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Exploring Factors that Serve as Predictors for Mathematics and Sciences Pre-Service Teachers to Use ICT in Teaching

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ABSTRACT

While the importance of incorporating technology in teaching and learning is acknowledged by several scholars, there are still serious challenges in using technology to enhance the teaching and learning of science and mathematics. In this quantitative study, the technological, pedagogical content knowledge (TPACK) framework was used to analyse factors that serve as predictors for pre-service mathematics and science teachers to use technology effectively in their teaching. The sample for this study consisted of 416 final year Bachelor of Education students from two South African universities. The sample included 243 (54%) females and 175 (42%) males. Questionnaires were used to collect data. The results of the study show that the content knowledge (CK), pedagogical knowledge (PK), pedagogical content knowledge (PCK), technological content knowledge (TCK) and technological pedagogical knowledge (TPK) were the significant predictors for pre-service teachers to incorporate technology in their mathematics and science classrooms.

KEYWORDS

ICT; mathematics; science; TPACK; preservice teachers.

INTRODUCTION

It is commonly accepted by practitioners and scholars (Chen et al., 2020) that the developments in technology have an impact on various sectors of the economy. This impact, amongst others, poses a global challenge of new skillset demands for the workforce in various sectors (Cobo, 2013; Mutongoza et al, 2021). The education sector is no exception to these demands and thus requires innovative digital pedagogies (Tai et.al. 2015). Both the National Council of Teachers of Mathematics (NCTM) and the Department of Basic Education (DBE) agree that the use of technology enables learners to reflect on and verify their conjectures during problem solving (NCTM, 2008; DBE, 2011). In its standards, the NCTM (2008) indicates that technology can facilitate communication, reasoning and problem solving in mathematics. The DBE contends that learners' understanding and appreciation of mathematics can be supported by technology (DBE, 2011). While the central focus on incorporating ICT in mathematics and science classrooms is to improve teaching and learning, the attainment of this goal is dependent on many factors, including teachers` passion for ICT in classrooms. Thus, a conceptual framework, technological, pedagogical and content knowledge (TPACK), was developed and become more popular after the work of Koehler and Mishra (2006). TPACK is made explicit in its geometric representation which shows that it is constructed from an intersection of three knowledge constructs, namely technological knowledge, pedagogical knowledge and content knowledge (Mishra & Koehler, 2006).

LITERATURE REVIEW

The integration of technology in science and mathematics classrooms has gained significant attention as a plausible way to develop and transform teaching and learning (Bere & Rambe, 2016, Celebi, 2019; Erbilgin & Şahin, 2021; Dikmen, 2022). In their study, Bere and Rambe (2016) contend that the use of technology in classroom increases students' motivation and consequently student performance is improved. In addition, incorporating technology in teaching and learning boosts students' confidence and enables them to develop positive attitudes towards learning (Dlamini & Mbatha, 2018; Fu, 2013; Williams & Williams, 2011). According to Ogbonnaya (2010), using technology in the teaching and learning of mathematics improves learners' attitudes towards mathematics and consequently improves their performance in the subject. According to Kurt (2010), the use of technology nurtures/enhances? the classroom environment that promotes the development of higher order thinking through experimentation and active engagement. As Kurt (2010, p. 11) explains, the teaching of mathematics using technology "…increase[s] student collaboration which is a highly effective tool for learning". This view is also shared by Tandiono (2021) who maintains that students live in a technological world and if their learning environment mirrors their lived experiences, they will be encouraged to take an active role in their learning and thus excel in their studies. Thus, the use of technology in teaching and learning embodies the actions of construction, ideation and investigation which can help learners to integrate their knowledge in ways that enable them to compartmentalise and structure their thinking.

Cognisant of the foregoing argument, Buckingham (2013) contends that technology is a powerful distributor of learning and has the power to transform the classroom into the active learning environment. This is because technology provides hands-on learning opportunities. As Ogbonnaya (2010) argues, the use of technology allows/enables? students to understand concepts rather than just possessing facts. The conceptual understanding that technology brings gives students intellectual power/ability? to deal with unfamiliar problems and to grasp intuitively what they know regarding a new phenomenon not previously encountered (Dlamini & Mbatha, 2018; Laurillard, 2013; Kazmi, 2020; Skhephe & Mantlana, 2021). Similarly, Chronaki and Matos (2013, p.14) contend that the use of technology in the mathematics classroom "…favours experimentation and nurtures advanced mathematical thinking rich with creativity and imagination". Thus, the use of technology encourages a constructivist approach to learning as learners become engaged and active. Moreover, Edwards-Groves (2012) maintains the use of technology enables a visual interactive classrooms space which has the potential to win the hearts, minds, and souls of the students, making them more interested in mathematics.

However, as noted by Laurillard (2013), teachers are struggling to use technology in their classrooms because they themselves are incompetent and have had inadequate training on the use of technology in teaching. So and Kim (2009) and Laurillard (2013) agree that knowing how technology tools should be used is necessary but not sufficient. It is critical to know the pedagogical function of the technology as well. Thus, only having technological knowledge is not enough. As Ferdig (2006, p. 752) argues, "…a good technology innovation is consequently defined in relation to what it is as well as how it is implemented". According to Hollebrands and Okumus (2017), incorporating technology in the mathematics and science classrooms is about using technology to enable the learning of mathematics and science; technology should not be the focus of instruction. Thus, as teachers capitalise on opportunities and possibilities presented by emerging technologies, they need to maintain a focus on mathematics and science learning goals.

Theoretical Framework: Technological Pedagogical Content Knowledge (TPACK)

In 1987, Shulman coined the concept of pedagogical content knowledge (PCK). Building on the work of Shulman's (1987) PCK, Mishra and Koehler (2006) introduced the conceptual framework of technological pedagogical content knowledge (TPACK) to enable the integration of educational technology into pedagogy. Mishra and Koehler (2006) stated the following:

> Our framework emphasizes the connections, interactions, affordances, and constraints between and among content, pedagogy, and technology. In this model, knowledge about content (C), pedagogy (P), and technology (T) is central for developing good teaching. However, rather than treating these as separate bodies of knowledge, this model additionally emphasizes the complex interplay of these three bodies of knowledge. (p. 28)

The TPACK diagram shows the interconnectedness and interdependence of the knowledge domains as in Figure 1.

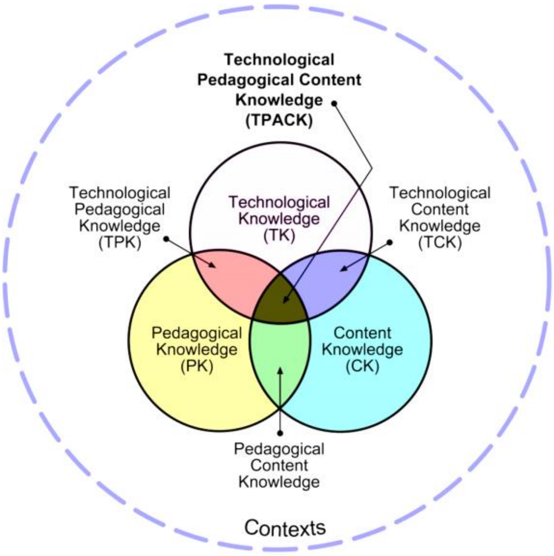

Figure 1. *TPACK Framework* (Source: http://www.tpack.org)

The diagram above shows the interconnectedness of the knowledge domain. Therefore, teachers ought not be taught technology as an isolated domain but as a link to pedagogical content knowledge. That is, the content to be taught directs the teaching method to be used and thereafter the kind of technology to be incorporated (Ferdig, 2006). The choice of technology is dependent on its fitness for purpose and should be motivated by the impact that such technology would bring to the learning process.

Problem Statement

It has been acknowledged that the development of ICT is a vital tool to meet the needs of the education system. ICT is a tool that supports the learning process and holds the promise of bringing solutions to challenges that the education system is facing (Earle, 2002; Rajasingham, 2011; Das, 2019; Morris & Rohs, 2021). The NCTM contends that the use of technology to enhance the teaching of mathematics is a necessity and that technology must be adapted to the teaching and learning process (NCTM, 2008). However, despite many efforts towards the use of technology in the teaching and learning of mathematics and science, it is still safe to say that many teachers are unaware of how to apply it correctly; therefore, there has been little paradigm shift. Several studies suggest that technology is not being used adequately to bring about reform or improve the quality of teaching and learning of mathematics and science. Teachers, as the main drivers of education change, lack skills to incorporate technology effectively into the teaching and learning. If teachers are not competent to incorporate technology into their teaching, the dreams, that the incorporation of technology into mathematics and science seeks to achieve cannot be realised. Thus, this study seeks to understand the factors that serve as predictors for pre-service teachers to incorporate ICT in the teaching and learning of mathematics and science.

Study Objective and Research Question

The central objective of this study was to determine factors that serve as predictors for pre-service teachers to use ICT in their teaching of mathematics and science. Emanating from the study objective, the study seeks to answer the following question:

- What factors serve as predictors of the use of ICT by final-year mathematics and science pre-service teachers?

METHODOLOGY

Research Design

The study was approached quantitatively and a case study design was adopted to gain deeper insights into the selected case for investigation (Creswell & Poth, 2016). Two cases were used, namely University A and University B, to explore factors that serve as predictors for mathematics and sciences pre-service teachers to use ICTs in their teaching.

Population and Sample

According to Cresswell and Poth (2016), It is impossible to study everyone, everywhere. doing everything. This then makes sampling crucial in research (Gaikwad, 2017). A convenient sampling technique was used to select 500 final-year Bachelor of Education (mathematics and science majors) students from two South African universities. Participation was voluntary and questionnaires were completed anonymously. Following ethics clearance from the two universities, participants were recruited by sending questionnaires online. A sample of 416 students (Table 1) participated in the study. The data from the Likert scale-type of questions were analysed using descriptive statistics while thematic analysis was used to analyse data from open-ended questionnaires (Józsa & Morgan, 2017).

Table 1. *Demographic Profile of Students*

Variables	Frequency	Percentage
Gender		
Male	223	53.6
Female	175	42
Not indicated	18	4.4
Total	416	100.0
Age		
20-27	195	46.9
28-35	221	53.1

Data Collection Instruments

Data were collected using questionnaires. The questionnaire comprised three sections. Section A contained two items about the demographics of the participants (age and gender) and Section B comprised fifteen items that measured participants' levels of perceived competency on TPACK and its constructs. The first six questions in section B were open ended while the remaining nine were Likert scale-type. The participants were asked to express their level of agreement or disagreement on a four-point Likert scale (agree, strongly agree, disagree, strongly disagree). The reliability of the instruments, namely internal consistency, was established using Cronbach's alpha. A value of 0.910 was obtained, indicating that the instruments could be judged as reliable

Data Analysis

Multiple regression analysis was employed to determine the statistically significant predictor variables. In so doing, a stepwise regression was performed to build three models. In the first model no technology-related construct was added, namely pedagogical content knowledge, pedagogical knowledge, and content knowledge. For the second model, the next step was to add the variables technological knowledge, technological pedagogical knowledge and technological content knowledge. The analysis was further carried out by computing the R-squared/R^2 and hypothesis testing to determine how much variation in TPACK and/can? be explained by a linear combination of predictor variables and how significant the independent variable is.

RESULTS

This section presents the results of analysis of data in response to the research question, namely "What factors serve as predictors of the use of ICT by final-year mathematics and science pre-service teachers?" Table 2 presents the results of descriptive analysis of the levels of pre-service teachers' perceived competency on the constructs of TPACK and their perceived TPACK.

For each of the constructs of TPACK the mean, standard division, minimum and maximum values are calculated and presented in Table 2. The Cronbach alphas reported in Table 2 excluding PCK and ICTs sources, show acceptable reliability coefficients for all the scales with a minimum of α = 0.68 and a maximum of α= 0.91. The preceding reliability coefficients are consistent with the study by Yang and Green (2011) which reported a range from 0.67 to 0.83. For PCK and ICTs source variables, Cronbach's alpha was not suitable owing to the low number of items in the scales. Thus, a different measure of reliability was used, namely average inter-item correlation as suggested by Clark and Watson (2016). The average inter-item correlation reported in Table 2 shows that PCK ($\alpha = 0.30$) and ICTs sources ($\alpha = 0.32$) were reliable since they were between 0.15 and .50 (Clark & Watson, 2016).

Table 2. *Descriptive statistics on TPACK perceived competency*

Variables	*Mean*	α	*SD*
TK	3.92	0.85	0.59
CK	4.02	0.68	0.58
PK	4.03	0.91	0.49
PCK	3.95	0.30	0.68
TCK	3.57	0.82	0.71
TPK	3.90	0.77	0.43
ICTs Source	3.40	0.32	0.59
TAPCK	3.92	0.85	0.07

$\alpha\sim$Reliability measure & $SD\sim$ standard deviation

The standard divisions are less than one, which means that there is less variation in the distribution of the participants' perceived competencies. Thus, given these fewer variations for all variables and the small range between minimum and maximum values, the mean values could be understood as representing good estimates of the levels of participants' competencies.

The regression results of model 1 in Table 3 indicate that the predictors PK, CK and PCK explained 33.5% of the variance in the perceived competency in the use of ICT by final-year science pre-service teachers (R-Squared = 0.33.5, F (3,416) = 69.19, $p < 0.01$). In addition, all predictor variables in model 1 were significant predictors of final-year science pre-service teachers' perceived competency in the use of ICT PK (β = 0.38, $p < 0.01$), CK (β = 0.21, $p < 0.01$) and PCK (β = 0.23, $p < 0.01$). While the results of model 1 show that PK, CK and PCK were significant predictors of final-year science pre-service teachers' perceived competency in the use of ICTs, the model's R-Squared could still be improved to account for more variation.

Thus, technology constructs of the TPACK framework, namely TK, TCK and TPK were added as predictor variables to improve model 1. These improvements were evident in the value of R-squared in model 2 which increased to account for 51.6% of the variation in final-year science pre-service teachers' perceived competency in the use of ICT (R-Squared = 0.516, F (6,416) = 72.58, $p < 0.01$). However, it was interesting to note that, while TCK (β = 0.26, $p < 0.01$) and TPK (β = 0.48, $p < 0.01$) were significant predictors of science pre-service teachers' perceived competency to use ICTs, TK was found to be insignificant (β=0.02, $p = 0.66 > 0.05$). This means that, knowing that a pre-service teacher has an appropriate level of competency in technological knowledge does not translate into a predictive ability that he/she will be competent in the use ICTs for teaching and learning.

Table 3. *Summary of multiple regression results*

	MODEL 1		MODEL 2		MODEL 3	
Variables	β	p	β	p	β	p
Intercept	0.65179	0.00529**	-0.7159	0.004906	-0.48774	0.100018
PK	0.37796	0.00000**	0.14080	0.031904**	0.16351	0.017386*
CK	0.21073	0.00022**	0.12490	0.015607*	0.11652	0.029226*
PCK	0.22583	0.00000**	0.14856	0.000282**	0.14582	0.000494**
TK			0.02087	0.658688	0.03613	0.502367
TCK			0.26218	0.000000**	0.25554	0.000000**
TPK			0.48137	0.000000**	0.48058	0.000000**
ICTs Sources					-0.06817	0.131866
AGE						
23 - 26					0.07727	0.196932
27 - 32					0.03290	0.666996
> 33					0.04675	0.541970
Gender						
F					-0.02436	0.616091
M					0.41516	0.134667
Area specialisation						
IP					-0.09695	0.396504
SP					-0.10821	0.396266
FET					-0.19192	0.040308*
SP & FET					-0.08785	0.343853
Other					-0.14246	0.131080
R- Squared		0.335		0.5157		0.5328
F		69.19		72.58		20.37

*p < 0.05, **p < 0.01

Model 3 in Table 3 shows the results of adding demographic predictor variables such as gender, age, and specialisation. Moreover, sources of ICTs were added to determine whether different sources of ICTs had more predictive power in the use of ICT by final-year science pre-service teachers. A comparative analysis of models 2 and 3 show that TK remained an insignificant predictor variable (β=0.04, p = 0.50 > 0.05). Similarly, all added demographic independent variables in model 3 appeared to be insignificant predictors except for FET specialisation. This means that, age, gender and programme specialisation do not serve as predictors of the use of ICT by final-year science pre-service teachers. However, FET specialisation appears to be a significant predictor of the use of ICT by final-year science pre-service teachers. The integrated knowledge constructs, namely PCK, TCK and TPK, were far more important in explaining the pre-service teachers' TPACK at a 0.01 significant level.

DISCUSSION

The current study sought to answer the question as to what factors serve as predictors on the use of ICT by final year mathematics and preservice science teachers. The results of the study in response to the foregoing question revealed that pedagogical knowledge, content knowledge and pedagogical content knowledge contribute significantly to the use of ICT in teaching. The preceding was evident in the results of all three models. These results confirm that the three knowledge domains (PK, CK, and PCK) are fundamental to developing the technological competency for teaching mathematics and science. These findings contribute to the body of knowledge on using ICTs for teaching. For instance, the foregoing results are contrary to the findings of Dikmen (2021), which revealed that PK, CK and PCK are not significant predictors of using ICTs in their path modelling for technology integration in teaching.

Furthermore, an interesting result of the current study was that access to ICT resources does not seem to be a determining factor that mathematics and science teachers will use ICTs. What makes this finding to be particularly interesting is that if teacher educators are intentional in developing the necessary knowledge domains needed for ICT use for teaching, it suggests that, despite the lack of ICTs resources which is common in many schools (Dikmen, 2021), teachers with developed ICT competency may always find possible ways to leverage on the potential of ICTs to enhance their pedagogy.

The study also show that age is not a significant predictor of mathematics and science pre-service teachers' use of ICTs. This finding refutes the findings of Gómez-Trigueros et al. (2019) which revealed a significant difference in the age groupings of pre-service teachers on knowledge related to teaching technologies. It is crucial to refute significant differences in age in use or knowledge of ICTs as it challenges the notion that younger pre-service teachers tend to make more use of ICTs.

Moreover, the study makes a contribution by revealing that the type of programme that seems to matter is FET, which is for pre-service teachers teaching in high or secondary schools. The results of model 3 showed that amongst the three programmes sampled in the current study, only the FET variable was a predictor of where teachers could use ICTs in their teaching of mathematics and science. This finding contributes by refuting, amongst others, the finding of Celebi (2019) which was consistent with general literature despite teachers' daily use of the Internet for teaching purposes.

Lastly, in terms of gender analysis, the current study's results were consistent with the findings of Ahmed and Kazmi (2020) which revealed that there are no gender differences in the use of ICT for teaching. Thus, the foregoing suggests that there is no need for gender considerations in pedagogy or gender policy implications for teacher education in integrating ICTs into the teacher education programme.

CONCLUSION

It is important that opportunities for technological knowledge (TK) be presented together with mathematics and science content knowledge (CK). Teachers need to understand content to be able to integrate technology into mathematics and to know what technology is relevant to teach a particular topic in mathematics and science. If integrated, the technological skills could provide a meaningful and practical context to teach the content. The usage of technological tools in mathematics and science is highly dependent on the content knowledge and the converse is also true. Again, choosing the appropriate technology for teaching a particular concept is also dependent on content knowledge and pedagogy (PCK) and the converse again holds.

Thus, if technological skills and mathematics content knowledge are not taught in isolation, the students will be able to understand problems and find innovative and creative ways of solving them. However, if the factors affecting the effective use of technology are not taken care of and technology-based activities are not carefully thought through for specific topic and objectives in mathematics and science, we will be trapped in the wrong and shadow use of technology in our science and mathematics and science classroom.

Limitations

It should be noted that this study has several limitations. Firstly, the study was delimited to only fourth-year (final year of study) B.Ed. mathematics and science students because they are about to practise teach in this scarce skill field. Therefore, the study is strictly applicable to prospective mathematics and science teachers. Secondly, the study was only conducted at two South African universities. A broader study that covers more than two institutions is recommended for the future to clarify to large extent the predictors of mathematics and sciences pre-service teachers to use ICTs in teaching.

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