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Student-Teachers' Technological Pedagogical Content Knowledge Preparedness for Mathematics Instruction

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Abstract

The study aimed to assess student-teachers' preparedness for technological pedagogical content knowledge of Mathematics instruction. This study employed the survey design, and the sampling technique was the simple random technique. A structured questionnaire was used to collect data to analyze the research questions. The data for the first research question was analyzed using means and standard deviations. Furthermore, the One-way Multivariate Analysis of Variance was performed to analyze data for the second research question. The results and findings revealed that student-teachers were generally prepared. However, they were more prepared for technological knowledge. This finding depicted the significant differences in preparedness. It was concluded that stakeholders assess the content needs and include mathematical models that address needs, pedagogy, and content knowledge. This finding calls for continuous updates of the mathematics curriculum to ensure comprehensive and effective preparedness.

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INTRODUCTION

Due to the present information and communication era, the educational horizon has received ICT literacy and skills as core components. Many universities generally offer mandatory courses, and ICT is one of them (Akour & Alenezi, 2022; Dwivedi & Joshi, 2021; López-Díaz and Peña, 2021). In this light, more teamwork, logical analysis, inquiry, and innovation, combined with information and communication technology literacy and skills, are the expectations of the new era. It has, therefore, introduced an additional dimension to educational objectives where teaching and learning must be directed toward achieving this goal. There is a need to introduce ICT as a course and as an instructional tool to improve learners' technological efficacy and teaching and learning, respectively, especially in Mathematics instruction.

As a result, many schools around the globe are investing huge sums of money into technological tools for learner-centered instruction (Humes, 2017; Stapf & Martin, 2019). This measure is not just in developed countries like the United States of America but also in developing countries such as Sub-Saharan Africa (Addico et al., 2020). Furthermore, formal organizations dedicated to mathematics instruction have endorsed using ICT in the classroom as a teaching tool. For instance, in Ghana, the new curriculum suggests that learners should be exposed to ICT tools around them to build their confidence and increase their motivation to apply ICT in later years. The new Mathematics curriculum also recognizes that incorporating ICT into mathematics instruction will help students improve their technological knowledge (Ministry of Education, 2019).

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Again, the advent and adoption of new technologies have allowed teachers to create collaborative learning experiences (Nayak & Akmar, 2020). This has equipped teachers to explore new instructional technologies to perform in the 21st-century classroom (Apau, 2017; Ministry of Education, 2019) and to be prepared with technology-related skills, which start with teacher training (Khalid, et al., 2018). This has, therefore, placed a task on teacher educators to guarantee that student-teachers graduate with information to infuse technology, pedagogy, and content in their teaching process. Teacher education institutions need to support and implement training programs to assist teachers in learning how to incorporate technology into the curriculum (Alrajeh & Shindel, 2020; Wilson et al., 2020). However, for technology integration to be effective, it is essential to understand the types of knowledge teachers must possess to facilitate meaningful learning experiences.

One widely recognized framework that supports technology integration in education is the Technological Pedagogical Content Knowledge (TPACK) model. This framework highlights the interplay between three core components of teacher knowledge: content, pedagogy, and technology (Mishra, 2019; Tseng et al., 2022; Yeh et al., 2021). Effective teaching requires teachers to balance these elements, ensuring that technology is not just an add-on but an integral part of instruction. Kurt (2019) further classifies teacher knowledge into various domains, including content knowledge, general pedagogy, curriculum, pedagogical content knowledge, awareness of learners, and understanding of academic settings. These domains align with the TPACK framework, where teacher expertise is expanded to include Technological Knowledge (TK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and Technological Pedagogical Content Knowledge (TPACK), which collectively define the essential knowledge base for integrating ICT into classroom instruction.

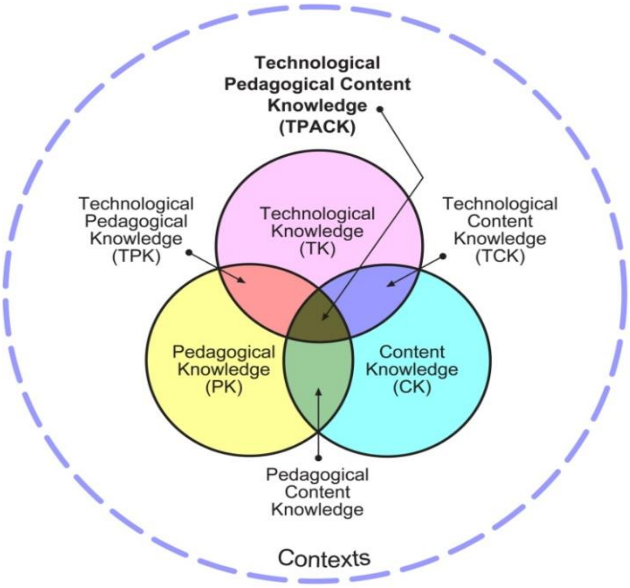

Figure 1. TPACK Framework (Kurt, 2019; Mishra, 2019)

Figure 1 differentiates between three types of knowledge of TPACK. The content describes what is being taught, and the pedagogy enumerates how the teacher imparts that content as the foundation for effective educational technology integration. The technology being implemented enables effective communication between the content and pedagogy. This order enhances students' learning experiences in the mathematics classroom (Power School, 2022).

From one perspective, content is the knowledge teachers must possess for the subject matter. For example, in algebra, the mathematics teacher requires the facts of it to teach it effectively. The various stages of the education sector have a unique way of structuring their content (Kurt, 2019). Pedagogy describes a special way of presenting content based on students' needs. This involves the knowledge required to select the right methods and strategies. For example, a mathematics teacher with knowledge of geometry will need the right teaching strategy to transfer his/her knowledge to the pupils. Technology includes the teacher's understanding of using conventional and advanced artifacts that can be incorporated into the school's curriculum. These are a variety of technologies, from simple ones to more advanced internet software programs and whiteboards. Therefore, teachers must upgrade their knowledge and skills through professional development sessions to be abreast with time and knowledge of new technologies (López-Díaz & Pena, 2021).

Therefore, Content Knowledge (CK) describes teachers' knowledge of the subject matter. CK may include knowledge of concepts, theories, evidence, and organizational frameworks within a particular subject matter, such as mathematics, or a particular domain, such as geometry and trigonometry. Pedagogical Knowledge (PK) describes teachers' knowledge of the practices, processes, and methods regarding teaching and learning. It may apply to more specific areas, including understanding student learning styles, classroom management skills, lesson planning, and assessments. Technological Knowledge (TK) describes teachers' knowledge of, and ability to use, various technologies, technological tools, and associated resources.

The intersection of content and technology is TCK, which seeks to represent subject matter that improves students' understanding and practice. The intersection between technology and pedagogy is TPK, which seeks to use specific tools to make the content more understandable and accessible to students (Apau, 2017). The intersection between pedagogy and content is PCK, which seeks to bring different techniques, strategies, and methods into the curriculum, assessment, and presenting results (Mishra, 2019; López-Díaz & Pena, 2021; Power School, 2022).

TPACK combines all three constructs involving content, pedagogy, and technology. The interaction of these three components enables teachers to develop appropriate content and knowledge of teaching. It is a tool that integrates content and pedagogy to facilitate student learning (Apau, 2017; Mishra; 2019). In the TPACK framework, teachers meaningfully and effectively engage students, making the situation more interesting. It demonstrates a comprehensive understanding of the knowledge required of student-teachers to identify students' needs and challenges in the mathematics classroom through modern instructional strategies and effective educational technologies. The framework also determines the mathematics content that could be included in the teacher training programs offered at the teacher training institutions. This helps to set standards for the successful preparation of the mathematics teacher in this 21st century (Apau, 2017). Karatas and Tutak (2016) provide a basis for understanding teachers' expectations and behavior when incorporating technology into curriculum and instruction.

In Ghana, Ali and Agyei (2016) and Addico et. al. (2020) report that mathematics students offer ICT in the first semester of the first year, where they learn fundamental computing skills. Still, the programs do not center on preparing student-teachers adequately for successful ICT integration in their teaching. On the other hand, the University level offers courses that equip teachers with the requisite experience, skills, values, and attitudes needed at the basic level of the education system of Ghana. At the Department of Mathematics curriculum, students undertake a semester course on introduction to ICT where basic computer skills in Microsoft Office, information literacy skills, and educational technology.

Nonetheless, the mathematics curriculum requires lecturers to introduce students to the optimum use of ICT for mathematics instruction. This can be done using technological tools to understand mathematical concepts like algebra (Winneba, 2020). Ozudogru (2019) opines that TPACK has been widely used in quantitative and qualitative studies for preservice teachers concerning gender. For this reason, the student-teacher should be adequately equipped in TPACK to handle issues on ICT integration in mathematics instruction as part of their teaching portfolio during the supported teaching in school (STS) in Year four (4) of the program (Addico, et. al., 2020). The mathematics curriculum exposes students to TPACK. However, no evidence supports that the mathematics curriculum has been achieved. Also, no data shows that the student-teachers have acquired the requisite training programs in TPACK and are ready to integrate technology into mathematics instructions.

In addition, a few research studies in Ghana (Ali & Agyei, 2016; Apau, 2017) have been conducted on using ICT tools in the mathematics classroom. Even though the findings of these studies are inconclusive on student-teacher preparedness, the findings of Alrajeh and Shindel (2020) and Nayak and Akmar (2020) revealed that TPACK preparedness differs according to gender, previous technology experience, ICT support, and age. Other research findings of Apau (2017), Ozudogr (2019), and Uslu (2018) found positive relations between TPACK preparedness and the gender of students. It is critical to examine the gender differences in this study.

This study aims to assess student-teacher TPACK preparedness for mathematics instruction. If student-teachers demonstrate preparedness, the next objective is to statistically analyze the influence of gender and/or ICT support on their TPACK preparedness. To achieve these aims, the study formulates the following research objectives:

1. To explore how student-teachers are prepared to use the TPACK framework to teach mathematics.
2. To investigate the statistical differences in TPACK preparedness based on gender and ICT support.

Accordingly, the researchers formulated the following research questions:

1. How are student-teachers prepared to use the TPACK framework to teach mathematics?
2. What statistically significant differences exist in TPACK preparedness concerning gender and ICT support?

METHOD

The research methodology of this study consists of several key components, including research design, participant selection, research instruments, data collection procedures, and data analysis methods. Figure 2 presents a flowchart summarizing the overall methodological process.

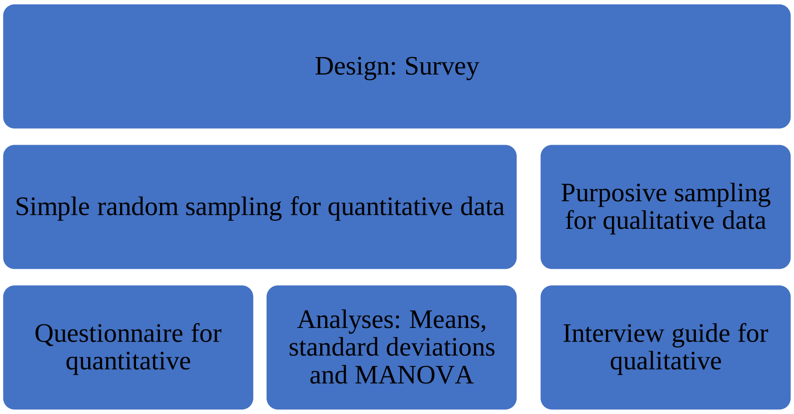

Figure 2. The Flowchart of the Research Methods

Figure 2 shows the flowchart of the research method, which includes the research design, the participants, the research instrument, and the data processing procedures.

Research Design

The survey research design describes procedures by which investigators administer a survey to a sample to describe the population's attitudes, opinions, or behaviors (Ozudogru, 2019). The survey describes the characteristics of a large population, so the researcher deemed it necessary because the sample size for this study was enormous. In addition, Apau (2017) opined that survey designs measure the characteristics of a homogeneous group of people, thus a group with common characteristics. This study's samples were all at the same academic level (level 300) and offered the same academic program. The survey design is flexible and can measure attitudes, knowledge, preferences, etc.; hence, it is suitable for this study since this study was focused on students' perception and preparedness in TPACK.

The Participants

The sampling process in this study involved multiple techniques to ensure a representative and purposeful selection of participants. First, the simple random sampling technique was utilized to provide equal opportunities for all students in the target population to be included in the study, minimizing selection bias. This technique ensures that every participant has an equal chance of being chosen, thereby enhancing the generalizability of the findings. In addition to random sampling, the purposive sampling technique was employed. The rationale behind using purposive sampling was that the researchers specifically targeted students who had successfully completed the necessary training programs, equipping them with the foundational knowledge and skills related to the TPACK framework. This approach was justified because these students were deemed capable of applying

TPACK principles in their mathematics classrooms, making them suitable candidates for assessing their preparedness in integrating technology into their instructional practices.

Furthermore, the census technique was applied to comprehensively include all students at the Level 300 stage in the Department of Basic Education. A total of 450 students were invited to participate in the study, consisting of 176 males and 189 females. The final response rate achieved was 81%, with 365 participants completing the survey. The high response rate indicates strong participation and engagement from the students, which enhances the reliability and validity of the study's findings. By integrating these three sampling techniques—simple random sampling, purposive sampling, and the census approach—the study ensured a balanced, representative, and contextually relevant participant pool, aligning with the study's objectives to examine student-teachers TPACK preparedness in mathematics instruction.

Table 1. Distribution of Gender of Basic Education Students

Gender	Frequency	Percentages
Male	176	48.2
Female	189	51.8
Total	365	100

Source: Field survey (2020)

Research instrument

A close-ended questionnaire was employed for the data collection. The questionnaire was adapted from Addico et. al. (2020). This instrument contained 5-point Likert scale items. However, some modifications were made to dimensions and item stems or response options. Therefore, the researchers altered the format and presentation of the number of responses. So, the original 5-point Likert was converted to a 4-point Likert scale. According to Saha (2019), using an even-numbered Likert scale is more appropriate and convenient as it omits the state's indifference when responding to items. Thus, the participants either agreed or disagreed with the statement presented. Also, the internal consistencies achieved a reliability coefficient of 0.7 and above.

The first part was labeled as 'Section A,' made up of the biographical data of the respondents, including gender (Male and Female) and ICT support (Access to a computer, Personnel, Internet access, Finance, and Others). The TPACK preparedness was labeled as 'Section B' and comprised the four components of TPACK. The instrument contained items for all the components of the TPACK framework. The adapted questionnaire was pilot-tested in a different group of 45 students at a different university. These 45 accounted for 10% of the sample size used in the main study. Literature (Apau, 2017) shows that this should be accepted for a pilot study sample. The piloted sample was used because the characteristics of those students are not significantly different from their peers at the Department of Basic Education. The reliability coefficient was 714, and it was adjudged adequate and suitable for the actual study. The researchers addressed ethical concerns of informed consent, anonymity, and confidentiality. Also, all information taken from different literature sources was acknowledged (Addico et. al., 2020).

Data Collection Procedure

Permission was sought, approved, and granted to conduct the study. A questionnaire was uploaded onto the Google form platform resource and linked to social media platforms such as WhatsApp. The students then uploaded the questionnaire, answered it, and returned the responses to the same platform. The text provided adequate coverage of the study and assured student-teachers of full participation, voluntary contribution, and confidentiality. The survey lasted nine weeks, and student-teachers constantly and continuously interacted with the researchers. Apart from only four respondents who failed to return their completed work, the data collection achieved an 81% response rate.

Data Analysis

We used SPSS version 21 to process and analyze the data. The researchers used the means and standard deviations to analyze the first research question. In contrast, the One-Way Multivariate Analysis of Variance (MANOVA) was used to analyze the second research question at a 0.05 level of significance or 95% confidence level.

RESULTS and DISCUSSION

This study's analysis takes the two research questions in turn. It describes the four cores of TPACK constructs (content, pedagogical, technological, and TPACK) and their intersecting constructs as contained in the findings of Nayak and Akmar (2020), Khalid et al. (2018), Ozudogru (2019), and Altun and Akyildiz (2017). The first part presents the results, and the second presents the discussion.

Research question one: How are student-teachers prepared to use the TPACK framework to teach mathematics?

The results were analyzed based on 'agree' or 'disagree.'If student-teachers agreed, the findings were interpreted based on three criteria: low, moderate, and high. If the mean score was below the standard mean, then the preparedness was considered 'low'; if the mean score equaled the standard deviation, then the preparedness was considered 'moderate/average'; and if the mean score was above the standard deviation, then the preparedness was considered 'high'.

Table 2. TPACK Preparedness

TPACK Preparedness	Mean (M)	Standard deviation (SD)
Technological	2.89	.94
Content	2.54	.86
Pedagogical	2.50	.91
TPACK	2.64	.92

In Table 2, the results show that student-teachers were prepared to use the TPACK framework. This is because almost all the subscales of TPACK are greater than the average mean. Even though the student-teachers were generally prepared to use the TPACK framework, they were more prepared to use TK, followed by TPCK, TCK, and TPACK. Eventually, the overall preparedness was lower than the individual constructs. Many differences among the student-teachers may cause this. However, gender and ICT support were adjudged the most precarious hindrances in this study.

Research question two: What statistically significant differences are there in Gender and ICT support?
This research question was broken into two parts to investigate the differences. The first part is TPACK preparedness and gender, and the second is TPACK preparedness and the ICT support system.

Part one: TPACK preparedness and gender

Subsequent to analyzing the statistically significant differences between gender and TPACK preparedness, conditions and the assumptions of independence, normality, and homogeneity were tested and satisfied, respectively. With regards to the MANOVA assumptions, the Shapiro-Wilk statistics showed normality, and the Box's M test equally showed that the homogeneity of variance-covariance matrices was satisfied. Having met these two key assumptions, the multivariate test was conducted, and the results are displayed in Table 3.

Table 3. Multivariate Test of Student-Teachers' Preparedness

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	0.984	5607.187[b]	4.000	360.000	0.000	0.984
	Wilks' Lambda	0.016	5607.187[b]	4.000	360.000	0.000	0.984
	Hotelling's Trace	62.302	5607.187[b]	4.000	360.000	0.000	0.984
	Roy's Largest Root	62.302	5607.187[b]	4.000	360.000	0.000	0.984
Gender	Pillai's Trace	0.013	1.190[b]	4.000	360.000	0.041	0.13
	Wilks' Lambda	0.987	1.190[b]	4.000	360.000	0.041	0.13
	Hotelling's Trace	0.013	1.190[b]	4.000	360.000	0.041	0.13
	Roy's Largest Root	0.013	1.190[b]	4.000	360.000	0.041	0.13

Source: Field survey (2020), N = 365

The results in Table 3 show that Wilks' Lambda was $p < 0.05$. This means that TPACK preparedness in the TK, TCK, TPK, and TPCK significantly differ concerning the gender of student-teachers. The Partial Eta Squared shows that the effect sizes were small. Generally, the researchers could infer that the multivariate test was statistically significant. This, therefore, required further investigation into the sources of the significant differences. The researchers thus used the Test of the Between-Subjects Effect, as presented in Table 4.

Table 4. Test of Sources of Statistical Significance of Gender

Source	Dependent Variable	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	TK	10.894[a]	1	10.894	2.276	0.021	0.006
	TCK	53.923[b]	1	53.923	3.356	0.032	0.009
	TPK	55.823[c]	1	55.823	1.903	0.012	0.005
	TPCK	28.731[d]	1	28.731	2.775	0.045	0.008
Intercept	TK	76318.336	1	76318.336	15941.224	0.000	0.978
	TCK	150769.945	1	150769.945	9384.457	0.000	0.963
	TPK	322776.919	1	322776.919	11001.725	0.000	0.968
	TPCK	124731.361	1	124731.361	12046.806	0.000	0.971
Gender	TK	10.894	1	10.894	2.276	0.021	0.006
	TCK	53.923	1	53.923	3.356	0.032	0.009
	TPK	55.823	1	55.823	1.903	0.012	0.005
	TPCK	28.731	1	28.731	2.775	0.045	0.008
Error	TK	1737.856	363	4.787			
	TCK	5831.929	363	16.066			
	TPK	10649.969	363	29.339			
	TPCK	3758.464	363	10.354			
Total	TK	78099.000	365				
	TCK	156644.000	365				
	TPK	333590.000	365				
	TPCK	128542.000	365				
Corrected Total	TK	1748.751	364				
	TCK	5885.852	364				
	TPK	10705.792	364				
	TPCK	3787.195	364				

Source: Field survey, N = 365

The results in Table 4 show that Wilks' Lambda was $p< 0.05$. Thus, there were statistically significant differences in TPACK preparedness concerning gender. However, the most statistically significant differences were observed in TK, TCK, TPK, and TPACK. Technology (T) runs through all these four and exemplifies how essential it is in teaching and learning mathematics. In our particular research, it was necessary to understand the statistics behind the constructs. Therefore, the descriptive statistics in Table 5 shed more light on these results.

Table 5. Descriptive Statistics

	Gender	Mean (m)	Std. Deviation (SD)	N
TK	M	15.6420	2.13869	176
	F	13.2963	2.23298	189
	Total	14.4630	2.19186	365
TCK	M	20.7216	3.96654	176
	F	18.9524	4.04665	189
	Total	20.3233	4.02118	365
TPK	M	30.1477	5.07890	176
	F	33.3651	5.71291	189
	Total	29.7425	5.42324	365
TPCK	M	18.7784	3.18600	176
	F	16.2169	3.24702	189
	Total	18.4877	3.22558	365

Source: Field survey (2020) N = 365

The results in Table 5 show that student-teachers were most prepared in TPK, followed by TCK, TPACK, and TK. There is no doubt that male (M) and female (F) student-teachers significantly differed in their TPACK preparedness. However, the differences were much more recorded in TPK. Integrating technology into content in the training and education of student-teachers is essential. This is not all. It is equally essential to integrate technology into pedagogy. The net effect is that technology must be integrated into not only the theories, formulas, and hypotheses of mathematics but also the methods, techniques, and strategies of teaching mathematics.

Research question two continued.

Before the analysis, the researchers tested for all assumptions of multivariate normality and Shapiro-Wilk. The homogeneity of variance-covariance matrices assumption was also tested using Box's M-test. Once all assumptions and conditions were satisfied, the multivariate test was conducted to test the existence or otherwise of any statistically significant differences among groups (access to a computer, internet access, finance, personal, and others) on the dependent variables (TK, TCK, TPK, and TPCK) as presented on Table 6.

Table 6. Multivariate Test

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	0.979	4197.025[b]	4.000	357.000	0.000	0.979
	Wilks' Lambda	0.021	4197.025[b]	4.000	357.000	0.000	0.979
	Hotelling's Trace	47.025	4197.025[b]	4.000	357.000	0.000	0.979
	Roy's Largest Root	47.025	4197.025[b]	4.000	357.000	0.000	0.979
ICT Support	Pillai's Trace	0.045	1.031	16.000	1440.000	0.021	0.11
	Wilks' Lambda	0.955	1.030	16.000	1091.291	0.025	0.11
	Hotelling's Trace	0.046	1.028	16.000	1422.000	0.013	0.11
	Roy's Largest Root	0.028	2.536[c]	4.000	360.000	0.0311	0.27

Source: Field survey (2020) N = 365

The results in Table 6 show that Wilks' Lambda was $p < 0.05$. This means that TPACK preparedness significantly differs in ICT support. Partial eta squared (0.11) was also moderate, which signified a mild effect of the independent variables. Once the results in Table 6 were statistically significant, it was sacrosanct to explore the ICT support that differed significantly on all the constructs. The researchers explored the Test of Between-Subjects Effect as presented in Table 7.

Table 7. Test of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	TK	25.732[a]	4	6.433	1.344	0.030	0.015
	TCK	30.901[b]	4	7.725	0.475	0.049	0.005
	TPK	168.083[c]	4	42.021	1.436	0.051	0.016
	TPACK	25.198[d]	4	6.299	0.603	0.032	0.007
Intercept	TK	57437.897	1	57437.897	12000.826	0.000	0.971
	TCK	114411.573	1	114411.573	7034.759	0.000	0.951
	TPK	243561.115	1	243561.115	8320.784	0.000	0.959
	TPCK	94627.942	1	94627.942	9055.313	0.000	0.962
ICT Support	TK	25.732	4	6.433	1.344	0.030	0.015
	TCK	30.901	4	7.725	0.475	0.049	0.005
	TPK	168.083	4	42.021	1.436	0.051	0.016
	TPACK	25.198	4	6.299	0.603	0.032	0.007
Error	TK	1723.018	360	4.786			
	TCK	5854.951	360	16.264			
	TPK	10537.709	360	29.271			
	TPACK	3761.997	360	10.450			
Total	TK	78099.000	365				
	TCK	156644.000	365				
	TPK	333590.000	365				
	TPACK	128542.000	365				
Corrected Total	TK	1748.751	364				
	TCK	5885.852	364				
	TPK	10705.792	364				
	TPACK	3787.195	364				

The results in Table 7 show that student-teacher TPACK preparedness significantly differed concerning their ICT support. Except for TPK, the p-values for TK, TCK, and TPACK concerning ICT support were less than 05, respectively, with small effect sizes. Once again, the results show how important the researchers need to use technology for the training and education of student-teachers in mathematics education.

Once the results in Table 7 were statistically significant, it was proper to explore the ICT support that pooled the most significant support. The researchers used Table 8 to explore the descriptive statistics.

Table 8. Descriptive Statistics of the Constructs

	ICT Support	Mean (M)	Std. Deviation (SD)	N
TK	Others	13.7097	2.55856	31
	Personal	14.4844	2.03144	64
	Finance	14.5532	2.03030	47
	Internet Access	15.3014	2.45337	73
	Access to Computer	16.6600	1.07843	150
	Total	14.4630	2.19186	365
TCK	Others	15.8710	3.49039	31
	Personal	16.8750	3.79013	64
	Finance	20.6596	4.41970	47
	Internet Access	22.2740	4.29231	73
	Access to Computer	20.5267	3.97930	150
	Total	20.3233	4.02118	365
TPK	Others	29.4194	5.38995	31
	Personal	28.5469	5.16991	64
	Finance	33.1702	6.76088	47
	Internet Access	30.3014	5.16044	73
	Access to Computer	31.2267	5.15680	150
	Total	29.7425	5.42324	365
TPCK	Others	17.8065	3.56295	31
	Personal	18.8125	3.05440	64
	Finance	16.5745	3.24871	47
	Internet Access	20.2877	2.23814	73
	Access to Computer	19.5600	3.62840	150
	Total	18.4877	3.22558	365

Table 8 shows that the student-teachers were more prepared in TPK, TCK, TPCK, and TK. Also, it was discovered that among the sub-constructs in each of the four constructs, access to computers became one of the most significant factors, aside from internet access, personal, and finance. Thus, many student-teachers found accessing ICT tools such as desktop computers, laptops, and scientific calculators challenging. This challenge was intrinsically linked to the other factors. It is incumbent to have access to the hardware and software to ease the training and education of mathematics.

Discussion

The discussion of findings was done according to the research questions:

Research question one: How are student-teachers prepared to use the TPACK framework to teach mathematics?

The TPACK preparedness of student-teachers was examined based on the components of TPACK. Students were prepared in all the components of TPACK, namely, Technological Knowledge (TK), Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), and Technological Pedagogical Content Knowledge (TPCK). It should be acknowledged that these findings are evidenced in the literature. For instance, Khalid, Karim, and Husnin (2018) reported that student-teachers are competent in the various elements of TPACK, such as TK, TCK, PK, CK, PCK, and TPK. The current findings of this study agree with Nayak and Akmar (2020), Khalid et al. (2018), and Ozudogru (2019) are similar to the findings of Altun and Akyildiz (2017). These two findings reported that student-teachers agree they have a good level of TPACK in general and are ready to integrate technology in their classrooms.

Ali and Agyei (2016) and Uslu (2018) also reported that preservice teachers have a high knowledge of these constructs. These results indicated that student teachers in the Department of Basic Education had above-average preparedness in TK and TPCK but average preparedness in TCK and TPK. Overall, student teachers are prepared to integrate TPACK into Mathematics instruction, which conforms to Ali and Agyei's (2016) findings.

On the contrary, Apau (2017) revealed that student-teachers generally lack knowledge of technological pedagogical content. This finding means that some student-teachers lack the knowledge to integrate TPACK in mathematics instruction classrooms. The study findings disagree with the findings of Apau since the study revealed that student-teachers are generally prepared to integrate TPACK in Mathematics instruction (López-Díaz & Pena, 2021). Student-teachers in the Department have high perceptions and are prepared to integrate technology into mathematics instruction. One would expect that they are also prepared in TPACK. The good perceptions and their ability to integrate technology might have given them enough know-how to apply what they have learned from the lectures in the Department, hence, the results.

Again, students' TPACK preparedness significantly differed concerning gender. This result is obvious in that the utilization of technology, for example, in the 21st century, can be linked with users' gender, and similar reasons can be attributed to this current result. It should be pointed out that technology use is linked with learning and practice, and whether a male student is linked with better use of technology, training, and constant practice compared to female students can result in differences in TPACK preparedness. Regarding gender, there was a high likelihood that male teachers had practiced enough compared to females (Addico et al., 2020). Cetin-Karatas et al. (2017) reported significant differences in TPACK, with males being more prepared than females. Both findings corroborate each other to determine whether the TPACK preparedness of student-teachers depended on or differed gender. Furthermore, it was confirmed that student-teachers have a high TPACK preparedness in terms of gender. Therefore, gender differences in TPACK preparedness are a reality and must be considered in mathematics instruction (Uslu, 2018).

On the contrary, Altuni and Akyildiz (2017) reported that in terms of TPACK, gender was not a determining factor. They found little TPACK preparedness in gender. Their findings disagree with the findings of this study since the TPACK preparedness of student-teachers did not significantly differ in gender. Again, Khaliet al. (2018) found no gender differences in TPACK preparedness. This is because the study's findings revealed that the TPACK preparedness of student-teachers or preservice teachers did not significantly differ in terms of gender. Apau (2017) also reported no differences in TPACK preparedness concerning their gender. This is in disagreement with the findings of this study since the TPACK preparedness of student-teachers did not differ concerning gender in Apau (2017).

Research question two: What statistically significant differences are there in Gender and ICT support?

Regarding TPACK preparedness and ICT support, the students' TPACK preparedness significantly differed in terms of their ICT support. Naturally, the kind of ICT support students receive is necessary for using technology in instruction, such as TPACK. Support in terms of equipment, finance, and help, among others, shape the competencies and add to students' practical abilities. For the student-teachers, there is the likelihood that they received support from themselves and their lecturers and/or the department to which they belong, which might have resulted in this current finding. It should be acknowledged that the finding is evidenced in the literature. Altuni and Akyıldız (2017) collaborated on this current finding and indicated that student-teachers who own personal computers obtained higher TPACK scores of the TPACK dimension, Technological knowledge (TK) since most of them are in contact with technology in their daily lives.

The study further revealed a statistically significant difference between students' TPACK scores and personal computer ownership. These findings revealed that student-teachers with access to a computer and those with personal computers had higher TPACK preparedness (Addico et. al., 2020). Similarly, Altun (2019) confirmed this current finding and reported a statistically significant difference between students' TPACK scores and personal tablet ownership. The findings revealed a statistically significant difference in student-teacher TPACK preparedness and family income. The findings agree that student-teachers with personal computers have higher TPACK preparedness, as in the case of Altuni and Akyıldız, where student-teachers with personal tablet ownership had higher TPACK preparedness. By implication, the use of such personal equipment and the ability to afford them add to the individual's experience and present to him or her understanding of the future usage of such equipment, including TPACK.

Suggestions

Although the study found that student-teachers had average preparation towards TPACK integration in Mathematics, it was recommended that educational institutions continuously update their curriculum to ensure that student-teachers are maximally prepared in TPACK. This can be achieved by assessing the content needs of society and bringing out mathematical models that can address all needs. Faculty should encourage female student-teachers to develop a habit that adequately prepares them in all the constructs of TPACK. This can be achieved by emphasizing the need to use constructs in the teaching of mathematics. Student-teachers should develop positive habits and interest in using the internet and personal computers to increase their knowledge base in technology, which can also increase their TPACK. This can be achieved by encouraging student-teachers to make good use of the internet and personal computers and providing them with the ICT support they need since that can positively influence their TPACK.

CONCLUSION

It could be concluded that the student-teachers were prepared to use ICT tools to teach mathematics. However, the preparedness of the components of TPACK of student-teachers differed concerning their gender, favoring male student-teachers. For TK, TCK, and TPCK, males were likely to do better than females, while female student-teachers were likelier than males in TPK. The preparedness of the student-teacher components of TPACK differed concerning their ICT support. Here, female student-teachers needed more support than male student-teachers. The support comes in varied forms, but the components of TPACK were paramount.

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AUTHOR CONTRIBUTIONS STATEMENT

ALA : Conceptualization, design, data acquisition, analysis, drafting the manuscript, and defending
CAA : Editing, reviewing, supervision, correction, counseling, final approval, and publishing
NSA : Editing, reviewing, supervision, proofreading, technical support, and review

REFERENCES

Addico, A. L., Ali, C. A. & Adzifome, N. S. (2020). *Student-teachers' technological pedagogical content knowledge preparedness for teaching and learning of mathematics* (Master's Thesis, University of Education, Winneba).

Akour, M., & Alenezi, M. (2022). Higher education future in the era of digital transformation. *Education Sciences*, *12*(11), 784. https://doi.org/10.3390/educsci12110784

Ali, C. A. & Agyei, D. D. (2016). Preservice teachers' technological, pedagogical and content knowledge in utilizing Merrill's first principles in solving polynomials. *Merit Research Journal of Education and Review,* 4(10), 133-142.

Alrajeh, T.S., & Shindel, B.W. (2020). Student engagement and math teachers support. Journal on mathematics education, 11(2), 167-180. https://doi.org/10.22342/jme.11.2.10282.167-180

Altun, D. (2019). Investigating preservice early childhood education teachers' technological pedagogical content knowledge (TPACK) competencies regarding digital literacy skills and their technology attitudes and usage. *Journal of Education and Learning*, 8(1), 249-263. https://doi.org/10.5539/jel.v8n1p249

Altuni, T. & Akyildiz, S. (2017). Investigating student teachers' technological pedagogical content knowledge (TPACK) levels based on some variables. *European Journal of Education Studies*, 3(5), 467-485.

Apau, S. K. (2017). Technological pedagogical content knowledge preparedness of student-teachers of the department of arts and social sciences education of the University of Cape Coast. (Unpublished master's dissertation).

Dwivedi, V. J., & Joshi, Y. C. (2021). ICT Perspectives of Productive and Sustainable Development for 21st Century Higher Education Institutions. *International Journal of Education and Development Using Information and Communication Technology*, *17*(3), 81–96

Humes, V. (2017). The impact of TPACK, SAMR, and teacher effectiveness on student academic growth in eighth grade language art and mathematics (Unpublished Master's Thesis, Youngstown State University).

Khalid, F., Karim, A. A., & Husnin, H. (2018). Preservice teachers' preparedness in integrating pedagogy, content and technology knowledge. *Journal of Advance research in Dynamical and Control Systems*, 10(12), 1467-1473.

Karataş, F. I., & Tutak, F. A. (2015). An examination of secondary mathematics teachers' technological pedagogical content knowledge. In *CERME 9-Ninth Congress of the European Society for Research in Mathematics Education* (pp. 2361-2366).

Erme. (2015). Prague, Czech Republic, pp.2361-2366. https://hal.archives-ouvertes.fr/hal-01289265

Karatas, I., Tunc, M. P., Yilmaz, N., & Karaci, G. (2017). An investigation of technological pedagogical content knowledge, self-confidence, and perception of preservice middle school mathematics teachers towards instructional technologies. *Educational Technology & Society*, 20 (3), 122-132.

Kurt, S. (2019). TPACK: Technological pedagogical content knowledge framework, available at https://educationaltechnology.net/technological-pedagogical-content-knowledge-tpack-framework/.

López-Díaz, M.T., & Pena, M. (2021). Mathematics training in engineering degrees: an intervention from teaching staff to students. *Mathematics* 9, (1475), 2-13.
https://doi.org/10.3390/math9131475

Mishra, P. (2019). Considering contextual knowledge: the tpack diagram gets an upgrade, journal of digital learning in teacher education, 35:2, 76-78. https://doi.org/10.1080/21532974.2019.1588611

Ministry of Education (2019). Mathematics curriculum for primary school. National Council for Curriculum and Assessment (NaCCA), available at https://nacca.gov.gh/wp-content/uploads/2019/04/MATHS-UPPER-PRIMARY-B4-B6.pdf

Nayak, A. K., & Akmar, S. N. (2020). Technology pedagogical content knowledge (TPCK) and techno pedagogy integration skill (TPIS) among preservice science teachers- case study of a university based ICT based teacher education curriculum. *Journal of Education and Practic*e, 11 (6), 54-65.

Ozudogru, M., & Ozudogru, F. (2019). Technological pedagogical content knowledge of mathematics teachers and the effect of demographic variables. *Contemporary educational technology*, *10*(1), 1-24. https://doi.org/10.30935/cet.512515

Power School (2022). The TPACK framework explained (with classroom examples). Resource Library, available at https://www.powerschool.com/blog/the-tpack-framework-explained- with-classroom-examples/

Saha, S. (2019). What is the problem with using only4categories in a Likert scale? Available at https:www.researchgate.net/post/.

Stapf, K. & Martin, B. (2019). TPACK mathematics: a review of current TPACK literature. *International Journal on Integrating Technology in Education (IJITE)*, 8(3).
https://doi.org/10.5121/ijite.2019.8302

Tseng, J.-J., Chai, C. S., Tan, L., & Park, M. (2022). A critical review of research on technological pedagogical and content knowledge (TPACK) in language teaching. *Computer Assisted Language Learning*, *35*(4), 948–971. https://doi.org/10.1080/09588221.2020.1868531

Uslu, Ö. (2018). Factors associated with technology integration to improve instructional abilities, a path model. *Australian Journal of Teacher Education*, 43(4). https://doi.org/10.14221/ajte.2018v43n4.3

Wilson, M. L., Ritzhaupt, A. D., & Cheng, L. (2020). The impact of teacher education courses for technology integration on pre-service teacher knowledge: A meta-analysis study. *Computers & Education*, *156*, 103941. https://doi.org/10.1016/j.compedu.2020.103941

Winneba (2020). B.Ed basic education. University of Education, Winneba, available at https://www.uew.edu.gh/academic-programmes/b-ed-basic-education.

Yeh, Y.-F., Chan, K. K. H., & Hsu, Y.-S. (2021). Toward a framework that connects individual TPACK and collective TPACK: A systematic review of TPACK studies investigating teacher collaborative discourse in the learning by design process. *Computers & Education*, *171*, 104238. https://doi.org/10.1016/j.compedu.2021.104238