0.916	0.706	-0.058	-0.072	0.047	0.041	0.138	0.603	0.840	0.209	0.622	0.219	0.809
ICTPedPr	0.896	0.865	0.552	-0.054	0.017	0.055	-0.058	0.205	0.162	0.209	0.743	0.195	0.280	0.257
TeKnXict	0.922	0.898	0.662	-0.022	0.070	0.031	0.180	-0.045	0.403	0.622	0.195	0.814	0.117	0.644
PEffStud	0.927	0.911	0.588	0.008	-0.002	0.113	0.102	0.302	0.207	0.219	0.280	0.117	0.767	0.273
TechINtn	0.926	0.880	0.806	-0.158	-0.011	-0.000	0.025	0.201	0.588	0.809	0.257	0.644	0.273	0.898

Note: CRC = Composite Reliability Coe□cient, CAC = Cronbach Alphas Coe□cient, AVE = Average Variance Extracted. The o□-diagonal elements depict the correlations among constructs while the bold fonts in the leading diagonals are the square roots of AVEs.

Table 4: Item loadings and cross-loadings

	Age	**Subject**	**Teach Exp**	**Clas Size**	**TDev Own**	**Per Tech**	**PKn 4INg**	**ICT PedPr**	**TeKn Xict**	**PEff Stud**	**Tech INtn**
Age	**1.000**	0.167	0.586	0.008	0.088	-0.041	-0.058	-0.054	-0.022	0.008	-0.158
Subject	0.167	**1.000**	-0.038	0.271	0.041	-0.043	-0.072	0.017	0.070	-0.002	-0.011
TeachExp	0.586	-0.038	**1.000**	-0.091	0.068	0.076	0.047	0.055	0.031	0.113	-0.000
ClasSize	0.008	0.271	-0.091	**1.000**	-0.077	0.018	0.041	-0.058	0.180	0.102	0.025
TDevOwn	0.088	0.041	0.068	-0.077	**1.000**	0.172	0.138	0.205	-0.045	0.302	0.201
TKI	-0.053	-0.111	0.023	-0.029	0.092	**0.658**	0.479	0.142	0.388	0.084	0.447
TKII	-0.037	-0.075	0.088	-0.012	0.152	**0.828**	0.499	0.180	0.372	0.163	0.477
TKIII	0.057	-0.043	0.097	-0.075	0.061	**0.709**	0.375	0.032	0.170	0.128	0.339
TKIV	-0.090	-0.014	0.025	0.064	0.158	**0.659**	0.436	0.096	0.314	0.281	0.472
TKV	0.025	0.089	0.120	0.034	0.227	**0.737**	0.415	0.152	0.214	0.147	0.401
TKVI	-0.084	-0.035	-0.032	0.096	0.056	**0.742**	0.419	0.095	0.294	0.105	0.425
TCK	-0.087	0.000	0.028	0.079	0.090	0.492	**0.774**	0.067	0.613	0.103	0.661
TPKI	-0.124	-0.157	-0.016	0.058	0.143	0.620	**0.843**	0.085	0.466	0.141	0.683
TPKII	-0.039	-0.114	-0.009	0.008	0.195	0.596	**0.853**	0.241	0.485	0.249	0.724
TPKIII	-0.046	-0.057	0.040	0.030	0.035	0.350	**0.763**	0.229	0.437	0.264	0.592
TPKIV	-0.009	-0.047	0.053	0.032	0.051	0.465	**0.912**	0.179	0.596	0.169	0.713
TPKV	0.001	0.015	0.134	0.006	0.176	0.508	**0.887**	0.246	0.541	0.182	0.702
IT4Inst	-0.034	-0.086	0.121	0.020	0.148	0.259	0.363	**0.718**	0.240	0.318	0.347
SuppLes	-0.009	0.149	-0.019	0.048	0.157	0.189	0.176	**0.717**	0.179	0.132	0.205
HelpAdv	-0.081	0.068	0.012	0.010	0.211	0.185	0.214	**0.781**	0.186	0.214	0.237
OrgObSt	-0.124	0.081	-0.015	-0.063	0.251	-0.025	0.062	**0.750**	0.095	0.148	0.151
EvaStud	-0.000	0.037	0.079	-0.121	0.139	-0.043	-0.072	**0.754**	0.019	0.262	0.087
Feedbac	0.010	-0.106	0.096	-0.144	0.041	0.157	0.130	**0.746**	0.124	0.169	0.125
ManStgr	-0.038	-0.059	0.015	-0.047	0.115	0.130	0.221	**0.735**	0.175	0.216	0.190
PKI	-0.004	0.021	-0.059	0.193	-0.005	0.271	0.551	0.174	**0.829**	0.041	0.520
PKII	-0.076	0.048	-0.069	0.177	-0.112	0.343	0.544	0.149	**0.855**	0.093	0.538
PKIII	-0.055	-0.020	0.062	0.137	-0.129	0.332	0.460	0.136	**0.801**	0.033	0.450
PKIV	-0.116	0.092	0.001	0.095	-0.014	0.349	0.490	0.229	**0.812**	0.153	0.602
PKV	0.065	0.090	0.135	0.117	-0.039	0.329	0.456	0.071	**0.808**	0.106	0.490
PCKII	0.087	0.113	0.091	0.156	0.086	0.343	0.535	0.192	**0.776**	0.147	0.543
KnofSub	-0.095	-0.070	0.029	0.069	0.292	0.143	0.180	0.302	0.065	**0.899**	0.227
ICTSkil	-0.090	-0.059	-0.014	0.003	0.265	0.204	0.181	0.297	0.021	**0.771**	0.158
LearnMo	0.016	0.045	0.040	0.141	0.248	0.216	0.191	0.225	0.063	**0.790**	0.193
MessSki	0.054	0.031	0.135	0.094	0.147	0.186	0.240	0.252	0.133	**0.718**	0.249
InfoPrS	0.066	0.100	0.141	0.098	0.091	0.178	0.161	0.190	0.191	**0.760**	0.214
CoopSki	0.061	-0.020	0.149	0.035	0.251	0.135	0.134	0.145	0.011	**0.705**	0.162
SelfDir	0.037	0.030	0.128	0.103	0.236	0.199	0.160	0.112	0.112	**0.747**	0.255
ProSolS	0.049	0.016	0.145	0.107	0.251	0.105	0.151	0.149	0.097	**0.803**	0.224
StuConf	-0.025	-0.083	0.045	0.051	0.302	0.060	0.112	0.256	0.122	**0.706**	0.205
TPCKI	-0.231	-0.082	-0.038	-0.018	0.167	0.495	0.731	0.169	0.567	0.220	**0.906**
TPCKII	-0.136	0.008	-0.021	0.075	0.204	0.543	0.755	0.195	0.622	0.257	**0.897**
TPCKIII	-0.057	0.047	0.059	0.010	0.170	0.545	0.692	0.329	0.544	0.259	**0.890**

Note: CRC = Composite Reliability Coe□cient, CAC = Cronbach Alphas Coe□cient, AVE = Average Variance Extracted. The o□-diagonal elements depict the correlations among constructs while the bold fonts in the leading diagonals are the square roots of AVEs.

Highlights

- The model in the study depict interactions among factors at teacher level that influence technology integration
- Teachers' technological knowledge both directly and indirectly contributed to their technology integration
- Teachers' Information and Communication Technology -pedagogical practice was the lowest predictor of technology integration
- The results inform strategic and practical professional training that could improve the teachers' technology integration

Author contributions

Manuscript Title: Factors affecting Nigerian teacher educators' technology integration: Considering characteristics, knowledge constructs, ICT practices and beliefs.

Author 1: Eloho Ifinedo

- Designed the model used in the paper
- Collected the data
- Preprocessed and analysed the data
- Wrote the method, result, discussion and limitation aspect of the paper

Author 2: Dr. Jenni Rikala

- Provided the literature on which basis the model was designed
- Wrote: took responsibility of the literature review and construction of the body of the manuscript.

Author 3: Professor Timo Hämäläinen

- Supervising the article, reviewing the article before submission for spelling and grammar and for its intellectual content.