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Technological pedagogical content knowledge self-efficacy of pre-service science and mathematics teachers: A comparative study between two Zambian universities

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Abstract

Pre-service science and mathematics teachers' beliefs and attitudes concerning technology integration significantly influence how confident they are to integrate technology into their teaching. This study is a comparative examination of the technological pedagogical content knowledge (TPACK) self-efficacy of 202 pre-service science and mathematics teachers enrolled at two Zambian universities. It also investigated the influence of selected demographic variables on the TPACK self-efficacy of pre-service science and mathematics teachers. The study employed a cross-sectional survey research design to collect data, which was analyzed using the independent samples t-test and one-way ANOVA. The findings reveal that pre-service teachers have moderate TPACK self-efficacy. Furthermore, the results indicate that students' self-efficacy at the two universities was not statistically different (t[200]=2.11, p=.83); nonetheless, their TPACK self-efficacy was influenced by gender, year of study and subject specialization in some TPACK constructs. The implications of these findings were discussed.

Keywords: science and mathematics, pre-service teachers, technology integration, TPACK

INTRODUCTION

The development of teachers' knowledge base to improve teaching and student learning has been a prime focus in teacher education around the world (Meier, 2021). Teachers' understanding of digital technologies and ability to use them in the classroom is becoming increasingly important in education research (Adebusuyi et al., 2020; Jita & Sintema, 2022; Thohir et al., 2021). The advent of new technologies has altered education, particularly in how teaching and learning are experienced. The global science education discourse is shifting towards preparing teachers who are adaptable to technology-enhanced teaching and learning (Penn & Mavuru, 2020). It is necessary for modern teachers to possess knowledge of technology integration into classroom practice to improve teaching and learning (Segal et al., 2021). Today's teachers are thus required to possess knowledge of how technologies can be integrated into classroom practice to improve teaching and learning. According to Salas-Rueda (2020), a successful integration of technological tools in the teaching-learning process requires teachers to enhance their technological and pedagogical competencies. Mishra and Koehler (2006) proposed the technological pedagogical content knowledge (TPACK) model for integrating technology in teaching and learning. The TPACK model builds on Shulman's (1986) pedagogical content knowledge (PCK) by incorporating technology in the investigation of teachers' professional knowledge to enhance teachers' knowledge and skills in the integration of technology into classroom practice (Cetin-Dindar et al., 2018).

TPACK is the competency teachers possess in incorporating knowledge of content, pedagogy, and technology into a learning practice. Mishra and Koehler (2006) noted that TPACK is largely achieved when a teacher is aware of how technological tools affect students' knowledge of subject matter as well as how pedagogical approaches and content representations for teaching a particular subject matter are transformed by technological tools. Koehler and Mishra (2009)

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Contribution to the literature

- The study will bring awareness of the TPACK self-efficacy of pre-service science and mathematics secondary school teachers in Zambia. The researchers found no studies focused on the Zambian pre-service teachers' TPACK self-efficacy.
- The study also highlights the influence of gender, institution of study, level of study, and subject specialization on the TPACK self-efficacy of pre-service teachers.
- The study found that pre-service teachers have moderate overall TPACK self-efficacy. The highest mean score was recorded in PK while the lowest was in TK. Furthermore, findings reveal that males exhibited higher TK, TPK, and TPACK self-efficacy than females and the university of study was found to have no influence on the TPACK self-efficacy of the pre-service teachers.

emphasize that TPACK is the cornerstone of effective technology-enhanced teaching. TPACK is a requirement for modern teacher candidates to be well-equipped to fulfil today's educational needs at the appropriate level (Putri et al., 2020).

Despite the evident need to improve pre-service teachers' skills and knowledge in the integration of technology in the classroom, evidence from literature suggests that the integration of technology in teaching by pre-service teachers in most African countries, Zambia inclusive, remain very low (Jita & Sintema, 2022; Kafyulilo et al., 2015; Mulenga & Masumba, 2019; Sintema & Phiri, 2018). There are many reasons, which have been advanced for this observation including lack of training on technology integration (Kafyulilo et al., 2016; Niess, 2011), lack of skills and knowledge of technology integration in teaching (Irmak & Yilmaz Tuzun, 2019; Njiku et al., 2021), pre-service teachers' attitudes and beliefs towards technology integration (Abbitt, 2011b; Aquino, 2015a; Lee, 2010; Lee & Tsai, 2010) as well as influence of demographic variables among other reasons (Kartal & Afcan, 2017; Koh et al., 2010). Sintema and Phiri (2018) observed that pre-service teachers at one public university in Zambia did not receive any training pertaining to teaching with technology. Despite this problem, limited research has been conducted on the TPACK self-efficacy of pre-service science and mathematics teachers in Zambia. Previous studies conducted have focused on the assessment of technology integration among in-service teachers in Zambia (Mulenga & Masumba, 2019). This study is conducted to

(1) assess and compare the TPACK self-efficacy of pre-service science and mathematics teachers at two teacher training public universities in Zambia and

(2) examine the influence of gender, year of study, university of study and subject specialization on the TPACK self-efficacy of pre-service science and mathematics teachers.

The study will help to highlight the competencies regarding technology integration in teaching that pre-service science and mathematics teachers gain at university and their confidence of practical integration of technology in their future classroom instruction.

According to Kartal and Afcan (2017), there are few studies, which have examined the relationship between demographic variables and TPACK perceptions of teachers. The information on the relationship between demographic variables and TPACK perceptions of pre-service science and mathematics teachers can be used by universities to create appropriate training programs for teachers (Ibrohim et al., 2022).

Self-judgment regarding one's ability to successfully plan and carry out particular tasks is defined as self-efficacy (Bandura, 1997). Self-efficacy focuses on an individual's self-belief to perform a given task. In teacher education, self-efficacy is one factor that is considered to affect the success and goals of teachers' professional life (Bandura, 1997). Several studies (Aquino, 2015a; Farjon et al., 2019; Lee & Tsai, 2010) have shown that teachers' confidence in their abilities to use technology in the classroom has a big impact on how much technology they actually integrate into their lessons. According to Njiku et al. (2020) and Wang et al. (2004), teachers that have a high level of technology integration self-efficacy typically have more success incorporating technology into their lessons.

Academic self-efficacy is also known to predict students' academic performance. The belief that one will operate successfully at a particular level is known as academic self-efficacy (Abbitt, 2011b). According to Bandura (1997, p. 5), "there is a strong and positive influence of self-efficacy on various aspects of student achievement and motivation." Tafli (2021) asserts that there is a strong relationship between student teachers' self-efficacy and enthusiasm, motivation, and commitment of the teacher in the profession, as well as students' success. It is more likely that students with high self-efficacy are more highly motivated learners, more successful, and more attentive to their profession.

Some studies have been conducted on the TPACK self-efficacy of pre-service teachers (Abbitt, 2011b; Aquino, 2015a; Lee, 2010; Lee & Tsai, 2010; Schmid et al., 2021; Tafli, 2021). Abbit (2011) investigated the relationship between pre-service teachers' perceived understanding of TPACK and their perceptions about their ability to integrate technology. The findings show that this relationship exists. Tafli (2021) compared the TPACK self-efficacy of prospective biology teachers from two different faculties at the same university. According to the survey, there were notable differences between the prospective biology teachers from the two faculties. TPACK self-efficacy was shown to be higher in prospective students from the faculty of education than it was in those from the faculty of science, according to the findings. The impact of the vocational courses in the programs of the education faculty was cited as the cause of the disparity.

A study by Aquino (2015a) investigated pre-service teachers' self-efficacy on TPACK. The study compared the responses of male and female students, it also looked at the influence of the number of gadgets owned by the students as well as their access to the internet on their TPACK self-efficacy. Results indicated that students show good TPACK self-efficacy, however, female students showed a higher TPACK self-efficacy as compared to their male counterparts. Additionally, students with more gadgets had higher TPACK self-efficacy than those with few gadgets.

According to Ibrohim et al. (2022), investigating the competency of teachers is needed to improve the quality of training provided to teachers. In most African countries, Zambia inclusive, teacher training programs do not equip upcoming teachers with the necessary skills for teaching effectively with technology (Kafyulilo et al., 2016; Yeh et al., 2014). Thus, assessing TPACK self-efficacy will help to highlight the pre-service teachers' competency in technology integration and has potential to improve the training they are receiving at university regarding integration of technology in classroom instruction. However, there is inadequate research being conducted to assess the pre-service teachers self-efficacy about technology integration in classroom instructions (Ibrohim et al., 2022).

Despite this problem, there is a dearth of research in Zambia on pre-service secondary school science and mathematics teachers' TPACK self-efficacy (Mulenga & Masumba, 2019; Sintema & Phiri, 2018). Thus, this study sought to assess the TPACK self-efficacy of pre-service secondary school science and mathematics teachers at two teacher training universities in Zambia during the academic year 2022-2023. The study sought to answer the following research questions:

1. What is the level of the TPACK self-efficacy of pre-service secondary school science and mathematics teachers enrolled at Kaba University and Moyo University?
2. Do the students' TPACK self-efficacies differ based on gender, year of study, subject specialization, and university of study?

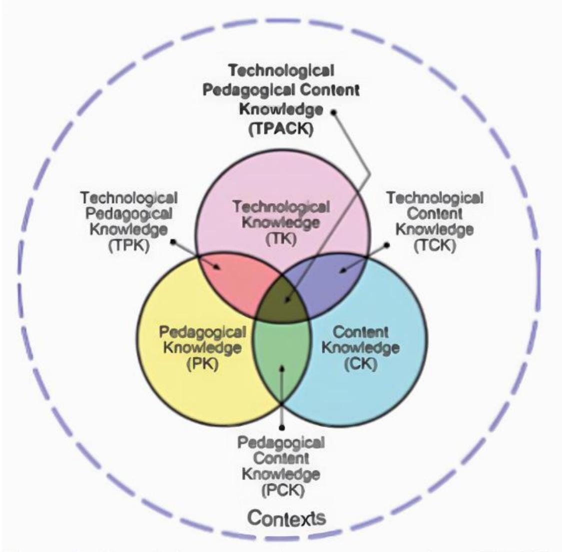

Figure 1. TPACK framework (Koehler & Mishra, 2009)

Theoretical Framework

This study used the TPACK integrative framework conceptualized by Koehler and Mishra (2009) as a theoretical framework to describe and assess the TPACK self-efficacy towards technology integration in teaching among pre-service science and mathematics teachers at two teacher training universities in Zambia. The entire concept of the TPACK framework was used because it is suitable for assessing teachers' knowledge under different domains and in its integrated form. The study assessed pre-service teachers' self-perception of their technological knowledge (TK), pedagogical knowledge (PK) as well as their specialized content knowledge (CK). The study also examined pre-service teachers' self-efficacy in the integrated knowledge forms of technological content knowledge (TCK), technological pedagogical knowledge (TPK), PCK, and TPACK. Globally, TPACK is one of the most popular professional teacher development framework (Mishra & Koehler, 2006). The TPACK framework extends Shulman's (1986) PCK to discuss how technology is used effectively in instruction (Koehler & Mishra, 2009) (**Figure 1**). Shulman (2013) noted that "the TPACK framework is made up of three key domains: PK, CK, and TK." The other key competencies, which make up the framework include: PCK, TCK, TPK, and TPACK.

CK is defined as the knowledge possessed by teachers about the subject matter that is intended to be taught (Shulman, 2013). It represents subject knowledge and its organization in the teachers' mind (Shulman, 1986).

PK is defined as "teachers' knowledge about methods of teaching, procedures, practices, strategies, and classroom management" (Shulman, 2000, p. 8). This knowledge needs insight into theories of learning and how they can be applied in a typical classroom setting.

Table 1. Demographic profiles of the participants (n=202)

Institution	n	Gender		Year of study		Specialization			
		M	F	4	3	Biology	Chemistry	Physics	Mathematics
Moyo University	64	46	18	29	35	20	13	10	21
Kaba University	138	85	53	77	61	39	24	15	60

TK refers to knowledge about various technologies that can be used to effectively teach subject content (Schmidt et al., 2009). It entails knowing the best form of technology that can be used to make learning and teaching more meaningful.

PCK is the integration of CK with instructional strategies. It involves the understanding of the content to be taught and how it ought to be taught. The teacher can represent content in a way that enhances learners' understanding. PCK also involves understanding the learners and how to maintain a good learning environment (Aquino, 2015a).

TCK is the integration of content with the appropriate technology. The teacher needs to know the best technology, which can be used for presenting particular content of a subject matter (Abbitt, 2011a; Cetin-Dindar et al., 2018; Mishra & Koehler, 2006). According to Zhang and Tang (2021), "TCK is the interaction between technology and content" (p. 9).

TPK refers to understanding technology's benefits and limitations as an enhancer of various teaching styles (Voogt et al., 2013). It pertains to the knowledge of how various technologies can be used in the classroom and the potential for technology to alter how teachers teach (Schmidt et al., 2009).

The amalgamation of these three knowledge domains precipitates TPACK. Mishra and Koehler (2006) noted that understanding the relationships among these three knowledge components is essential for successful technology integration, as there is a dynamic equilibrium among all components and how they apply to the students in classroom settings. Mishra and Koehler (2006) stressed that awareness of the links between various knowledge components is necessary for efficient technological integration. Teachers must therefore acquire abilities not only in each of these three key knowledge areas, but also in how these domains interact with one another.

METHODOLOGY

This section describes the methodology that was used to obtain the data needed to answer the research questions under the following subheadings: research design and sampling, instrument and procedures, and data analysis.

Research Design and Sampling

This study used a cross-sectional survey research design to gather data on pre-service science and mathematics teachers' TPACK self-efficacy. According to Creswell (2014), a cross-sectional survey design can assess a population's current opinions, trends or attitudes. This study utilized a validated TPACK questionnaire adapted from Schmidt et al. (2009), refer to **Appendix A**. The target population for this study were pre-service science and mathematics teachers enrolled at teacher-training public universities in the academic year 2021-2022 in Zambia. Currently, Zambia has three public universities with a mandate to train teachers. The sample comprised 202 pre-service teachers selected purposively from two teacher-training public universities in Zambia. The universities were given pseudo-names in order to protect their identity. **Table 1** shows the sample characteristics.

Instrument and Procedures

The survey instrument for this study was adapted from the TPACK survey tool created by Schmidt et al. (2009) to the TPACK self-efficacy questionnaire (TPACK-SE) for the Zambian pre-service teachers. The instrument was peer-reviewed by two PhD students and expertly reviewed by three lecturers in science education who are PhD holders. The instrument was pilot tested on 50 students and the reliability of the instrument was calculated using Cronbach's alpha and ranged from .844 -.930 implying they were reliable. The overall reliability of the TPACK-SE was .903, which per Schmid et al. (2021) is reliable. The survey was composed of a Likert scale with five possible responses: strongly agree (5), agree (4), neither strongly agree nor disagree (3), disagree (2), and strongly disagree (1) (**Appendix A**).

Mean responses of 1-2.9 were considered low, those of 3-3-9 were considered moderate whereas 4-4.9 was considered high-level self-efficacy, with mean scores of five being considered very high-level self-efficacy. The classification of mean responses as low, high and very high were adopted from Mapulanga et al. (2022) and applied to the context of this study.

The questionnaire was administered online using Google Forms. The link to the Google Form was shared through the class WhatsApp groups of the targeted participants after obtaining their consent. The lecturers for the targeted students assisted in posting the link to their WhatsApp groups. The respondents were 3rd year and 4th year students of different specializations; biology, chemistry, mathematics, and physics enrolled in the Bachelor of Science with education (BSc Ed) program in the academic year 2022-2023 at Kaba and Moyo university.

Table 2. Level of pre-service teachers' TPACK self-efficacy (n=202)

Constructs	Group	n	Mean	Standard deviation	Level
CK	Kaba University	138	3.89	.83	Moderate
	Moyo University	64	3.81	.87	Moderate
PK	Kaba University	138	3.98	.81	Moderate
	Moyo University	64	3.86	.87	Moderate
TK	Kaba University	138	3.33	.72	Moderate
	Moyo University	64	3.34	.85	Moderate
TPK	Kaba University	138	3.41	.91	Moderate
	Moyo University	64	3.57	.81	Moderate
TCK	Kaba University	138	3.34	.96	Moderate
	Moyo University	64	3.56	.84	Moderate
PCK	Kaba University	138	3.98	.69	Moderate
	Moyo University	64	3.84	.74	Moderate
TPACK	Kaba University	138	3.44	.74	Moderate
	Moyo University	64	3.55	.79	Moderate
Total TPACK	Kaba University	138	3.63	.62	Moderate
	Moyo University	64	3.65	.65	Moderate

Table 3. TPACK self-efficacies of pre-service teachers by university

Constructs	Groups	n	Mean	Standard deviation	df	t	p	Mean difference
CK	Kaba University	138	3.89	.83	200	.74	.55	.08
	Moyo University	64	3.82	.87				
PK	Kaba University	138	3.98	.81	200	.42	.31	.13
	Moyo University	64	3.86	.87				
TK	Kaba University	138	3.33	.72	200	2.67	.92	-.01
	Moyo University	64	3.34	.85				
TPK	Kaba University	138	3.42	.91	200	1.24	.24	-.16
	Moyo University	64	3.57	.81				
TCK	Kaba University	138	3.34	.96	200	2.53	.12	-.21
	Moyo University	64	3.56	.84			.	
PCK	Kaba University	138	3.98	.69	200	1.55	.18	.14
	Moyo University	64	3.84	.74				
TPACK	Kaba University	138	3.44	.74	200	2.25	.35	-.11
	Moyo University	64	3.55	.79				
Total TPACK	Kaba University	138	3.63	.62	200	2.10	.83	-.02
	Moyo University	64	3.65	.65				

Data Analysis

Data obtained was checked for normality to determine appropriate method of data analysis. Kolmogorov-Smirnov test for normality was conducted and results indicated a non-significant value (p=1.023), which meant that data were approximately normally distributed.

Data were therefore analyzed using mean (M), standard deviation (SD), one-way ANOVA, and independent samples t-test. The significance of the hypothesis was set at 0.05 alpha level.

Effect size was calculated to understand the practical significance of the results obtained by measuring how big the difference between two groups is. This is not possible to determine by using the statistical significance (Cohen, 1988). According to Cohen (1988), effect size of .002 is considered small, .05 is medium while anything above .08 is considered high.

RESULTS

This section presents the results regarding pre-service secondary school science and mathematics teachers' TPACK self-efficacy.

Level of Pre-Service Teachers' TPACK Self-Efficacy

TPACK self-efficacy of pre-service science and mathematics teachers at Kaba and Moyo University was at a moderate level (**Table 2**). The highest mean score was recorded in PK, Kaba (M=3.98, SD=.81) and Moyo University (M=3.85, SD=.87) while the lowest mean score was recorded in TK, Kaba (M=3.33, SD=.72) and Moyo (M=3.34, SD=.85).

TPACK Self-Efficacy of Pre-Service Teachers by University

The results in **Table 3** for an independent samples t-test show that the total TPACK, Kaba (M=3.62, SD=.62) and Moyo University (M=3.64, SD=.68) were not

Table 4. TPACK self-efficacies of pre-service teachers by gender

Constructs	Groups	n	Mean	Standard deviation	df	t	p	Mean difference
CK	Male	131	3.90	.85	200	.74	.459	.09
	Female	71	3.81	.82				
PK	Male	131	3.96	.81	200	.42	.673	.05
	Female	71	3.91	.89				
TK	Male	131	3.44	.76	200	2.68	.008*	.29
	Female	71	3.14	.74				
TPK	Male	131	3.52	.87	200	1.24	.216	.16
	Female	71	3.36	.91				
TCK	Male	131	3.53	.86	200	2.54	.012*	.34
	Female	71	3.19	1.01				
PCK	Male	131	3.99	.64	200	1.56	.122	.16
	Female	71	3.83	.81				
TPACK	Male	131	3.56	.74	200	2.26	.025*	.25
	Female	71	3.31	.75				
Total TPACK	Male	131	3.70	.59	200	2.11	.036*	.19
	Female	71	3.51	.68				

statistically different (t[200]=2.11, p=.83, two tailed). Concerning TPACK constructs, results indicate that the TPACK self-efficacies did not differ by university in all the TPACK constructs.

TPACK Self-Efficacy of Pre-Service Teachers by Gender

To determine the influence of gender on the TPACK self-efficacy of pre-service science and mathematics teachers, an independent samples t-test was conducted. The results in **Table 4** show a significant difference in the total TPACK for males (M=3.70, SD=.59) and females (M=3.51, SD=.68) in favor of males (t[200]=2.11, p=.036). Cohen's d (Cohen, 1988) effect size was calculated to determine if the difference between the two groups is practically significant. The effect size was found to be very small (eta squared=.002). Further analysis on the influence of gender on other TPACK constructs indicate that the TK for males (M=3.44, SD=.76) was also higher than that of females (M=3.14, SD=.74), (t[200]=2.68, p=.008). In terms of TCK, males (M=3.53, SD=.86) had higher self-efficacy than the females (M=3.14, SD=1.01), (t[200]=2.53, p=.012), although the effect size was small (eta squared=.003). The TPACK for males (M=3.56, SD=.74) was also higher than that of females (M=3.31, SD=.75), (t[200]=2.11, p=.036) very small effect size was found (eta squared=.002).

The results for other TPACK constructs, such as CK, PK, TCK, and PCK were not statistically different.

TPACK Self-Efficacy and Year of Study

Comparison of TPACK self-efficacy for 3rd year and 4th year students using the independent samples t-test showed that the total TPACK for 3rd year (M=3.75, SD=.60) was higher than the 4th years (M=3.53, SD=.64), (t[200]=2.51, p=.013). Although a significant difference was found between the two groups, effect size was found to be very small (eta squared=.002).

Concerning TPACK constructs, results indicate that 3rd year (M=3.46, SD=.83) had higher TK than 4th years (M=3.23, SD=.68), (t[200]=2.13, p=.035) although the effect size was very small (eta squared=.002), the TCK for 3rd years (M=3.70, SD=.89) was also higher than 4th years (M=3.14, SD=.88), (t[200]=4.54, p<.001).

Effect size was found to be small (eta squared=.003), the TPK for 3rd years (M=3.69, SD=.74) was higher than the 4th years (M=3.27, SD=.86), (t[200]=3.46, p=.001). The effect size was also small (eta squared=.003), and concerning TPACK, 3rd years (M=3.69, SD=.74) scored higher than 4th years (M=3.27, SD=.86), (t[200]=3.46, p=.001) very small effect size was found (eta squared=.002) (**Table 5**).

However, the results for other TPACK constructs of CK, PK, and PCK were not significant.

TPACK Self-Efficacy and Subject Specialization

The one-way ANOVA was conducted to compare the TPACK self-efficacy of pre-service teachers of different subject specializations. Results revealed that subject specialization did not affect the TPACK self-efficacy of pre-service teachers in all TPACK constructs except the TPK component. The perceived TPK of pre-service biology, chemistry, mathematics and physics pre-service teachers were significantly different (F[3, 199]=3.62, p=.006).

Post-hoc Dunnett's test showed that there is a significant difference in the perceived TPK of biology and mathematics pre-service teachers (p=0.035). However, there were no statistically significant differences between the biology and chemistry pre-service teachers (p=.118), biology and physics pre-service teachers (p=1.0), chemistry and mathematics (p=1.0), chemistry and physics pre-service teachers (p=.403) and also between mathematics and physics pre-service teachers (p=.382).

Table 5. TPACK self-efficacies of pre-service teachers by year of study

Constructs	Groups	n	Mean	Standard deviation	df	t	p	Mean difference
CK	Year 3	96	3.85	.80	200	-.197	.844	-.02
	Year 4	106	3.88	.87				
PK	Year 3	96	3.96	.74	200	.263	.793	.03
	Year 4	106	3.92	.90				
TK	Year 3	96	3.45	.83	200	2.128	.035*	.22
	Year 4	106	3.22	.67				
TPK	Year 3	96	3.68	.85	200	3.459	.001*	.41
	Year 4	106	3.26	.86				
TCK	Year 3	96	3.70	.89	200	4.521	.000*	.56
	Year 4	106	3.13	.88				
PCK	Year 3	96	3.92	.69	200	-.279	.780	-.02
	Year 4	106	3.95	.71				
TPACK	Year 3	96	3.65	.71	200	3.294	.001*	.34
	Year 4	106	3.31	.75				
Total TPACK	Year 3	96	3.74	.60	200	2.506	.013*	.21
	Year 4	106	3.52	.63				

DISCUSSION

This section presents discussion and the implications of the results for practice, policy, and research

Overall TPACK Self-Efficacies of Pre-Service Teachers

The self-professed overall TPACK of science and mathematics pre-service secondary school teachers at Kaba University and Moyo University was found to be at a moderate level. One possible explanation for this observation is that there is no training to prepare pre-service teachers for technology integration in their classrooms at both universities. This result is contrary to various studies (Kavanoz et al., 2015; Koh et al., 2010; Lee & Tsai, 2010), which found that pre-service teachers rated themselves highly on the overall TPACK. The results from this study suggest that pre-service science and mathematics teachers at the two universities could have moderate confidence in the integration of technology in teaching. This may affect the degree of technology integration in their teaching once they graduate, which may affect students' academic achievement (**Table 6**).

According to Abbitt (2011b), teachers with a high level of self-efficacy in technology integration tend to be more successful at integrating technology into their lessons. With regard to other TPACK constructs, the highest mean score was recorded in PK while the lowest mean score was in TK. This result is consistent with Lee (2010), Wang and Liu (2020), and Wright and Akgunduz (2018) who also found similar results.

TPACK Self-Efficacies of Pre-Service Teachers and University Attended

According to the results, the university attended did not influence the TPACK self-efficacy of the students. This could partly be explained by the fact that the two universities (Kaba University and Moyo University) are using a similar curriculum to train their teachers. The curricula of the two institutions does not have courses focused on preparing pre-service teachers for technology integration in their classroom. This is supported by Sintema and Phiri (2018) who posited that teacher training institutions in Zambia are not preparing teachers to teach with technology. Our findings are contrary to findings by Chukwuemeka et al. (2019), Tafli (2021), and Wright and Akgunduz (2018) who found significant differences in the TPACK self-efficacies of pre-service students enrolled at different institutions. Aquino (2015b) also found significant differences in TPACK self-efficacies of pre-service biology teachers belonging to different faculties of the same institution.

TPACK Self-Efficacies of Pre-Service Teachers and Gender

Gender influenced the overall TPACK self-efficacy of pre-service teachers in this study. The overall TPACK self-efficacy for males was found to be higher than that for females. The study also revealed that males have superior TK, TPK, and TCK compared to females. This outcome is in line with Aquino (2015b) and Koh et al. (2010, 2013) who found that gender is an effective factor in terms of TK, TCK, and TPACK in favor of male teachers. Similar findings were made by Jang and Tsai (2013), who found that male science teachers rated their expertise of technology considerably higher than female teachers. This might be due to males being more inclined to use technological devices than female folks. Jang and Tsai (2013) noted that males tend to often use computers from as early as elementary school thus developing more positive computer self-efficacy than females. Results might suggest that male pre-service teachers are more likely than female ones to use technology in their instruction. Thus, concerted efforts must be made to encourage female pre-service teachers to use technical tools more frequently to raise their TK self-efficacy.

Table 6. TPACK self-efficacies of pre-service teachers by subject specialization

Constructs	Subject specialization	Mean	Standard deviation	F	p
CK	Biology	3.78	.94	.361	.249
	Chemistry	3.88	.95		
	Physics	3.90	.81		
	Mathematics	3.92	.68		
PK	Biology	3.83	.88	.820	.294
	Chemistry	3.93	.95		
	Physics	3.97	.84		
	Mathematics	4.05	.69		
TK	Biology	3.37	.87	.715	.863
	Chemistry	3.56	.85		
	Physics	3.46	.89		
	Mathematics	3.56	.79		
TPK	Biology	3.39	1.00	3.632	.006*
	Chemistry	3.87	.89		
	Physics	3.41	1.14		
	Mathematics	3.81	.74		
TCK	Biology	3.35	1.09	1.571	.122
	Chemistry	3.70	.91		
	Physics	3.40	1.09		
	Mathematics	3.65	.88		
PCK	Biology	3.83	.83	1.469	.344
	Chemistry	4.02	.60		
	Physics	3.94	.69		
	Mathematics	4.07	.60		
TPACK	Biology	3.42	.88	2.240	.133
	Chemistry	3.72	.76		
	Physics	3.52	.93		
	Mathematics	3.74	.71		
Total TPACK	Biology	3.57	.75	2.094	.106
	Chemistry	3.81	.69		
	Physics	3.66	.77		
	Mathematics	3.83	.52		

Note. Respondents: Biology=59; Chemistry=37; Mathematics=81; & Physics=25

TPACK Self-Efficacies of Pre-Service Teachers and Year of Study

The year of study influenced the overall TPACK self-efficacy of the pre-service teachers in this study. The overall TPACK self-efficacy, for 3rd year pre-service teachers, was higher than their 4th year counterparts. Interestingly, pre-service teachers in year three recorded higher TK, TPK, TCK, and TPACK than their 4th year colleagues. One possible explanation for the observation in this study could be that the 3rd year students took the introduction to computers course in their first year of study while those in the fourth year did not because the course had not been introduced at the time.

The other explanation could be that younger generations are more technologically savvy than older generations. These results are contrary to findings by Kartal and Afcan (2017) and Lee and Niess (2011) who found that naive teachers are less likely to associate technology, pedagogy and content.

TPACK Self-Efficacy of Pre-Service Teachers and Subject Specialization

Results indicate that the overall TPACK self-efficacy of the pre-service teachers was not influenced by subject specialization. However, there were differences in TPK scores between the biology majors and mathematics majors. The mathematics pre-service teachers had significantly higher mean scores in TPK than the biology majors. The underlying reasons are open to further research; however, it was speculated that the teaching staff for mathematics were using technologies more in their teaching than the biology instructors and thus acted as role models to influence prospective mathematics teachers.

Tondeur et al. (2012) argued that if educators in teacher training institutions lack the knowledge and experience about technology integration in education then their students are not likely to exhibit confidence in the use of technology in their future teaching. These results are consistent with those of Suzuk and Akinci (2021) who found a significant difference in the TPACK self-efficacy of biology and physics pre-service teachers in the TK component but contrary to findings by Cetin-Berber and Ederm (2015) who found significant differences among pre-service teachers' perceptions in all the TPACK subscales except the PK component.

CONCLUSIONS

The study assessed and compared the TPACK self-efficacy of pre-service secondary school science and mathematics teachers at Kaba University and Moyo University. It further examined whether the TPACK self-efficacies of the teacher students are influenced by gender, year of study, and subject specialization. The study found that the overall TPACK self-efficacy of students at the two universities is moderate. The pre-service teachers rated their PK highest and TK as the lowest. The results further showed no statistically significant difference in the TPACK self-efficacy of pre-service teachers at the two universities. Furthermore, gender and year of study influenced the TPACK self-efficacy of students in TPACK constructs of TK, TCK, and TPK. In contrast, subject specialization did not influence the overall TPACK self-efficacy of the pre-service teachers. However, the component of TPK showed differences between the mathematics and biology majors. Conclusively, the two teacher training universities in Zambia are doing well in impacting on PK of the students as evidenced by the pre-service teachers' high self-efficacy in the PK construct. However, the aspect of technology knowledge and its interaction with content and pedagogy has not been embraced in their curriculum. This was evidenced by moderate TPACK self-efficacy and low TK scores recorded among pre-service science and mathematics teachers at the two universities in Zambia. The study recommends curriculum review to incorporate courses that focus on integrating technology in teaching. This could improve the TPACK self-efficacies of students and enhance the students' technology integration skills in teaching.

Limitations

There are a number of limitations to this study. Firstly, the study used a self-reported questionnaire, which might not reflect the actual TPACK competencies of the participants. Secondly, the participants were drawn from only two universities where the author had permit and ethical clearance to conduct research. Therefore, the results may not be generalized to all pre-service science and, mathematics secondary school teachers in Zambia. The study used google forms, which were distributed through WhatsApp groups of the students, it is possible that some potential participants who are not frequent users of WhatsApp were excluded. Future research might consider lesson observations, interviews, and analysis of lesson plan reports to gain deeper insights on the TPACK competencies of pre-service teachers.

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APPENDIX A: TPACK SELF-EFFICACY QUESTIONNAIRE

Thank you for taking the time to complete this survey. Please respond to each question to the best of your ability. Your thoughts and openness will be immensely appreciated. Your responses will be kept strictly confidential.

Demographic Information

1. Gender
   a. Male
   b. Female
2. Age range
   a. 16-22
   b. 22-28
   c. 28-34
   d. 34+
3. Year of study
   a. 3rd year
   b. 4th year
4. Subject major/specialization
   a. Biology
   b. Mathematics
   c. Chemistry
   d. Physics
   e. Other
5. Name of university, where you are training
   a. Kwame Nkrumah University
   b. Mukuba University
   c. Other

Content Knowledge (CK)

1. Strongly Disagree = SD 2. Disagree = D 3. Neither Agree/Disagree = N 4. Agree = A 5. Strongly Agree = SA

S/No		SD	D	N	A	SA
1	I have sufficient knowledge of my subject area.	1	2	3	4	5
2	I can use a scientific way of thinking.	1	2	3	4	5
3	I have various ways and strategies for developing my understanding of my subject area.	1	2	3	4	5
4	I can develop my understanding of my subject content matter by reading textbooks or scientific articles.	1	2	3	4	5
5	I know the daily life applications of every topic in my subject area.	1	2	3	4	5

Pedagogical Knowledge (PK)

1. Strongly Disagree = SD 2. Disagree = D 3. Neither Agree/Disagree = N 4. Agree = A 5. Strongly Agree = SA

S/No		SD	D	N	A	SA
6	I know how to assess student performance in a classroom.	1	2	3	4	5
7	I can adapt my teaching on what students currently understand or do not understand.	1	2	3	4	5
8	I can adapt my teaching style to different learners.	1	2	3	4	5
9	I can assess student learning in multiple ways.	1	2	3	4	5
10	I can use a wide range of teaching approaches in a classroom setting.	1	2	3	4	5
11	I am familiar with common student understandings and misconceptions.	1	2	3	4	5
12	I know how to organize and maintain classroom management.	1	2	3	4	5
13	I know how to guide students to construct their information	1	2	3	4	5
14	I know how to motivate students to lesson & keep their attention throughout the lesson.	1	2	3	4	5

Technological Knowledge (TK)

1. Strongly Disagree = SD 2. Disagree = D 3. Neither Agree/Disagree = N 4. Agree = A 5. Strongly Agree = SA

S/No		SD	D	N	A	SA
15	I know how to solve my technical problems.	1	2	3	4	5
16	I can learn technology easily.	1	2	3	4	5
17	I keep up with important new technologies.	1	2	3	4	5
18	I frequently play around with technology.	1	2	3	4	5
19	I know about a lot of different technologies.	1	2	3	4	5
20	I have the technical skills I need to use technology.	1	2	3	4	5
21	I have had sufficient opportunities to work with different technologies.	1	2	3	4	5

Technological Pedagogical Knowledge (TPK)

1. Strongly Disagree = SD 2. Disagree = D 3. Neither Agree/Disagree = N 4. Agree = A 5. Strongly Agree = SA

S/No		SD	D	N	A	SA
22	I can use different technologies for different teaching approaches.	1	2	3	4	5
23	I can choose technologies that enhance students' learning for a lesson.	1	2	3	4	5
24	I can use strategies appropriate technologies & teaching approaches that I learned about in my coursework.	1	2	3	4	5
25	I can provide leadership in helping others to coordinate the use of technologies, and teaching approaches at my school and/or district.	1	2	3	4	5
26	I can choose technologies that enhance teaching for a lesson.	1	2	3	4	5

Technological Content Knowledge (TCK)

1. Strongly Disagree = SD 2. Disagree = D 3. Neither Agree/Disagree = N 4. Agree = A 5. Strongly Agree = SA

S/No		SD	D	N	A	SA
27	I know about technologies that I can use for understanding & doing my subject of specialization.	1	2	3	4	5
28	I can choose appropriate technology to suit specific content in my subject of specialization.	1	2	3	4	5
29	I know how to use multiple representations of my subject concepts using digital technologies.	1	2	3	4	5
30	I can use a wide range of technologies to teach my subject of specialization.	1	2	3	4	5
31	I know technologies I can use to effectively teach my subject area.	1	2	3	4	5
32	I know appropriate technologies for teaching specific topics in my subject area.	1	2	3	4	5

Pedagogical Content Knowledge (PCK)

1. Strongly Disagree = SD 2. Disagree = D 3. Neither Agree/Disagree = N 4. Agree = A 5. Strongly Agree = SA

S/No	Technological pedagogical knowledge (TPK)	SD	D	N	A	SA
33	I can select effective teaching approaches to guide student thinking & learning in my subject area.	1	2	3	4	5
34	I can select appropriate teaching strategies to address difficult concepts in my subject of specialization.	1	2	3	4	5
35	I can facilitate a meaningful discussion about the learning of my subject content.	1	2	3	4	5
36	I can guide students to make connections between various concepts in my subject area.	1	2	3	4	5
37	I am comfortable with teaching various topics in my subject of specialization.	1	2	3	4	5
38	I can facilitate student self-learning in my classroom.	1	2	3	4	5
39	I can guide students to learn different concepts in my subject area.	1	2	3	4	5

Technological Pedagogical Content Knowledge (TPACK)

1. Strongly Disagree = SD 2. Disagree = D 3. Neither Agree/Disagree = N 4. Agree = A 5. Strongly Agree = SA

S/No		SD	D	N	A	SA
40	I can provide leadership in helping others to coordinate the use of subject content, technologies, & teaching approaches at my school and/or district.	1	2	3	4	5
41	I can use strategies that combine subject content, technologies, and teaching approaches that I learned about in my coursework.	1	2	3	4	5
42	Using technology, I can involve students in active learning of each topic in my subject area.	1	2	3	4	5
43	I can collaboratively help my fellow teachers to integrate technology in teaching their specific subjects.	1	2	3	4	5
44	I know appropriate technologies to improve student learning of a topic that is difficult for students to understand.	1	2	3	4	5
45	I can evaluate the appropriateness of digital technology for teaching specific concepts in my subject area.	1	2	3	4	5
46	I can identify online resources that support learning specific topics in my subject of specialization.	1	2	3	4	5
47	I can structure technology-based activities to help students construct multiple representations of concepts in my subject area.	1	2	3	4	5

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