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Analysing the Nigerian Teacher's Readiness for Technology Integration

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ABSTRACT

Technology integration promises better quality in education. This integration is challenging to accomplish, especially for teachers in a developing country like Nigeria where the demand for education remains a struggle in the face of dwindling resources. The technological pedagogical content knowledge (TPACK) framework promotes designing strategies suitable for the teachers' needs. Therefore, in order to determine the readiness of the Nigerian teachers for technology integration, this study examines the Nigerian teacher educators' (N=136) TPACK and the relationship among the constructs using self-completion survey and partial least square techniques. The results reveal that among the seven knowledge constructs, the teachers' technological, pedagogical, and technological pedagogical knowledge are the most significant predictors of their TPACK. The theoretical and practical implications of the result are discussed thereafter.

Keywords: *Technology integration; Teacher educators; Nigeria; TPACK; Partial Least Squares; Structural Equation Modelling*

INTRODUCTION

Information and communication technology (ICT) has become widespread and ICT tools have become accessible and useful in fulfilling mundane needs. This usefulness has moved from supporting traditional roles to substantially supporting different sectors, such as education, health, government and businesses. Owing to the perceived role of ICT in education, a growing number of studies continue to discuss and debate its impact on learning outcomes. Thus, developments in ICT has led to changes in the dynamics of how teaching and learning are fostered (Okanlawon et al., 2017; Sinha & Bagarukayo, 2019). E-learning offers access and flexibility to people who want to work and learn at the same time, which is an improvement on the traditional distance learning programme of study (Owolabi & Owolabi, 2015). The developments in the usability of mobile devices have also led to the paradigm known as mobile learning. This paradigm emphasizes the possibility for learning to occur regardless of time and location and thus leverages on the diffusion of mobile devices (Adedoja et al., 2013). Another development is blended learning, which uses both traditional face-to-face teaching and learning involving the use of ICT (Olelewe & Agomuo, 2016). Finally, developments in ICT have given rise to possibilities and challenges even for teachers and their professional development needs (Dintoe, 2019; Dlamini & Mbatha, 2018). Therefore, education and ICT remain effective channels to develop any country as some studies have indicated the economic benefits of such investments (Howie, 2010; Oluwatobi, Olurinola & Taiwo, 2016; Watanabe, Naveed & Neittaanmaki, 2017).

It is recognized that Nigeria lags behind in terms of quality of education and resources for teacher education (Okolie et al., 2019; Olulobe, 2006; UNESCO, 2014). However, at the same time, Nigeria ranks as Africa's largest Internet user (Edo, Okodua & Odebiyi, 2019) and the diffusion of mobile devices is evident among Nigerian students (Ifinedo et al., 2017; Utulu & Alonge, 2012). Consequently, the attraction and benefits of ICT in education could offer some solution to combating these issues (Ifinedo & Kankaanranta, 2018). In terms of policy, the Federal Ministry of Education (2014) shows the significance of ICT for promoting the delivery of education in Nigeria with emphasis on developing teachers, capacity and infrastructure. Nevertheless, Yusuf (2005) attributes the lack of appropriate strategies for integration of technology in education as well as lack of vibrant ICT policies as contributors to the problem of employability of graduates in Nigeria. This indicates the need for initiatives that fill such employability gaps. Previous studies have implied that preparing an information society acquiescent workforce led to the success of some economies (Howie, 2010; Oluwatobi, Olurinola & Taiwo, 2016; Watanabe, Naveed & Neittaanmaki, 2017). Thus, the preparation of this workforce is a direct result of learners that easily adapt to the continuous evolving technological, socio-cultural and economic environs.

Following from the benefits that ICT integration offers in education, our research investigates the teacher educators' knowledge that is required for technology integration in their classrooms, that is, their technological pedagogical content knowledge (TPACK). Thus, this study aims to provide answers to the following research questions:

1. What are the Nigerian teacher educators TPACK perceptions?
2. What relationship exists among the variables of the TPACK construct?

Having highlighted the development and significant role of ICT particularly in education in the introductory section, we seek hereafter to answer our research questions, by first discussing the context of the study from where the sample was drawn and reviewing the technology integration related studies that have been conducted within this context. Next, we provide the theoretical underpinning, and the research method, participants, survey instrument and the data analysis technique are described. Subsequently, the results followed by a discussion on the findings are presented. The conclusions, implications, and limitations, alongside future work are explained.

Research Context: Nigerian Teacher Education

As part of on-going efforts to improve the quality of education, the government of Nigeria made provision especially for colleges of education as the institutions where professional teachers are produced within a three-year span. The National Commission for Colleges of Education (NCCE) was established through the 1989 Education Act and the Amendment Act 12 of 1993, specifically to oversee the higher education institutions in the country with focus on improving the quality of teacher educators (Federal Ministry of Education, 2014). At present, however, along with the other tertiary institutions in the country (that is, the universities and polytechnics), the colleges of education are being governed by the NCCE, the National Board for Technical Education and the National Universities Commission.

There are 89 colleges of education in Nigeria (NCCE, 2017), which signifies the emphasis placed on teacher education in the country. These colleges of education are equally shared (that is, 44:45) between the northern and southern part of the country. They are categorised according to their administrators (that is, governed by federal: 22, state: 20 or, private: 47) and in accordance with the programmes offered (in this case, technical: nine, conventional: 79 or special: one).

It is expected that colleges of education would be institutions where future teacher educators acquire pedagogical skills relating to their fields of study or interest (Federal Ministry of Education, 2014) but it is only realistic that these future teachers will eventually teach based on what skills they have received or practiced from training (Shonola & Joy, 2014a). Igwe & Rufai (2012) showed in their evaluation of professional qualifications of Nigerian teachers that the majority of the teachers are indeed qualified with degrees ranging from NCE (Nigeria Certificate in Education) to master's level certificates and are therefore capable of providing quality teaching service. However, the study by Olelewe & Okwor (2017) revealed differences in skill levels between the teachers in the university, polytechnics and colleges of education even though the teacher education provided is expected to produce teachers who are professionally skilled for service in all levels of the education system. The way that teachers are trained at their respective colleges of education is therefore important. For example, stand-alone computer courses did not translate into ICT competence among the preservice teachers investigated by Garba (2014) because the teaching method was characterized by the traditional face-to-face method, devoid of the practical approach and active participation of the students. It is therefore necessary, that in order to prepare the future teachers and learners with 21st-century skills, the teacher educators themselves should be the front-runners in matters of technology integration. Understanding the critical role that adequately equipped teachers play, inspires the need to consider their perspectives, experiences and beliefs and the advantages that seemingly new innovations add to their teaching practices.

Related studies on technology integration in Nigerian Education

Developments in technology have brought about opportunities for improving teaching and learning especially in terms of access to resources. The Internet, for example offers learning platforms and capabilities in bridging the distance between learners and teachers. As such, developments in technology have led to its various forms of integration in education with examples like mobile learning, online learning and blended learning. As a result of these technological developments, educational activities can occur through electronic mail, chats, web-based conferencing, messaging platforms and web pages for sharing information resources (Utulu & Alonge, 2012). These educational activities in turn facilitate interactive and collaborative learning and enhances assessment during the teaching-learning process (Olelewe & Agomuo, 2016).

A number of authors within the Nigerian context have produced scholarly works that assessed the extent to which the higher education institutions in Nigeria have attempted to infuse ICT based teaching and learning techniques. At the secondary school level, a factor analysis study by Ogundile et al., (2019) found five categories of factors that influence the use of ICT in Nigerian schools namely, support, availability, infrastructure, learning tools and cognitive. Chaka & Govender (2017) found that students of three colleges of education from the north-central part of Nigeria expressed enthusiasm in implementing mobile learning. Utulu & Alonge (2012) revealed the engagement of mobile devices by lecturers and students in their institution mostly for communication, recording results, accessing resources online and sharing knowledge. Likewise, Adedoja et al. (2013), studied students' attitude towards the use of mobile phones for lesson delivery and the result showed a positive, increased interest and motivation of students to learn. Their study further suggested that attitude is influenced by the perceived benefit, which implied students' perceived benefit (such as, flexibility in terms of studying time and location offered by the mobile phone delivery platform) triggered the students' motivation to learn. Olelewe & Agomuo (2016), using a quasi-experimental design investigated the effects of blended learning and face-to-face learning on computer education student achievement. The result, which was attributed to interaction and active participation among the students, showed that with the blended learning approach, the students' achievement improved significantly. Owing to the ubiquitous, collaborative and social features, Oyelere et al., (2018) designed a mobile learning application to aid learning among computer science students and it was observed that their learning outcome improved significantly.

Common to the above described related studies is the use of ICT in various forms, which is observed to enable access to educational content, result in increased motivation to learn and eventually improve the outcome for learners. Although these studies describe the positive impact of technology integration in education, they, however, focus on student perspectives. What is therefore lacking is the perspectives of teacher educators. Igwe & Rufai (2012) recommended the continuous review of the teacher education programme in order to improve the efficiency of the teaching service. The perception of teacher educators in the adoption, implementation and use of any technological innovation in an education system, cannot be overemphasized since it is their responsibility to decide the appropriate mode of communication, technique and teaching aid that would be effective for service delivery.

Oluwafeyikemi, Ajayi, & Gata, (2018) investigated the use of an interactive board in teaching Christian Religion Knowledge in Colleges of Education in the Northcentral region of Nigeria. Although the teachers complained that the devices were too few, the level of use was also observed to be low. Inije et al., (2013) considered the use of e-learning technologies in business education instructional delivery in colleges of education in the Delta state of Nigeria. The findings indicated low usage levels at the institutions despite the availability of e-learning technologies such as e-lectures, e-examination, e-drill, e-books and an e-library. Another constraint identified in the study was the low proficiency of teacher educators in the integration of the available technologies in their schools.

Although Samuel, Onasanya & Olumorin (2018) suggest in their study that lecturers had a positive disposition towards the use of mobile technologies for research purposes, the authors also maintain that the lecturers' perceived usefulness and ease of use of these technologies were average. Likewise, Shonola & Joy (2014a) describe the barriers to mobile learning in higher education institutions within the southwest of Nigeria. In doing so, they highlighted constraints such as obsolete curriculum, lack of infrastructure, funding and policy issues. In addition, a major challenge was the lack of skills among teachers and their attitude towards using technology, specifically, because the training they received was not in accordance with the present day digital era. Also mentioned, was the fear of losing control over the students and that the students are more likely to become technology dependent with improvements in their technological skills that would not necessarily translate to improving their learning outcomes. Further investigation by Shonola & Joy (2014b) through interviews on perspectives of 30 lecturers of computer science departments at three higher education institutions, on security issues pertaining to the use of technology (mobile devices) as teaching aids, found that the majority of these lecturers feared the exploitation of security, and privacy breaches. Specifically, in the area of the interception of personal and confidential information by students and outsiders as well as unauthorised access to learning content or unpermitted sharing of copyrighted e-materials by the students. In addition, they feared virus and malware attacks leading to loss of confidential information, loss of control leading to examination malpractices for example, during e-assessment and e-examination.

In most of these studies, a common feature of the barrier to use ICT in the classroom is the question surrounding the teacher educators' competence. In addition, noticeable in these studies, is the lack of evaluation of teachers' knowledge domain using the TPACK framework despite the fact that the framework is acclaimed to provide a basis for understanding how teacher educators integrate technology in their classrooms (Stoilescu, 2015).

TPACK FRAMEWORK

The TPACK framework has emerged as a theoretical framework needed for understanding the teacher's integration of ICT into teaching. Shulman (1986) in an analysis of the distinct knowledge construct known as pedagogical content knowledge (PCK), which is required by a teacher, provides the basis for the TPACK framework. The TPACK framework (see Figure 1.) further describes a distinct knowledge construct required by teachers especially in today's technology-driven era (Mishra & Koehler, 2006). This distinct knowledge construct, that is, TPACK, is an aggregate of three main components of knowledge (TK, PK, CK) and their interrelationship which produces three other types of knowledge (TCK, PCK, TPK). The technology knowledge (TK) as the name implies, denotes the knowledge of different technologies. Pedagogical knowledge (PK) represents the teachers' deep knowledge about the systems, approaches, procedures and practices of teaching and learning. Content knowledge (CK) describes the teachers' knowledge on the subject taught as well as emphasizes the importance of teachers having a well-rounded knowledge of the field in which they teach. TCK is such that the teacher is able to combine both knowledge of technology and of subject matter while understanding the resultant effect they individually have on each other. This knowledge can influence the teachers' decision on the appropriate technology for specific subjects and vice versa. Akin to the original concept by Shulman (1986), the PCK refers to the pedagogical knowledge required by a teacher for teaching a specific subject. TPK enables the teachers' understanding of the effect of learning and teaching with different technologies such that the tool is regarded as a facilitator of the learning or teaching process. The framework therefore, enables the design and evaluation of what knowledge is required and how such knowledge can be cultivated (Schmidt et al., 2009). In this way, understanding the knowledge base of the teachers is critical in revealing the prevalent gaps in regard to technology integration and thus provides strategic opportunities to address such gaps.

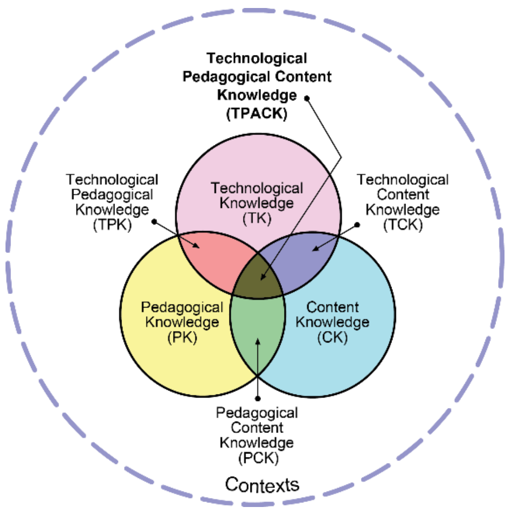

Figure 1: TPACK framework (reproduced by permission of the publisher, © 2012 by tpack.org

The TPACK framework has been utilized in many different contexts but it seems that so far, the use has been limited in the context of developing countries. We however, acknowledge the study by Kihoza et al., (2016) conducted in Tanzania where a combination of TPACK and the Substitution-Augmentation-Modification-Redefinition frameworks were used to assess teachers' technology integration. Previous studies using solely the TPACK framework have examined contexts such as, preservice teachers (Schmidt et al., 2009), in-service teachers (Liu, Zhang, & Wang, 2015) and in regard to the professional development of new higher education teachers (Wu et al., 2016). The framework has also been used in subject specific contexts like mathematics (Guerrero, 2010) or music (Bauer, 2013). Heitink et al., (2016), evaluated the perspective of teacher reasoning in relation to their technology usage within the Dutch context while Chuang & Ho (2011) reflect the Taiwanese context. In addition, previous studies have used the framework in comparing teachers' technology integration across country contexts (Alqurashi, Gokbel, & Carbonara, 2017; Redmond & Peled, 2018). In addition, the result of an international collaboration (Dalal, Archambault & Shelton, 2017) that assessed the perceived technology integration abilities of sixteen secondary school teachers from seven developing countries using the TPACK framework indicates development of all seven constructs of their TPACK. The authors of the latter study linked part of the gains of the study to the contextualised exposure of the teachers to educational technology tools, resources and applications with which they were equipped. Accordingly, the technological tools, resources and applications accessible to the Nigerian teacher educators have been noted earlier in this paper. Also, an overview of the TPACK studies contained in previous literature reviews (Voogt at al., 2013; Willermark, 2018) attest to the scarcity of studies from the developing country context. More specifically, references to studies that actually capture the knowledge of teachers in relation to ICT integration within the context of the Nigerian teacher education are sparse. Therefore, the current study is an exploratory one, where the TPACK framework and instrument is used to investigate the Nigerian teachers' knowledge for technology integration and thus provide answers to the specific research questions indicated earlier.

METHOD

This research is part of a larger study, which employed the use of both quantitative and qualitative methods to investigate the use of ICT in Nigerian schools. This paper, however, will offer insights relating to the analysis of data collected quantitatively using the TPACK framework as a guide. The convenience sampling technique was used to select the schools and participants of this study.

Sample

In this study, a paper-based self-completion survey was used to collect data from 148 teacher educators from various departments of three colleges of education from the southern part of Nigeria. Listwise deletion was used to eliminate cases that answered the TPACK questions incompletely, leaving 136 usable responses. The various departments were eventually categorised into three: Art (language, religious studies), science (physics, chemistry, database management), and social science (accounting, geography, agriculture). Of the participants, 60% were male (n = 81) and 35% female (n = 48). The participants consisted of various age groups; however, 75% were found to be 40 years and above. Most of them (50%) teach within the social science category and about 44% teach a class size of range between 0-50 students. From the 95% who responded, it can be observed that the majority of the participants engage in actual teaching activities. Over 90% own more than one mobile device. More details on the sample's demographics are shown in Table 1.

Common method bias (CMB) occurs as a result of the measurement method used in structural equation modelling (SEM) (Kock, 2015a). In accordance with reducing the effects of CMB (Podsakoff et al., 2003), some recommended measures were followed. First, the respondents' anonymity was ensured. Secondly, the questionnaire included clear instructions at the top and clear wording was used to design the items overall. Further, in assessing for CMB, the full variance inflation factors (VIF) for data analysis using WarpPLS software was employed (Kock, 2015a; Kock & Lynn, 2012). For the constructs, TPACK, TPK, TCK, PCK, PK, CK and TK, their VIFs were 3.55, 3.31, 2.23, 1.40, 1.97, 1.87 and 1.69 accordingly. Notably, VIFs above the benchmark of 3.3 are regarded as suggestive of models having the presence of CMB. However, this threshold remains under scrutiny and in particular, Kock (2015a) argues for higher benchmarks than 3.3 when factor-based PLS-SEM algorithms are utilized as is the case in this study. Therefore, the VIFs of the constructs of this study could be considered non-problematic for the data collected.

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
	Above 59	5	3.7
	Missing	1	0.7
Categorized department	Art	11	8.1
	Science	48	35.3
	Social science	68	50.0
	Missing	9	6.6
Work title	Lecturer	117	86.0
	Senior lecturers	5	3.7
	Principal/ Chief lecturer	6	4.4
	Non-academics (instructors)	2	1.5
	Missing	6	4.6
Teaching experience	below 2 years	2	1.5
	2 - 4 years	8	5.9
	5 – 9 years	36	26.5
	10 – 19 years	52	38.2
	Above 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	14.0
	Above 500	5	3.7
	Missing	15	11.0
Device ownership: (Phone, laptop, tablet, desktop computer)	Only one	10	7.4
	Combination of 2	70	51.5
	Combination of 3	43	31.6
	Combination of 4	12	8.8
	Others	1	0.7

These main TPACK survey questions contained five Likert Scale type questions (from strongly disagree to strongly agree) as designed by Schmidt et al. (2009) but with some revisions specifically to suit in-service teachers as against the initial design, which was for pre-service teachers. An example of such revision was in generalising the questions in terms of subjects taught to accommodate the various departments in the Nigerian colleges of education sampled. This implied that the TCK construct consisted of only one item ‘I know about technologies that I can use for understanding and teaching my subject'. Another example was in the TPK construct where the item referring to the teacher education program was not included. In addition, the item, "I can adapt the use of the technologies that I am learning about to different teaching activities" was changed to "I can adapt the use of the technologies that I know in different teaching activities". Table 2 contains the complete record of items used to measure the constructs for this study together with descriptive statistics. The mean of their responses to the items ranged between 2.66 and 4.77.

Table 2: *Items in the Questionnaire along with their Descriptive Statistics and Item Loadings*

Construct	Item	Item description	Mean	Standard deviation	Item loading
Technical Knowledge	TK1	I know about a lot of different technologies	3.80	1.010	0.658
	TK2	I have the technical skills I need to use technology	3.82	0.913	0.828
	TK3	I know how to solve my own technical problems	3.34	1.027	0.709
	TK4	I can learn technology easily	4.04	0.888	0.659
	TK5	I frequently play around the technology	3.58	1.054	0.737
	TK6	I have had sufficient opportunities to work with different technologies	3.27	1.119	0.742
Content Knowledge	CK1	I have various ways and strategies of developing my understanding of the subject I teach	3.97	1.025	0.934
	CK2	I have examples of how to apply the subject I teach in the real world	4.07	0.809	0.934
Pedagogical Knowledge	PK1	I can use different teaching methods in the classroom (collaborative, instruction, inquiry, problem based etc.)	4.26	0.779	0.824
	PK2	I can adapt my teaching style to different learners	4.23	0.730	0.863
	PK3	I know how to assess student performance and learning in different ways	4.27	0.683	0.832
	PK4	I am familiar with common student understandings and misconceptions of the subject.	4.10	0.822	0.814
	PK5	I can adapt my teaching based on what students currently understand or do not understand	4.18	0.732	0.815
Pedagogical Content Knowledge	PCK1	I know that different concepts in the subject I teach do not require different teaching approaches	2.66	1.268	0.736
	PCK2	I know how to select effective teaching approaches to guide student thinking and learning in the subject I teach	4.13	0.814	0.736
Technological Content Knowledge	TCK	I know about technologies that I can use for understanding and teaching my subject.	4.00	0.834	1.000
Technological Pedagogical Knowledge	TPK1	I have the technical skills I need to use technology appropriately in teaching	3.74	1.018	0.831
	TPK2	I can adapt the use of technologies that I know in different teaching activities	3.80	0.921	0.868
	TPK3	I think critically about how to use technology in my class	3.76	0.996	0.800
	TPK4	I can choose technologies that enhance my teaching approaches for a lesson	3.94	0.865	0.911
	TPK5	I can choose technologies that enhance students' learning during a lesson	3.93	0.869	0.891
Technological Pedagogical Content Knowledge	TPCK1	I can teach lessons that appropriately combine my subject, technologies, and teaching approaches.	3.79	0.890	0.906
	TPCK2	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	0.897
	TPCK3	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 Analysis

Models entrenched in theory can be tested using structural equation modelling (SEM) (Henseler, Hubona, & Ray, 2016; Schreiber et al., 2006). Therefore, SEM using the partial least squares (PLS) procedure as described by (Hair, Ringle & Sarstedt, 2011; Lowry & Gaskin, 2014) was utilized in this study. Secondly, given that the aim of the study was testing the TPACK framework within the Nigerian teacher educators' context as well as to explore the relationships among the seven constructs, the PLS was found most suitable compared to other SEM procedures. In addition, PLS is convenient for small sample sizes and there is less restriction on the constructs' measurement properties (for example, constructs measured by a single item can be utilized) (Hair et al., 2016). The WarpPLS 6.0 software (Kock, 2017) was used to conduct the data analysis, which subsequently provided information on the structural and measurement model.

RESULTS

Measurement model

For reflective models as is the case with the model in this study, reliability and validity are assessed in accordance with the stipulated benchmarks (Hair, Ringle & Sarstedt, 2011). The internal consistency reliability of the constructs, which is indicated by their Cronbach Alpha Coefficient (CAC) and Composite Reliability Coefficient (CRC), should be above 0.70. For PLS-SEM however, the CRC is more reliable (Lowry & Gaskin, 2014). In addition, the indicator reliability which is reflected in the item loading should be higher than 0.70.

The data in Table 3 indicates that the conditions for the reliability of the model are satisfied. Convergent validity is derived from the Average Variance Extracted (AVE) and the value should be higher than 0.50 while in the case of discriminant validity, the indicator loading should be higher than all its cross-loading (Hair et al., 2011). The data in Table 4, indicate that these conditions for convergent and discriminant validity were met.

Table 3: *Composite Reliability, Cronbach Alphas, Average Variance Extracted and Inter-Construct Correlations*

	CRC	CAC	AVE	TPCK	TPK	TCK	PCK	PK	CK	TK
TPCK	0.926	0.880	0.806	**0.898**	0.794	0.661	0.442	0.626	0.640	0.588
TPK	0.935	0.912	0.741	0.794	**0.861**	0.681	0.418	0.571	0.619	0.590
TCK	1.000	1.000	1.000	0.661	0.681	**1.000**	0.430	0.592	0.522	0.492
PCK	0.702	0.152	0.541	0.442	0.418	0.430	**0.736**	0.496	0.326	0.284
PK	0.917	0.887	0.689	0.626	0.571	0.592	0.496	**0.830**	0.413	0.392
CK	0.931	0.853	0.872	0.640	0.619	0.522	0.326	0.413	**0.934**	0.512
TK	0.868	0.817	0.525	0.588	0.590	0.492	0.284	0.392	0.512	**0.724**

CRC = Composite Reliability Coefficient, CAC = Cronbach Alphas Coefficient, AVE = Average Variance Extracted. Correlations among constructs are shown in the off-diagonal elements; The bold fonts in the leading diagonals are the square roots of AVEs.

Table 4: *Item Loadings and Cross-Loadings*

	TPCK	TPK	TCK	PCK	PK	CK	TK
TPCKI	**0.906**	0.718	0.599	0.369	0.559	0.612	0.495
TPCKII	**0.897**	0.739	0.626	0.420	0.600	0.538	0.543
TPCKIII	**0.890**	0.682	0.555	0.401	0.527	0.574	0.545
TPKI	0.683	**0.831**	0.663	0.293	0.458	0.506	0.620
TPKII	0.724	**0.868**	0.552	0.331	0.462	0.534	0.596
TPKIII	0.592	**0.800**	0.403	0.289	0.433	0.450	0.350
TPKIV	0.713	**0.911**	0.672	0.447	0.580	0.598	0.465
TPKV	0.702	**0.891**	0.628	0.426	0.517	0.559	0.508
TCK	0.661	0.681	**1.000**	0.430	0.592	0.522	0.492
PCKI	0.107	0.110	0.096	**0.736**	0.054	0.120	0.076
PCKII	0.543	0.505	0.536	**0.736**	0.676	0.360	0.343
PKI	0.520	0.523	0.535	0.420	**0.824**	0.443	0.271
PKII	0.538	0.512	0.547	0.483	**0.863**	0.356	0.343
PKIII	0.450	0.435	0.455	0.353	**0.832**	0.274	0.332
PKIV	0.602	0.470	0.455	0.443	**0.814**	0.333	0.349
PKV	0.490	0.429	0.461	0.356	**0.815**	0.307	0.329
CKI	0.596	0.577	0.502	0.266	0.347	**0.934**	0.507
CKII	0.600	0.579	0.472	0.343	0.424	**0.934**	0.449
TKI	0.447	0.452	0.475	0.306	0.370	0.326	**0.658**
TKII	0.477	0.480	0.449	0.227	0.366	0.380	**0.828**
TKIII	0.339	0.365	0.311	0.192	0.164	0.319	**0.709**
TKIV	0.472	0.428	0.353	0.200	0.305	0.540	**0.659**
TKV	0.401	0.429	0.242	0.147	0.205	0.351	**0.737**
TKVI	0.425	0.416	0.317	0.176	0.294	0.326	**0.742**

Note. The bold fonts highlight the item loadings. They are all higher than their cross-loadings (that is, the discriminant validity condition is satisfied).

Structural model

The result of the analysis shows the relationship between the constructs of the study - TK, PK, CK, TPK, TCK, PCK and TPACK. The Goodness of Fit (GoF) is globally used as a measure of fit for explaining the performance of both the structural and measurement model (Tenenhaus et al., 2005). In this study, the GoF value for this model is 0.59, indicative of the data's capability in estimating the model when compared with the 0.36 threshold (Akter, D'Ambra, & Ray, 2011). According to Hair, Ringle & Sarstedt (2011) and their recommended benchmarks, the objective of evaluating the structural model is to explain the variance among the endogenous constructs. The R-squared measures (R^2), the path significance (ρ - value) and the path coefficient (β) which are criteria used to evaluate the structural model are shown in Figure 2. The figure shows that eight of the nine paths depicted in the model were supported significantly by the data and that the R^2 values are above the 0.20 benchmark (Hair, Ringle & Sarstedt, 2011). The model did not require a revision since the R^2 coefficients in the model were above 0.02 (Kock, 2017). The Q-squared (Q^2) coefficient through the endogenous constructs is used to evaluate the predictive validity of the model (Hair et al., 2011; Kock, 2015b). Thus, the Q^2 coefficient of TPCK, TPK, TCK and PCK are 0.67, 0.51, 0.36 and 0.35 respectively.

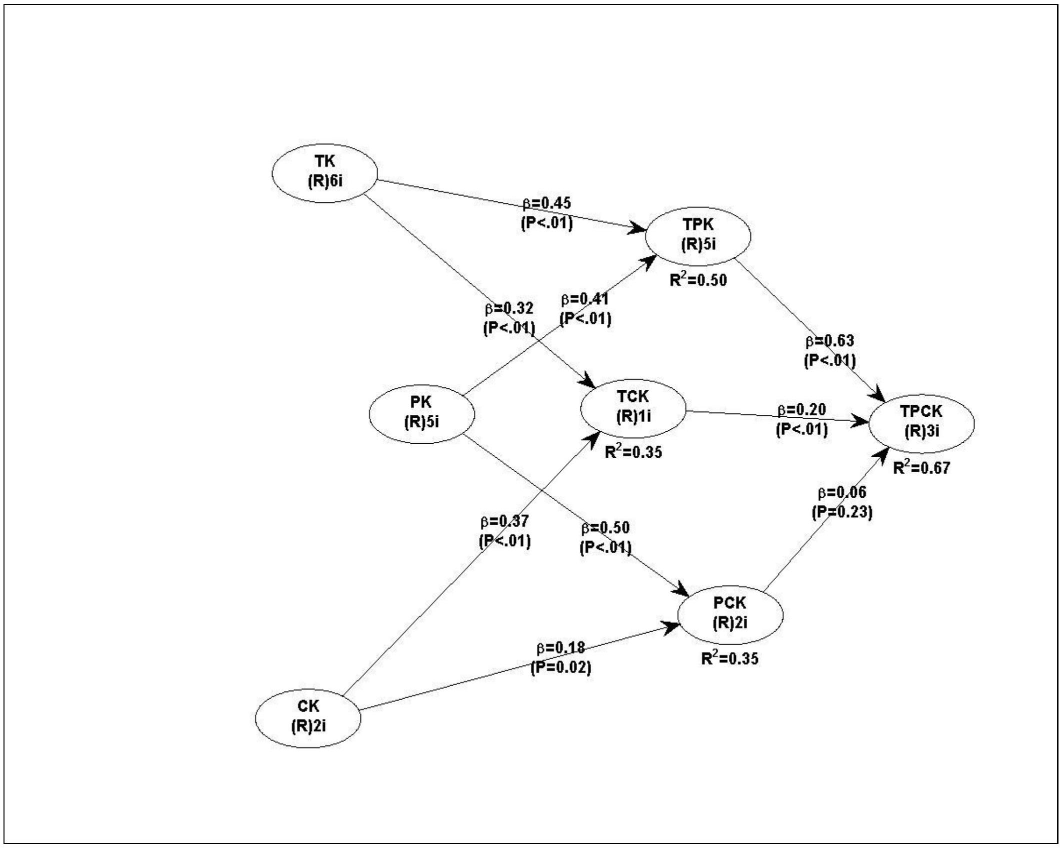

Figure 2: Partial least squares (PLS) analysis result for the proposed model.

Research Question 1: What are the Nigerian teacher educators' TPACK perceptions?

Table 2 shows the mean of each of the three items (TPCK 1, 2 and 3) used to measure the teachers' perception of their TPACK. The lowest mean of 3.79 is indicated by TPCK 1 (that assesses their ability to adequately combine knowledge of technology, subject and teaching approaches) while the highest mean of 3.83 is indicated by TPCK 3 (that assesses their ability to provide leadership in helping others to coordinate the use of content, technologies, and teaching approaches in their school). In summary, the average mean of the teacher educators' perception of their TPACK is 3.81 and in reference to the Likert scale used, this result is above average.

Research Question 2: What relationship exists among the variables of the TPACK construct?

The result shows that all three main components of knowledge (TK, PK, and CK) are direct predictors of their individual interrelationships resulting in TPK, TCK and PCK. Among the three dyadic constructs comprising of their primary knowledge constituents, TPK was best explained by the strength of TK and PK in their variation of 50%. Thus, implying that the teacher educators' knowledge of their technological and pedagogical skills improves significantly the perception of their TPK. In sum, the result shows that the range from 35 to 67% explains the amount of variance resulting from the interactions of the endogenous constructs. This implies the amount of variance in the teacher educators' belief of their TPACK that is explained by the relationship of their TPK, TCK and PCK at 67%.

The model shows that TK was significantly associated with both TPK ($\beta = 0.48$, $\rho < 0.001$) and TCK ($\beta = 0.32$, $\rho < 0.001$). Similarly, PK was significantly associated with both TPK ($\beta = 0.41$, $\rho < 0.001$) and PCK ($\beta = 0.50$, $\rho < 0.001$). In addition, CK was significantly associated with both TCK ($\beta = 0.37$, $\rho < 0.001$) and PCK ($\beta = 0.18$, $\rho = 0.02$ or $\rho < 0.05$).

Similarly, for the endogenous constructs, the model reflects significant and positive associations. The TPK was significantly associated with TPCK ($\beta = 0.63$, $\rho < 0.001$), TCK was significantly associated with TPCK ($\beta = 0.20$, $\rho < 0.01$) while PCK was not significantly associated with TPCK ($\beta = 0.06$, $\rho = 0.23$). In the TPK domain, it suggests that the teacher educators' perception of their Technological Knowledge ($\beta = 0.45$, $\rho < 0.001$) and Pedagogical Knowledge ($\beta = 0.41$, $\rho < 0.001$) were positively associated with their TPK. This relationship is explained by the 50% variance in the Technological Pedagogical Knowledge in the model. The instance of TCK indicates that the teacher educators' opinion of their TK ($\beta = 0.32$, $\rho < 0.001$) and CK ($\beta = 0.37$, $\rho < 0.001$) were positively associated with their TCK. The model explained 35% of the variance in their TCK. For the PCK, the teacher educators' view of their PK ($\beta = 0.50$, $\rho < 0.001$) and CK ($\beta = 0.18$, $\rho = 0.02$ or $\rho < 0.05$) were positively associated with their PCK. In the model, the variance of the teacher educators' PCK explained by their PK and CK is 35%. Finally, in the TPCK domain, while the teacher educators' perception of their TPK ($\beta = 0.63$, $\rho < 0.001$) and TCK ($\beta = 0.20$, $\rho < 0.001$) were associated positively with their TPCK belief, their PCK ($\beta = 0.06$, $\rho = 0.23$) was not.

DISCUSSION

The interactive relations between the primary knowledge constructs of the Technological Pedagogical Content Knowledge (TPACK) framework has provided a basis for a number of studies specifically in understanding how teachers can integrate technology in their classrooms. The objective of this study was to evaluate the TPACK of the Nigerian teacher educators and the relationships among their knowledge domains. On examining the Nigerian teacher educators' TPACK, the result shown in the model of the study suggests that at the primary knowledge level, TK, PK, and CK are significant predictors of their respective second level knowledge bases - TPK, TCK and PCK. However, at the second level knowledge bases, while the TPK and TCK of the Nigerian teacher educators are apparently significant predictors of their TPACK, their PCK's are not. This result is in keeping with that identified by Khine, Ali & Afari (2017); Koh, Chai, & Tsai (2013 in their studies of teachers within the UAE and Singaporean contexts respectively. Although, the hypothetical model proposed by Khine et al. (2017) does not include the TCK construct and examines the case of preservice teachers. Conversely, Celik, Sahin & Akturk (2014) in their investigation of Turkish pre-service teachers found that their TPACK was predicted significantly by their PCK and TCK but not TPK.

In addition, as a predictor of its secondary knowledge base, CK has the least direct effect size among the primary knowledge bases while the PK has the highest. Koh, Chai & Tsai (2013) study findings could be used to explain a possible reason for low CK effect size, which they describe as circumstantial in the sense that the teachers do not perceive ICT tools as integral aspects of the subjects they teach. Nevertheless, results from the study by Chai et al., (2011) show that during the training period, consisting of a combination of ICT designed courses and content courses occurring simultaneously, the Singaporean pre-service teachers' CK was clearly increased. Within the Nigerian context, the teacher educators' low CK can be adjudged to the fact that teachers use outdated teaching practices and are not motivated to enforce the curricula because they lack the necessary training opportunities (Ofoegbu, Okaro & Okafor, 2018). As such, 'learning by design approach' training (Koehler & Mishra, 2005) can provide conducive environments for teachers to understand practical ways in line with current methods, on how to apply ICT tools in their specific subjects.

Directly and indirectly, both PK and TK are significant predictors of the Nigerian teacher educators' TPACK. However, overall, the TPK has the highest direct effect size on TPCK. This could signify that being experienced teachers with average teaching experience above ten years (from the demographics), Nigerian teacher educators believe in the benefits of ICT use in their teaching. Similarly, this could imply that pedagogical knowledge when appropriately integrated with knowledge of technology produces a significant effect on technology integration. Contrary to our result is the finding by Koh, Chai and Tsai, (2013), where the Singaporean teachers perceived their TCK to have the largest effect on their TCPK. In the Shanghai context, the study by Wu et al., (2016) infers that the relatively new teachers perceived both TPK and PCK as significant predictors of their TPCK (with higher TPK) albeit it should be noted that in this case, the evaluation was conducted after an ICT professional training course. Thus, in reiterating the recommendations for the professional development of teachers, the Nigerian teacher educators' CKs and PCKs can be improved when adequate hands-on and subject specific training is designed to be integrative.

CONCLUSION

Theoretically, this study offers a broader insight on discussions surrounding teachers' technology integration by evaluating the teacher educators' perception of their technology integration within the Nigerian context. The result of the study showed that the TPACK framework is relevant for understanding how teachers integrate technology in their classrooms, and what professional development programmes can be designed to strengthen areas of their TPACK where they are found to be weak. Noteworthy is the identification of the seven constructs with the two paths to achieve TPACK as previously hypothesized by Koh et al., (2013). Within the Nigerian context, the result showed that the teachers' TPK predominantly explained their TPACK and that their PCK did not have any influence. In explaining the relationship between the seven constructs, all three primary knowledge bases were significant predictors of the secondary knowledge bases but only two of the latter predicted their TPACK significantly.

In practice, teachers are expected to champion the cause of technology integration in their classrooms in order to produce learners, future teachers and other professionals that fit the 21st century skills requirement of the workplace. In this light, one of the major practical implications of this research is the need for updating the content of the curricula in order to strengthen the teachers' content knowledge, which in turn strengthens their pedagogical content and technological content knowledge and eventually their technological pedagogical and content knowledge. School administrators can organise training that provide collaborative and motivating opportunities for the teachers to contribute to the process of developing the required content (Koehler & Mishra, 2005; Stoilescu, 2015). Subsequent training involving the use of available ICT tools in different subject areas as it applies to the teacher can be designed. From the data, over 90% of the teachers own more than one mobile device, which shows opportunities for technology integration in teaching abound. Nevertheless, the process of achieving success in teacher's technology integration demands the reinforcement of policies, appropriate strategies and investments by all relevant levels of the schools' governance. However, as pointed out by Dlamini and Mbatha (2018), these policies are more effective when teachers are involved in the decision-making process and when the implementation strategy uses a bottom-up approach (Dintoe, 2019).

Limitations and Future Work

In considering the limitations of this research, first, we point out that the data analysis was based on responses to self-completion questionnaires and thus social desirability bias may apply. Second, the participants are from three schools within the southern part of Nigeria; therefore, caution should be applied in generalizing to the entire country since differences in culture and values for formal education exist. Third, a convenience sample, which was affected by exogenous factors, was used. Fourth, the sample size is relatively small although any bias is reduced when PLS is applied. Fifth, it should be noted that the research participants are teacher educators and as such, the findings may not apply to teachers outside the colleges of education context. Future research can extend this study by addressing the above limitations. Further, studies comparing the teachers' TPACK pathways (with pre-service teachers) or with other regions within the Nigerian context as well as other African countries can be conducted. The use of longitudinal data, observation and interviews can be employed to enrich the data. In addition, increasing the items measuring the subscales of CK, PCK and TCK may improve the survey instrument as recommended by Schmidt et al. (2009).

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