How Do the Constructs of the TPACK Framework Relate with Use of ICT in Pedagogy among Teachers of Mathematical Disciplines in Universities in Uganda?

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ABSTRACT

This study sought to establish the relationship between use of ICT in pedagogy (UIP) and knowledge among teachers of mathematical disciplines in universities in Uganda. Knowledge was conceptualized according to the Technological Pedagogical Content Knowledge (TPACK) framework as having seven constructs, namely content knowledge (CK); pedagogical knowledge (PK); technological knowledge (TK); pedagogical content knowledge (PCK); technological pedagogical knowledge (TPK); technological content knowledge (TCK); and technological pedagogical content knowledge (TPACK). Data were collected from 261 respondents using a questionnaire, and analysed using factor analysis, Cronbach alpha, means and multiple regression. Means indicated that while the respondents rated themselves as only fair on UIP, they rated themselves high on pedagogical and content knowledge constructs (PCK, CK & PK) and low on technology knowledge constructs (TPACK, TPK, TK & TCK). Regression revealed that apart from the TPACK construct, none of the other six knowledge constructs was a significant correlate of UIP. It was concluded that in order to use ICT in pedagogy, teachers need TPACK in its entirety and not its constituents. It was thus recommended that when training teachers for UIP, the respective stakeholders in the various universities should ensure that the training is wholesome on content, pedagogy and technology.

Keywords: ICT, Knowledge, Mathematical disciplines, Pedagogy, Universities.

INTRODUCTION

Mishra and Koehler (2006) proposed the Technological Pedagogical Content Knowledge (TPACK) framework that predicts a teacher's use of ICT in pedagogy (UIP). According to Mishra and Koehler, for effective UIP, a teacher needs three primary domains of knowledge namely content knowledge (CK), pedagogical knowledge (PK) and technological knowledge (TK). The interaction between the three primary knowledge domains (CK, PK & TK) gives rise to three secondary knowledge domains namely pedagogical content knowledge (PCK), technological content knowledge (TCK) and technological pedagogical knowledge (TPK). These combinations of knowledge, according to TPACK, enhance UIP by teachers. When PCK, TCK and TPK knowledge domains interact, they form a triad, technological pedagogical content knowledge (TPACK), which according to TPACK, is the ideal combination of knowledge needed by a teacher for effective UIP. In summary, the TPACK framework suggests seven knowledge domains (CK, PK, TK, PCK, TPK, TCK, & TPACK) as major determinants of UIP by teachers. The definition and importance of each of the seven knowledge constructs according to Mishra and Koehler (2006) are given in Table 1.

Since the inception of the TPACK framework in 2006, several researchers have employed it to guide their studies. According to Batiibwe and Bakkabulindi (2016), while some researchers have made seminal contributions to TPACK, others have examined teachers and/ or students on how much TPACK they possessed. Yet others have had interest in the development of TPACK among teachers and/ or students. Some contributors have developed and tested survey instruments to measure TPACK, while others have reviewed literature on the progress of TPACK as a framework. However, none of the studies have related TPACK and the use of ICT in pedagogy as separate variables. Hence, in order to reduce this gap, in this study, the levels of use of ICT in pedagogy by the teachers were examined as the first objective of the study. Second, the study set out to examine the levels of TPACK that the teachers possessed and third, to establish the relationship between the two levels. Teachers of mathematical disciplines in universities in Uganda namely Makerere, Makerere University Business School, Kyambogo and Mountains of the Moon were used as the units of analysis.

Table 1: Definition and Importance of Each of the Knowledge Constructs

Knowledge construct	Definition of the construct of knowledge	Importance of the construct of knowledge
Content Knowledge (CK)	Knowledge about the actual subject matter that is to be taught (Mishra & Koehler, 2006, p. 1026).	Influences how the teacher engages students with the subject matter and how they evaluate and use instructional materials like ICT.
Pedagogical Knowledge (PK)	Knowledge about the processes and practices or methods of teaching and learning and how it encompasses…overall educational purposes, values and aims (Mishra & Koehler, 2006, p. 1026).	Gives a teacher an understanding of how students construct knowledge, acquire skills, and develop habits of mind and positive dispositions toward learning (Mishra & Koehler, 2006, p. 1027).
Technological Knowledge (TK)	Knowledge about standard technologies, such as books, chalk and blackboard, and more advanced technologies, such as the Internet and digital video (Mishra & Koehler, 2006, p. 1027)	Gives the teacher the ability to install, operate and use ICT tools in order to enhance learning.
Pedagogical Content Knowledge (PCK)	Knowledge of pedagogy that is applicable to the teaching of specific content (Mishra & Koehler, 2006, p. 1027)	Helps the teachers in the representation and formulation of concepts and gives them the knowledge to discern what makes particular concepts difficult or easy to learn.
Technological Pedagogical Knowledge (TPK)	Knowledge of existence, components, and capabilities of various technologies as they are used in teaching and learning settings, and conversely, knowing how teaching might change as the result of using particular technologies (Mishra & Koehler, 2006, p. 1028).	Helps the teachers to understand the range of ICT tools that exist for a particular task. The teacher is also able to choose ICT tools based on their fitness, have strategies for using the ICT tools' affordances, and know the pedagogical strategies which he/ she can apply for use of ICT.
Technological Content Knowledge (TCK)	Knowledge about the manner in which technology and content are reciprocally related (Mishra & Koehler, 2006, p. 1028).	Helps the teacher to know the manner in which the subject matter can be changed by the application of ICT tools.
Technological Pedagogical Content Knowledge (TPACK)	An emergent form of knowledge that goes beyond all the three components (content, pedagogy, and technology) (Mishra & Koehler, 2006, p. 1028)	Gives the teachers a chance to know what makes concepts difficult or easy to learn and how the use of ICT can help scale down some of the difficulties that learners face while learning. TPACK also helps teachers to develop pedagogical techniques that use ICT in constructive ways to teach content.

Source: Mishra and Koehler (2006)

RELATED LITERATURE

Studies on the Levels of Use of ICT in Pedagogy

Several researchers have devoted time and effort to establish the levels of use of ICT in teaching and learning by teachers and/ or students. For example, Coleman, Gibson, Cotton, Howell-Mooney and Stringer (2016) examined the relationship between internal barriers, professional development and computer integration outcomes among fifth-grade teachers in an urban, low-income school district in the southeastern United States. In their study, 66 teachers filled a questionnaire while they observed 54 teachers while teaching in a classroom. All these teachers were participating in a project titled "Integrating Computing across the Curriculum". Using descriptive statistics, Coleman et al. (2016) found fair levels of use of ICT in the teaching and learning process.

Ghavifekr and Rosdy (2015) analyzed the perceptions of teachers on the effectiveness of ICT integration to support the teaching and learning process in the classrooms. They collected data from 101 teachers from 10 public secondary schools in Malaysia using a self-administered questionnaire. Using descriptive statistics, Ghavifekr and Rosdy found that the teachers were not prepared well to use ICT tools while teaching, which implied low levels of UIP. Kolodziejczyk (2015) explored gender issues in the access, application and attitudes toward ICT in higher education institutions in Papua, New Guinea. In his mixed methods study, he collected data from 898 students and 64 faculty members by using two questionnaires (one for the students and the other for the academic staff) and interviews. Whereas all the participants filled a questionnaire, only twenty-three academic staff were interviewed. Using descriptive statistics and thematic networks, he found that the participants had access to computers only during their time at the institution, indicating fair levels of UIP.

Lubega, Mugisha and Muyinda (2014) assessed the adoption of ICT in pedagogy by the academic staff and students of Makerere University in Uganda. Using the substitution, augmentation, modification and redefinition (SAMR) model (Puentedura, 2010) of UIP, they developed an instrument that they used to collect data from 600 respondents. Lubega et al. used percentages to analyze their data. At the substitution stage they found that "a number of teaching activities had yet to be computerized even at the basic substitution level" (p. 110). As regards the augmentation stage, they reported that "more pedagogical activities in and outside the classroom had mainly ported onto substitution ICTs than augmentation ICTs" (p. 111). At the modification stage, Lubega et al. (2014) reported that "the most common modification ICT [was] the Internet" (p. 112). Finally at the redefinition stage, according to them, there were almost no activities. In other words, the majority of respondents had never used most of the modification and redefinition ICTs.

Salleh and Laxman (2015) developed and assessed a theoretical model that could predict and explain teachers' use of ICT by focusing on psychosocial factors. They employed a survey research method to collect data from 1,040 teachers using a questionnaire whose validity and reliability they had ensured. The teachers were from 18 government secondary schools in four districts in Malaysia. Using descriptive statistics, Salleh and Laxman indicated that although computers were highly accessible by the teachers, they were underused. However, the above empirical literature points at gaps. For example, of the five studies reviewed, only one (Lubega et al., 2014) had been conducted in Africa and particularly Makerere University in Uganda. However, none of them specifically dealt with the teachers of mathematical disciplines, which is the thrust of the current study.

Studies on the Levels of TPACK

Efforts to examine the extent to which teachers and/ or students possessed TPACK have been made by several researchers. For example, Chai, Chin, Koh and Tan (2013) investigated the profile of in-service Singaporean Chinese language teachers' TPACK and their pedagogical beliefs. They began by validating an adapted and contextualized questionnaire titled the "Technological Pedagogical Chinese Language Knowledge" (TPCLK), which also had open-ended questions. Using the questionnaire, they collected data from 349 in-service Chinese teachers who were attending courses in the Singapore Center for Chinese Language (SCCL). Using constant comparative analysis, they found that the teachers had rated themselves as most competent in content knowledge but least competent in TPACK.

Chong and Shaffe (2015) investigated the TPACK of elementary special education (hearing impairment) teachers in Malaysia, with respect to three key domains (TK, PK, CK), and their combinations. They developed a self-administered questionnaire which included all the seven constructs of TPACK, which they used to collect data from 88 teachers. The teachers were from three states, namely Selangor, Kuala Lumpur and Negeri Sembilan. Using descriptive statistics, Chong and Shaffe found that the teachers had perceived high confidence in CK, PK, and PCK. However, the teachers had been less confident when it came to TK. They also found that technology-related TPACK components had comparatively low mean scores which indicated that these teachers were struggling to be in the field of technology-driven instruction.

Karaca (2015) intended to determine the TPACK levels of pre-service education teachers at Ataturk Faculty of Education in Marmara University, Istanbul, Turkey. His sample of study involved 142 undergraduate students who completed a questionnaire. Using descriptive statistics, Karaca found that the teachers had only a fair level of TPACK. Redmond and Lock (2013) sought to describe the experiences with TPACK of pre-service secondary teachers. In their study, 55 teachers who were attending a curriculum and pedagogy course completed an online TPACK survey. These teachers were in their second year of a four year graduate diploma at a regional university in Australia. The teachers too, completed their second professional experience placement in schools at the end of the semester. Using descriptive statistics, Redmond and Lock found that the teachers' highest confidence had been in their CK component.

Xiang and Ning (2014) investigated the profile of Chinese pre-service mathematics teachers' TPACK. They used a 29-item instrument adapted from the 58-item Schmidt, Baran, Thompson, Mishra, Koehler and Shin's (2009) and the 24-item Archambault and Crippen (2009)'s surveys. Having translated the instrument into Chinese, they used it to collect data from 106 teachers, from Hunan in China. Hence, they used descriptive statistics to show that teachers had perceived themselves strongest in the construct of CK and weakest in terms of TPACK. Overall, they reported that scores of technology-related factors were lower than the non-technological related factors. Of the five studies reviewed, four (Chai, Chin et al., 2013; Chong & Shaffe, 2015; Karaca, 2015; Xiang & Ning, 2014) had been conducted in Asia; and one study (Redmond & Lock, 2013) in Australia, hence suggesting a bias against the African continent. This called for more research on the assessment of the levels of TPACK among teachers in Africa.

LITERATURE REVIEWS ON THE TPACK FRAMEWORK

Other than empirical studies on the levels of use of ICT in pedagogy, some researchers have reviewed literature on the studies that have employed the TPACK framework as their theoretical base. For example, Graham (2011) in a critical review of the studies on the TPACK framework, noted that most researches had been devoted more to the descriptive value of the TPACK framework than to its prescriptive value. The descriptive value of the theory according to Graham is its power to help in describing a phenomenon, while the prescriptive value is the way the theory facilitates the researchers' ability to develop interventions that will predictably influence the phenomenon. In other words, Graham was complaining that the TPACK framework has been used to describe how much TPACK a group of teachers and/ or students possess, but not to prescribe how much TPACK a given teacher and/ or student should have in order for him or her to effectively use ICT in pedagogy (UIP).

Hence, this study sought to test whether the constructs of TPACK really related to the constructs of UIP. Unlike in all the previous studies, in this study the constructs of TPACK were measured separately from the construct of UIP. On the basis of the TPACK framework, Figure 1 provided a framework relating the seven knowledge domains of TPACK to UIP. The dependent variable which is UIP was conceptualized as the use of substitution, augmentation, modification and redefinition ICTs (Lubega et al., 2014 basing on Puentedura, 2010). On the other hand, knowledge domains were conceptualized as CK, PK, TK, PCK, TPK, TCK and TPACK (Mishra & Koehler, 2006). Hence the following hypotheses were tested in the study using a quantitative method, namely, multiple regression:

H1: CK positively relates to UIP
H2: PK positively relates to UIP
H3: TK positively relates to UIP
H4: PCK positively relates to UIP
H5: TPK positively relates to UIP
H6: TCK positively relates to UIP
H7: TPACK positively relates to UIP

Independent Variables* (TPACK Knowledge Domains) **Dependent Variable**** (Use of ICT in Pedagogy)

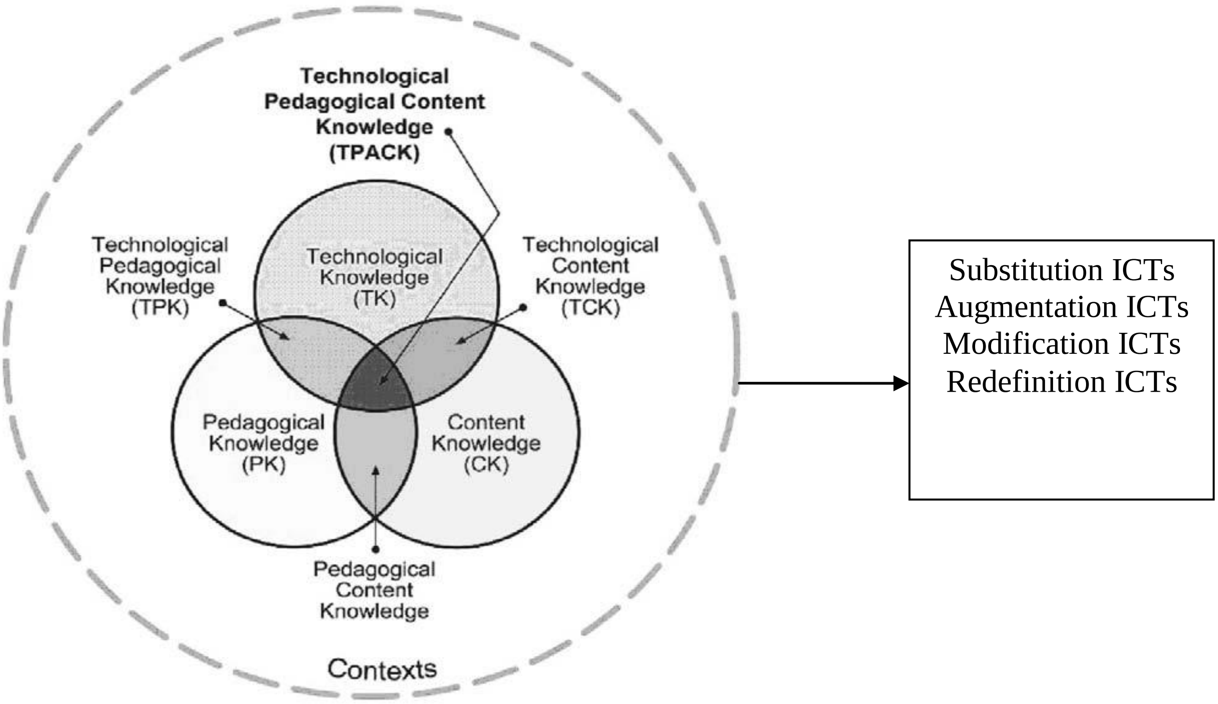

Figure 1: Conceptual framework relating the seven knowledge domains of TPACK to UIP
*Source: Concepts adapted from *Mishra and Koehler (2006) and **Lubega et al. (2014)*

METHOD

Instrument

The instrument had four constructs on the use of ICT in pedagogy (UIP). UIP was conceptualized as the use of substitution ICTs (S) (13 items); augmentation ICTs (A) (16 items); modification ICTs (M) (10 items); and redefinition ICTs (R) (six items). The 45 items on UIP were adapted from Lubega et al. (2014). Using face validity to eliminate items that did not conform to teachers of mathematical disciplines, the items on S reduced from 13 to 12; those for A reduced from 16 to nine; those for M reduced from 10 to five; and those for R reduced from six to five. Thus, in total, there were 31 items on UIP. However, neither the validity nor the reliability of the S, A, M, and R items on UIP had been ensured by Lubega et al. (2014). The items adapted from Lubega et al. (2014) had been scaled from 1 (Very rarely or never) to 5 (Very regularly).

On the other hand, the instrument had seven knowledge domains as suggested by the TPACK framework namely CK (three questions from Schmidt et al., 2009 with $\alpha = 0.85$); PK (seven questions from Schmidt et al., 2009 with $\alpha = 0.84$); TK (seven question from Schmidt et al., 2009 with $\alpha = 0.82$). PCK had five questions from Chai, Ng, Li, Hong and Koh (2013) with $\alpha = 0.92$; TPK had four items from Chai, Chin, et al. (2013) with $\alpha = 0.90$; and TCK had four questions from Chai, Ng et al. (2013) with $\alpha = 0.92$. Lastly, TPACK had six questions from Chai, Ng et al. (2013) with $\alpha = 0.92$. As Chai, Chin et al. (2013), Chai, Ng et al. (2013), and Schmidt et al. (2009) had done, the items being attitude or opinion items, were measured using Likert five-point ranked scale ranging from 1 (Strongly disagree) to 5 (Strongly agree).

Sample

The sample consisted of 261 academic staff teaching mathematical disciplines in universities in Uganda namely Kyambogo (KyU), Makerere (Mak), Makerere University Business School (MUBS), and Mountains of the Moon (MMU). The term mathematical discipline was taken to be broad and included a range of disciplines where quantitative skills were useful. Such disciplines included Science, Technology, Engineering and Mathematics (STEM) disciplines and their offshoots, such as Accounting, Biostatistics, Physics, and Quantitative Research Methods. The majority (62.9%) of the respondents were aged 30 but below 40 years as compared to those (21.4%) who were aged 40 years and above and those (15.7%) aged below 30 years. Thus, the majority of the respondents were middle aged.

The males (64.0%) dominated the sample as compared to the females (36.0%). The respondents as regards the universities to which they belonged were distributed as follows: MUBS (36.0%), Mak (33.3%), KyU (19.2%) and MMU (11.5%). Hence, MUBS contributed highest to the sample. When it came to tenure of lecturing at university level, the majority (56.6%) of the respondents had served for less than five years as compared to those (34.1%) that had served five but less than ten years and those (9.2%) that had served ten years and above. While 69.6% of the respondents held a Masters degree as their highest academic qualification attained, 22.7% held a PhD and 7.7% held a bachelors degree. Almost half (48.8%) of the respondents held the academic rank of lecturer, while the others were distributed as follows: assistant lecturers (26.2%), senior lecturers (14.2%), teaching assistants (7.7%), associate professors (2.3%) and professors (0.8%).

Data Analysis

The validities of multi-item constructs of UIP namely S, A, M, and R and those of TPACK namely CK, PK, TK, PCK, TPK, TCK, TPACK were tested using confirmatory factor analysis (CFA) and their reliabilities were tested using the Cronbach Alpha method. Accordingly, the items of S reduced from 12 to five in number; the nine items of A reduced to five in number; the five items of each of M and R were retained intact. All the items of each of the constructs of TPACK remained intact. To achieve the first and second objectives in the study, the items of TPACK and SAMR were described in terms of their means and their overall rating based on the five-point Likert scale. The third objective, that is, establishing whether the constructs of the TPACK framework related with the use of ICT in pedagogy, was achieved using multiple regression.

FINDINGS

Use of ICT in Pedagogy

The first objective of this study was to examine the levels of use of ICT in pedagogy (UIP) by the respondents. UIP had been broken into four constructs, namely the use of substitution ICTs (S) (five items; $\alpha = 0.920$); the use of augmentation ICTs (A) (five items; $\alpha = 0.861$); the use of modification ICTs (M) (five items; $\alpha = 0.842$); and the use of redefinition ICTs (R) (five items; $\alpha = 0.888$). Each item had been scaled from a minimum of 1 (for Very rarely or never) and 5 (for Very regularly). Tables 2 through 5 give the means and ratings of the items of each of the SAMR construct. According to Tables 2 through 5 respectively, the constructs S, A, M and R had means of 2.95, 2.82, 2.89, and 2.77 respectively. These values indicate fair use of each category of ICTs. An overall average index ("UIP" from the 31 items in Tables 2 through 5) had a mean = 2.86, which suggested that overall the respondents were fair users of ICT in pedagogy.

Table 2: Means for the construct of use of substitution ICTs (S)

Item	Mean	Rating
I upload my teaching and learning materials on electronic sites/ devices (e.g. MUELE) for students to access	3.10	Fair
During my lectures, I use the smart boards/ interactive boards installed in the lecture rooms for writing	3.10	Fair
I encourage students to submit their course work assignments through e-mail	3.05	Fair
When communicating to my students, I use electronic notice boards	2.72	Fair
When supporting my students, I communicate to them through social Media (e.g. blogs, chat rooms, discussion boards, Facebook, Instagram and Twitter)	2.86	Fair
Overall	2.95	Fair

Table 3: Means for the construct of use of augmentation ICTs (A)

Item	Mean	Rating
I use digital libraries (e.g. Mulib and MakIR) as a source of useful content for my lectures	2.68	Fair
I use the track changes tool in my word processor to review documents (e.g. student dissertations/ theses)	3.23	Fair
I use internet group lists to contact my students in matters related to their academics	3.06	Fair
I encourage my students to use Google docs to accomplish group course work assignments	3.05	Fair
I use different videos to illustrate different case studies during my lectures	2.10	Rare
Overall	2.82	Fair

Table 4: Means for the construct of use of modification ICTs (M)

Item	Mean	Rating
I assign students topics to research about from the Internet	4.09	Regular
I lecture modules in my discipline using e-learning platforms (e.g. MUELE)	3.17	Fair
I use content authoring software when preparing my lectures	2.90	Fair
I use online tools (e.g. RM Assessor) to assess my students	2.50	Fair
I use video conferencing or Skype to teach my students when I am not at the University	1.77	Rare
Overall	2.89	Fair

Table 5: Means for the construct of use of redefinition ICTs (R)

Item	Mean	Rating
I use open education resources (e.g. massive open online courses, MOOCs) as my lecturing materials	3.06	Fair
I use electronic games when lecturing	1.83	Rare
I use simulations (e.g. 2nd life) when lecturing	2.76	Fair
I use e-learning platforms (e.g. MUELE) to encourage group discussions among my students	3.15	Fair
I use e-learning platforms (e.g. MUELE) to assess my students' learning	3.06	Fair
Overall	2.77	Fair

TPACK Knowledge Constructs

The TPACK constructs in the study were CK (three items; α = 0.913); PK (seven items; α = 0.909); TK (seven items; α = 0.948); PCK (five items; α = 0.917); TPK (four items; α = 0.906); TCK (four items; α = 0.919); and TPACK (six items; α = 0.934). All the items were Likert-scaled from 1 (for Strongly Disagree) and a maximum of 5 (for Strongly Agree). Tables 6 through 12 give means and ratings of the items of each of the TPACK constructs. According to Tables 6 through 12, the means of the respective knowledge constructs were CK (4.35), PK (4.34), TK (2.52), PCK (4.36), TPK (2.66), TCK (2.41) and TPACK (2.68). These values imply that teachers rated themselves high on pedagogical and content constructs (PCK, CK & PK in that order) and low on the technology constructs (TPACK, TPK, TK & TCK in that order).

Table 6: Means for the construct of content knowledge (CK)

Item	Mean	Rating
I have sufficient knowledge about mathematical literacy relevant to what I lecture	4.32	Agree
I can use the mathematical way of thinking whenever lecturing	4.39	Agree
I have various strategies of developing my mathematical literacy	4.32	Agree
Overall	4.35	Agree

Table 7: Means for the construct of pedagogical knowledge (PK)

Item	Mean	Rating
I have adequate knowledge on how to assess student performance	4.37	Agree
I can adapt my lecturing based upon what students currently do not understand	4.35	Agree
I can adapt my lecturing style to different learner types	4.33	Agree
I can assess student learning in multiple ways	4.32	Agree
I can use a wide range of lecturing approaches	4.37	Agree
I am familiar with common student understandings and misconceptions in my discipline	4.23	Agree
I know how to organize and maintain a conducive lecture environment	4.37	Agree
Overall	4.34	Agree

Table 8: Means for the construct of technological knowledge (TK)

Item	Mean	Rating
I know how to troubleshoot technical problems that arise while I am lecturing	2.68	Undecided
I easily learn to use technology for lecturing	2.68	Undecided
I keep up with important new technologies for lecturing	2.63	Undecided
I easily play around with technology while lecturing	2.55	Undecided
I know a lot about different technologies for lecturing	2.54	Undecided
I have the technical skills I need to lecture with technology	2.64	Undecided
I have had sufficient opportunities to lecture with different technologies	2.00	Disagree
Overall	2.52	Undecided

Table 9: Means for the construct of pedagogical content knowledge (PCK)

Item	Mean	Rating
Without using technology, I can help my students to understand the content of my discipline through various ways	4.43	Agree
Without using technology, I can address the common learning difficulties my students have for my discipline	4.33	Agree
Without using technology, I can facilitate meaningful discussion among my students about the content in my discipline	4.41	Agree
Without using technology, I can engage students in solving real world problems related to my discipline	4.30	Agree
Without using technology, I can support students to manage their learning of my discipline	4.32	Agree
Overall	4.36	Agree

Table 10: Means for the construct of technological pedagogical knowledge (TPK)

Item	Mean	Rating
I am able to facilitate my students to use technology to find more information on their own	2.77	Undecided
I am able to facilitate my students to use technology to plan and monitor their own learning	2.51	Disagree
I am able to facilitate my students to use technology to construct different forms of knowledge representation	2.65	Undecided
I am able to facilitate my students to collaborate with each other using technology	2.73	Undecided
Overall	2.66	Undecided

Table 11: Means for the construct of technological content knowledge (TCK)

Item	Mean	Rating
I can use the software that are created specifically for my discipline	2.68	Undecided
I know the technologies available for research for content in my discipline	2.67	Undecided
I can use appropriate technologies to present the content of my discipline	2.31	Disagree
I can use specialized software to perform inquiry about my discipline	2.07	Disagree
Overall	2.41	Undecided

Table 12: Means for the construct of technological pedagogical content knowledge (TPACK)

Item	Mean	Rating
I can formulate in-depth discussion topics in my discipline and facilitate students' online collaboration with appropriate tools	2.73	Undecided
I can set authentic problems related to topics in my discipline and present them through technology to engage my students	2.69	Undecided
I can facilitate students' construction of knowledge in my discipline using appropriate technologies according to the requirements of the syllabi	2.73	Undecided
I can create technology-supported self-directed learning activities specifically for my discipline	2.62	Undecided
I can design inquiry-based learning supported by appropriate technologies to guide students in understanding knowledge related to my discipline	2.66	Undecided
I can design student-centered learning that integrates knowledge of my discipline, technologies and pedagogies	2.75	Undecided
Overall	2.68	Undecided

TPACK Knowledge Constructs as Correlates of Use of ICT in Pedagogy

The third and last objective of this study was to relate the use of ICT in pedagogy (UIP) and the knowledge constructs as per the TPACK framework. Multiple regression of the average index on UIP (from Tables 2 through 5) on the seven knowledge constructs (Tables 6 through 12), yielded the results in Table 13. Table 13 suggests that the seven knowledge constructs (CK, PK, TK, PCK, TPK, TCK and TPACK) were collectively not good explanatory variables ($F = 1.130$, $p = 0.345$, adjusted R square = 0.004) of UIP at the five percent level of significance ($p > 0.05$). Significances (p) in Table 13 led to rejection of the first six research hypotheses, leading to the inference that none of CK, PK, TK, PCK, TPK, and TCK significantly correlated with UIP at the five percent level of significance (all $p > 0.05$). Only the seventh hypothesis was accepted to the effect that TPACK positively related with UIP at the five percent ($p < 0.05$) level.

Table 13: Regression of use of ICT in pedagogy on TPACK constructs

TPACK Construct	Beta, β	Significance level, p
CK	-0.165	0.240
PK	0.228	0.206
TK	-0.108	0.367
PCK	-0.087	0.533
TPK	-0.010	0.922
TCK	-0.121	0.294
TPACK	0.246	0.017

DISCUSSION

The first objective of this study was to examine the levels of use of ICT in pedagogy (UIP). According to the means of each of the SAMR constructs (Tables 2 through 5) and the overall mean, the study suggested that the teachers were only fair on UIP. This finding was in consonance with other researchers (e.g. Coleman et al., 2015; Ghavifekr & Rosdy, 2015; Kolodziejczyk, 2015) who also found fair levels of UIP among teachers. The finding of the current study, suggests that the authorities in the respective universities responsible for the teaching and learning process need to find ways (e.g. training) of enhancing teachers' UIP.

The second objective of the study was to examine the levels of TPACK among teachers. Using the respective means of the constructs of the TPACK framework (Tables 6 through 12), teachers rated themselves as high on pedagogy and content constructs (PCK, CK & PK in that order) and low on technology constructs (TPACK, TPK, TK & TCK in that order). The finding on high rates on CK, PK and PCK coincided with that of some earlier researchers (e.g. Chong & Shaffe, 2015). Other researchers (e.g. Chai, Chin et al., 2013; Redmond & Lock, 2013) found teachers to have rated themselves low on TPACK. The teachers' high self-rating on CK, PK and PCK could mean that the teachers have the content to teach and know how to present it in varied ways. But their low self-rating on TK, TPK, TPACK and TCK suggests that the teachers do not have sufficient technological knowledge as regards what ICT tools to use while teaching and how to use them to enhance learning by the students. It is therefore recommended that the teachers be given an opportunity by the relevant stakeholders in the universities to learn about the available ICT tools for teaching and how they can successfully use them to enhance learning.

The third and last objective of this study was to establish whether the levels of UIP and TPACK were related. According to multiple regression (Table 13), the first six research hypotheses to the effect that each of CK, PK, TK, PCK, TPK, and TCK positively related to UIP were not supported. This implies that while each of the six constructs (CK, PK, TK, PCK, TPK and TCK) could be a knowledge construct necessary for a teacher to use ICT in pedagogy, none of them is individually sufficient. Such a finding is particularly in agreement with Abbitt (2011) who also found that "knowledge of technology [TK] is insufficient, by itself, to foster successful technology integration" (p. 286). The seventh hypothesis to the effect that TPACK positively related with UIP was supported. This means that for a teacher to integrate ICT into pedagogy, the teacher needs TPACK in its entirety. This is in line with Mishra and Koehler (2006) who stipulate that TPACK "is the basis of good teaching with technology" (p. 1029). It is thus recommended that when training teachers for UIP, the respective stakeholders in the various universities should ensure that the training is wholesome on content, pedagogy and technology.

CONCLUSION

The study attempted to establish whether knowledge constructs as per the TPACK framework related with the use of ICT in pedagogy (UIP). Using multiple regression, it was established that of the seven knowledge constructs (CK, PK, TK; PCK, TPK, TCK; TPACK), only the TPACK construct was a significant positive correlate of UIP. This means that in order for teachers to use ICT in pedagogy, they need TPACK in its entirety and not in bits. The current study has addressed the concern of Graham (2011) to the effect that, "researcher energy [had] been devoted more to the descriptive value than to the prescriptive value of the TPACK framework" (p. 19). The study however, had limitations. For example, the study applied to selected universities which were very few as compared to the many that exist in the country. This study was also limited to teachers of mathematical disciplines. The sample size could have been bigger as well. The use of ICT in pedagogy could also have other explanatory variables than knowledge as suggested by other theories.

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