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Demographic Drivers of Science Teachers' Technological Pedagogical Content Knowledge in Ghana

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Abstract Technological Pedagogical Content Knowledge (TPACK) is a critical framework for integrating technology into teaching, yet disparities in its development among educators can undermine efforts to improve educational outcomes. This study explored the demographic factors influencing science teachers' TPACK in Ghana's Central Region, focusing on the roles of gender and teaching experience. Through a cross-sectional survey involving 145 Junior High School science teachers selected via simple random sampling, primary data were collected using a structured questionnaire. Multivariate Analysis of Variance (MANOVA) revealed significant disparities with male science teachers demonstrating significantly higher TPACK knowledge compared to their female counterparts and teachers with more than six years of experience demonstrated superior TPACK compared to less experienced teachers. These findings highlight critical gaps that must be addressed to ensure equitable access to professional development opportunities. By tackling gender disparities and harnessing the potential of experienced educators, this research advocates for targeted strategies to strengthen TPACK and advance science education in Ghana, fostering enhanced learning experiences for students.

Keywords: *Technological Content Knowledge Technological Pedagogical Knowledge (TPACK), gender disparities, teaching experience, science teachers, technology integration*

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1. Introduction

The integration of technology into education has become essential in the 21st century, reshaping teaching and learning processes worldwide. Technology not only enhances educational outcomes for teachers and students by providing diverse resources and fostering independent learning but also bridges gaps in traditional pedagogical methods [1,2]. For instance, instructional videos simplify complex concepts, enabling more effective learning experiences [3]. Consequently, policymakers and stakeholders, particularly in developed nations, advocate for integrating information and communication technology (ICT) to improve education systems [4,5].

In developing countries, ICT adoption remains inconsistent despite its potential benefits [6,7,8]. In Ghana, the government initiated the "Ghana ICT for Accelerated Development" policy in 2002 and integrated ICT into educational reforms in 2007 to improve teaching quality and equip students with essential digital skills [9]. Investments in computer laboratories and ICT infrastructure have expanded accessibility [10,11], yet the effective integration of technology into pedagogy depends on teachers' ability to balance technology, pedagogy, and content [12,13,14]. This specialized skill set, termed Technological Pedagogical Content Knowledge (TPACK), is crucial for impactful teaching in the digital era [15,16].

Research highlights the influence of demographic factors such as gender and teaching experience on TPACK competencies [17,18]. While some studies report no significant gender differences in TPACK [19,20], others identify disparities linked to gender and teaching experience [21,22,23]. Gendered perceptions of technology and societal biases further exacerbate these disparities, often portraying ICT as a male-dominated field [24,25].

In Ghana, most TPACK-related research focuses on senior high school teachers or subjects other than science [5,26,27,28]. This study addresses a critical gap by examining how demographic factors such as gender and teaching experience influence the TPACK of junior high school (JHS) science teachers. By investigating these variables, the study aims to provide insights into enhancing science education through equitable and effective ICT integration. Specifically, it seeks to answer two research questions:

1. What is the impact of gender on the development of TPACK constructs among science teachers?
2. How does teaching experience influence the development of TPACK constructs in science education?

2. Literature Review

Technological Pedagogical Content Knowledge (TPACK) represents the intersection of content, pedagogy, and technology, offering a framework for effective teaching in the digital age. It is a seven-construct framework consisting of Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK) and Technological Pedagogical Content Knowledge (TPACK). This model emphasizes the integration and balance of these domains, enabling educators to select and apply appropriate technologies and teaching strategies to enhance student learning [29,30,31]. TPACK fosters the use of technology not merely as a tool for information delivery but as an integral part of teaching that simplifies complex concepts and enriches educational experiences [32,33,34] Consequently, 21st-century teachers must adopt technologies to transform traditional pedagogical methods and create engaging, student-cantered learning environments [22,35,36].

Several studies have highlighted the influence of demographic factors—such as gender, age, and teaching experience—on the development of TPACK competencies. Gender differences in TPACK components have been widely explored. For instance, [37] found significant gender-related differences in pre-service mathematics teachers' perceptions of TPACK in Central Anatolia, with male participants outperforming their female counterparts in Technological Pedagogical Knowledge (TPK), Technological Knowledge (TK), and overall TPACK variables. Similarly, [22] observed that male science teachers in Taiwan reported higher technology knowledge scores than their female peers. In contrast, [38] reported no significant gender differences in overall TPACK among Turkish pre-service teachers, though female participants demonstrated higher Pedagogical Knowledge (PK) scores. These mixed findings underscore the nuanced impact of gender on TPACK development.

Teaching experience also plays a significant role in shaping TPACK. Reference [39] reported that while teaching experience had minimal predictive power for TPACK components, it strongly correlated with constructivist-oriented TPACK subdomains, suggesting its complex relationship with TPACK development. Reference [40] found that male mathematics teachers with extensive experience demonstrated higher Technological Knowledge (TK), while female teachers with limited experience reported the lowest TK scores. Other studies, such as [18,41] have shown that experienced teachers tend to have stronger TPACK perceptions, particularly in Subject Matter Knowledge (SMK) and Pedagogical Content Knowledge (PCK). Interestingly, [42] observed higher TPACK perceptions among younger or less experienced teachers, suggesting that exposure to contemporary technological training might play a role.

While TPACK research has expanded globally, studies in Ghana have predominantly focused on senior high school teachers across various subjects, leaving a gap in understanding how demographic factors influence TPACK among science teachers at the junior high school level. This oversight limits the ability to design targeted professional development initiatives for educators. To address this gap, the present study investigates how gender and teaching experience shape the TPACK of junior high school science teachers in Ghana, providing insights for improving teacher training and enhancing science education outcomes.

3. Methodology

3.1. Research Design

The study adopted a cross-sectional survey design due to its efficiency in collecting extensive data and generalizing findings. The design provided diverse insights into respondents' opinions and behaviours at a specific point in time, which allowed for quantitative analysis using inferential statistics [40,43,44]. The cross-sectional survey approach was seen to be cost-effective and provided representative sample leading to appropriate generalization [45,46], although it has the limitation of requiring a large sample size. In this context, the use of a cross-sectional survey was particularly advantageous for capturing a snapshot of the current state of affairs, making it a suitable choice for this research. Despite the large sample size requirement, the benefits of obtaining comprehensive and representative data justify this approach.

3.2. Sample Size and Sampling Procedure

Two educational districts (Komenda Edina Eguafo Abrem and Cape Coast metropolis) within the Central region were randomly selected. Within these two districts, a random selection process was employed to choose 145 science teachers as respondents. The selection was made using computer-based random number generation to ensure unbiased sampling [47,48]. This method was aimed at generalizing the findings to all JHS science teachers in the region [49]. The respondents comprised 58% male and 42% female participants.

3.3. Instruments

The study used a questionnaire which was adapted from [50]. The questionnaire used had 55 items, divided into sections. Section "A" captured demographic information. Sections "B" through "H" focused on different aspects of TPACK: TK, CK, PK, PCK, TPK, TCK, and overall TPACK. A five-point Likert scale was used for all items, as it is straightforward for respondents [51]. The questionnaire ensured standardization, enabling data collection from a large sample efficiently and cost-effectively.

The questionnaire was subjected to reliability analysis to ensure that it was appropriate for the Ghanaian context being used although it had been validated by the authors. Cronbach's Alpha was used to gauge internal consistency, with all constructs exceeding the recommended minimum of 0.7, indicating high reliability [52]. The coefficients were: TK (0.748), PK (0.894), CK (0.794), PCK (0.777), TCK (0.831), TPK (0.887), and TPACK (0.873).

3.4. Data Collection and Analysis Procedure

The participants' right to privacy and anonymity were ensured throughout the study. All respondents were made aware of the objectives of the research and efforts were made to ensure that they understood them. Respondents signed a letter of informed consent that allowed the researchers to use the information gathered for the research purposes. Ethical responsibilities entail protecting the rights of respondents and reporting results fairly and accurately. After consent forms were signed, the questionnaire was made available to participants. the participants responded to the questionnaire and returned them to the researchers.

The data was processed using SPSS (v22.0) for editing, coding, and analysis. A Multivariate Analysis of Variance (MANOVA) was employed to estimate the influence of gender and teaching experience on continuous dependent variables, including TPACK constructs. The analysis aimed to elucidate the relationships between gender and TPACK constructs, as well as between teaching experience and TPACK constructs. By employing MANOVA, the study addressed research questions related to the impact of gender and teaching experience on TPACK constructs, providing a comprehensive understanding of the variables involved.

4. Result

The results of this study have been presented based on the research questions that guided the research. First, the results regarding gender differences have been presented which is then followed by the results of the teaching experience.

4.1. Gender Differences in Science Teachers' TPACK Constructs

The first research question sought to identify if differences existed between the TPACK of male and female science teachers. To answer this research question, the MANOVA was used to determine whether the means of two groups (male and female) are statistically significant. The study met the parametric test assumptions (such as normality, multicollinearity). The normality test, as well as the multicollinearity test were checked to ensure that the assumptions are not violated. The normality of the data set was checked using histogram as shown in Figure 1. The histogram showed that the data was normal and does not violate the MANOVA analysis assumption.

The normal probability plot was also used to check the normality of the data and results are shown in Figure 2. The results of the normal probability plot showed that the data is normally distributed. The graph revealed that the points spread around the diagonal line and follows the direction of the diagonal line and the points do not move away from the diagonal line therefore, the data is normal.

The variance inflation factor (VIF) was used to measure the multicollinearity among the variables. The results showed that tolerance values were greater than 0.1 and Variance inflation factors (VIF) figures were less than 10 suggesting that there was no problem of multicollinearity [53,54]. Table 1 shows the result of the Multicolinearity Test.

Table 2 depicts the output of the Box's test of Equality of Covariance Matrices of the MANOVA test result results. Box's M of 89.258 indicate that the homogeneity of the covariance matrices across groups was assumed [F (28, 58275.19) = 3.016, p < 0.001].

Table 3 gives the account of the results of the descriptive statistics, which shows that male teachers had high means scores for all the TPACK constructs than their female's counterparts.

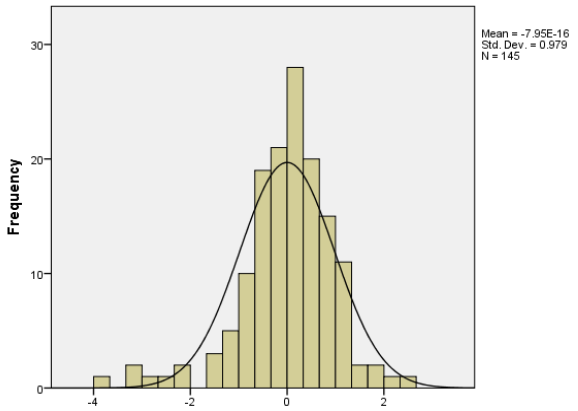

Figure 1. Regression standardized residual

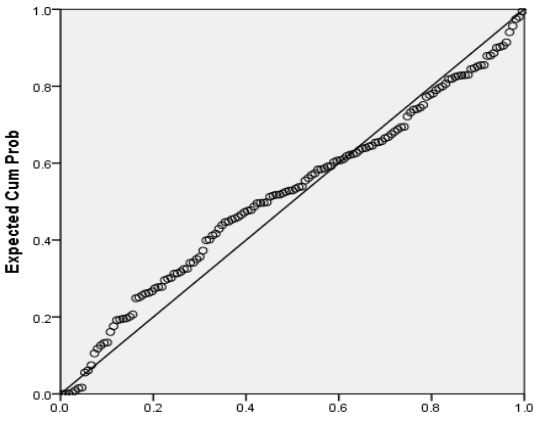

Figure 2. Observed Cum Prob

Table 1. Multicolinearity Test

Variables	Tolerance	VIF
TK	.712	1.405
CK	.577	1.732
PK	.744	1.344
PCK	.589	1.697
TPK	.704	1.420
TCK	.761	1.314

Table 2. Box's Test of Equality of Covariance Matrices for gender

Box's M	89.258
F	3.016
df1	28
df2	58275.187
Sig.	.000

Table 3. Descriptive Statistics male and female science teachers' TPACK

	Gender of respondent	Mean	Std. Dev	N
TK	Male	3.7279	.73502	84
	Female	3.2084	.88162	61
	Total	3.5094	.83754	145
CK	Male	4.3690	.51040	84
	Female	4.0615	.58569	61
	Total	4.2397	.56240	145
PK	Male	4.5104	.38477	84
	Female	4.2602	.59130	61
	Total	4.4052	.49636	145
PCK	Male	4.3065	.42750	84
	Female	4.0307	.62984	61
	Total	4.1905	.53786	145
TPK	Male	4.1865	.47382	84
	Female	3.8934	.81538	61
	Total	4.0632	.65383	145
TCK	Male	4.1037	.58895	84
	Female	3.7026	.68922	61
	Total	3.9350	.66133	145
TPACK	Male	4.2009	.46771	84
	Female	3.8361	.67025	61
	Total	4.0474	.58816	145

The inferential statistics of the MANOVA test to determine whether the means for the two groups (male and female) were statistically significant is presented on Table 4.

Table 4. Multivariate Test of TPACK across Gender

	Effect	Val	F	Hypodf	Error df	Sig.	PES	OP
Intercept	Pillai's Trace	.990	1946.710[b]	7.0	137.0	.000	.990	1.0
	Wilks' Lambda	.010	1946.710[b]	7.0	137.0	.000	.990	1.0
	Hotelling's Trace	99.4	1946.710[b]	7.0	137.0	.000	.990	1.0
	Roy's Largest Root	99.4	1946.710[b]	7.0	137.0	.000	.990	1.0
Gender	Pillai's Trace	.173	4.084[b]	7.0	137.0	.000	.173	.98
	Wilks' Lambda	.827	4.084[b]	7.0	137.0	.000	.173	.98
	Hotelling's Trace	.209	4.084[b]	7.0	137.0	.000	.173	.98
	Roy's Largest Root	.209	4.084[b]	7.0	137.0	.000	.173	.98

The MANOVA test was performed on the independent variables (Gender) and dependent variables (TPACK constructs) and the results of evaluation assumptions of normality and that of homogeneity of variance-covariance matrices across groups is assumed [F (28, 58275.19) = 3.016, p < 0.001], linearity and multicollinearity were achieved satisfactory. The combined Wilk's criterion showed that dependents variables (TK, CK, PK, TCK, TPK, and TPACK) were significantly different by gender (Male and Female).

The results of the MANOVA showed that there is a statistically significant difference between the gender (male and female) on combined dependent variables (TPACK constructs), (Wilks' $\Lambda = .83$, $F(7, 137) = 4.08$, $p < .001$; partial $\eta 2 = .17$, observed power = .98). These results from the MANOVA test indicated that there is enough evidence to acknowledge that there is a statistically significant difference in terms of gender on the TPACK constructs. The effect size was large and observed power was .98, meaning that there was a 98% chance that the outcome of the results could have come out statistically significant.

To determine where the differences lay, the marginal means of male and female teachers as presented in Table 3 were consulted. The results suggested that male teachers had higher marginal mean than female teachers did on all the constructs of TPACK framework. The magnitude of the differences in the means was (eta squared = .17). The mean difference in that of TCK scores for males (M = 4.10, SD = .59) and female (M = 3.70, SD = .69); $F = 4.08$, $p < .001$ in favour of males. The magnitude of the differences in the means was (eta squared = .17), which can interpret as large. The mean difference in that of TPACK scores for males (M = 4.20, SD = .47) and female (M = 3.80, SD = .67); $F = 4.08$, $p < .001$ in favour of males. The magnitude of the differences in the means was (eta squared = .17). In conclusion, male teachers can be said to have significantly higher level of TPACK than female teachers; and the difference could be observed for each construct of TPACK framework. The Post Hoc Tests analyses for pair wise comparisons could not be done because the independent variables are only two (male and female).

Males have higher mean scores than females for all the TPACK constructs. The differences between group means for each construct (TK, CK, PK, PCK, TPK, TCK, and TPACK) are significant; it implies that gender influence TPACK constructs significantly. The MANOVA results provide overall multivariate effects for gender. For instance, Wilks' Lambda measures differences between groups. The MANOVA has provided information about how gender influences TPACK constructs (TK, CK, PK, PCK, TPK, TCK, and TPACK). The significant results suggest that gender indeed plays a role in TPACK constructs. The results align with the previous studies of [21,22,23,37] who concluded that there is statistically significant difference between male and female teachers in their TPACK constructs.

4.2. Influence of Teaching Experience on Science Teachers TPACK

In answering the research question that sought to identify the influence teaching experience has on TPACK of science teachers, a multivariate analysis of variance (MANOVA) was used to compare the dependent variables and independent variable. This was done to help in determining whether the differences between the means of the TPACK framework constructs are significant according to teachers' teaching experiences. The test of normality and other assumptions had been checked already. Table 5 gives the account of the results of the

descriptive statistics, which shows teachers mean for teaching experience on TPACK constructs.

Table 5. Teachers' TPACK means across teaching experience

	Teaching Experience	Mean	Std. Deviation	N
Technological knowledge	1-5	3.5544	.93556	42
	6-10	3.7602	.60366	28
	11-15	3.5087	.85538	41
	16ab	3.6302	.99998	34
	Total	3.6423	.87613	145
Content knowledge	1-5	4.2530	.46484	42
	6-10	4.2232	.68496	28
	11-15	4.3537	.52359	41
	16abo	4.1323	.55896	34
	Total	4.1215	.06294	145
Pedagogical Knowledge	1-5	4.3512	.50924	42
	6-10	4.4464	.43757	28
	11-15	4.5274	.36712	41
	16ab	4.2978	.63291	34
	Total	4.2620	.62540	145
Pedagogical Content Knowledge	1-5	4.2262	.45802	42
	6-10	4.1786	.49234	28
	11-15	4.2530	.69512	41
	16ab	4.1250	.43519	34
	Total	4.0741	.62941	145
Technological Pedagogical Knowledge	1-5	4.1865	.65041	42
	6-10	4.0774	.51815	28
	11-15	4.1585	.56513	41
	16ab	4.0931	1.0051	34
	Total	4.1908	1.0335	145
Technological Content Knowledge	1-5	4.0272	.63044	42
	6-10	3.9898	.63404	28
	11-15	3.9094	.63868	41
	16ab	4.3739	1.2419	34
	Total	3.9990	.82813	145
Technological Pedagogical Content Knowledge	1-5	4.1280	.56342	42
	6-10	4.1741	.48033	28
	11-15	4.0854	.57516	41
	16ab	4.4595	.43161	34
	Total	4.0181	.58277	145

The results of the MANOVA test (Box's Test of Equality of Covariance Matrices, Multivariate Tests and Bonferroni Multiple Comparison) were presented in Table 6, Table 7 and Table 8 respectively.

Table 6. Box's Test of Equality of Covariance Matrices for Teaching Experience

Box's M	198.644
F	1.584
df1	108
df2	14143.487
Sig.	.000

The Box's M of 198.644 indicates that the homogeneity of covariance matrices across groups is assumed [F (108, 14143.487) = 1.58, p = .000].

A multivariate analysis of variance was performed on independent variables (years of teaching) and dependent variables (TPACK constructs). The results of homogeneity of variance-covariance matrices and evaluation assumptions of normality shows that the homogeneity of covariance matrices across groups is assumed (F (108, 14143.487) = 1.58, p < .001), satisfactory linearity and low multicollinearity were achieved. The combined Wilk's criterion showed that dependents variables (average TPACK constructs) were significantly different by years of teaching experience. The MANOVA results indicated that there was a statistically significant difference between the various levels of teaching experience (1-5 years, 6 -10 years, 11-15 years and 16 years above) on combined dependent variables (TPACK constructs), Wilks' Λ = .24, F (40, 578.12) = 5.62, p < .001; partial $\eta 2$ = .25), observed power = 1.00. From the result, there was enough evidence to depict that there is a statistically significant influence of teaching experience on the various constructs of TPACK Framework. The effect size ($\eta 2$ = .25) was large and observed power was 1.00, implies that there was a 100% chance that the outcome of the results could have come out statistically significant.

Table 7. Multivariate Tests of Teachers' TPACK across Teaching Experience

	Effect	Value	F	Hyp df	Error df	Sig.	P E S	O P
Intercept	Pillai's Trace	.976	663.46	8.0	132.0	.000	.976	1.000
	Wilks' Lambda	.024	663.46	8.0	132.0	.000	.976	1.000
	Hotelling's T.	40.210	663.46	8.0	132.0	.000	.976	1.000
	Roy's Largest R.	40.210	663.46	8.0	132.0	.000	.976	1.000
Teach. Exp.	Pillai's Trace	.931	3.89	40.0	680.0	.000	.186	1.000
	Wilks' Lambda	.239	5.62	40.0	578.12	.000	.249	1.000
	Hotelling's T.	2.525	8.23	40.0	652.0	.000	.336	1.000
	Roy's Largest R.	2.265	38.50	8.0	136.0	.000	.694	1.000

To further determine the impact of teaching experience on the various constructs, a univariate F-test using an alpha level of 0.05 was performed. The pair-wise comparison, which followed the univariate F-test, revealed statistically significant difference between teachers with teaching experience 1-5 years and those with teaching experience 11-15 years only in Pedagogical Knowledge (PK). There was also statistically significant difference between teachers with teaching experience between 1-5years and their counterparts 16 years and above in teaching experience only in technological pedagogical knowledge (TPACK) (see Table 8).

The results on the overall TPACK indicated continuous increase in level of TPACK as the years of teaching experience increases (Average TPACK Level: 1-5years =4.1280, 6-10years=4.1741, 11-15 years=4.0854, and 16 and above=4.4595). That is, the difference between any two of the means was found to be statistically significant at the five percent significance level (p-value < 0.05).

The MANOVA revealed that there is a statistically significant difference between different levels of teaching experience (1-5 years, 6-10 years, 11-15 years, and 16 years above) concerning combined TPACK constructs. The effect size ($\eta 2$) was large, indicating a substantial influence of teaching experience on TPACK. In summary, teaching experience plays a crucial role in shaping teachers' TPACK, with specific effects observed on different TPACK constructs based on their years of experience. It is fascinating to see how this knowledge can

influence educational practices. The findings align with the previous studies of [18,55].

Table 8. Bonferroni Multiple Comparison of TPACK Constructs across years of Experience

DV	(I) exper	(J) exper	Mean Dif (I-J)	Std. Error	Sig.	Post Hoc
		6-10	-.3571	1.50881	1.000	
TK	1-5	11-15	.7631	1.35772	1.000	
		16 above	.3025	1.42669	1.000	
		6 -10	-.5000	1.21914	1.000	
CK	1-5	11-15	-2.4129	1.09706	.177	
		16 above	-1.1303	1.15279	1.000	
		6 -10	-1.6667	1.19123	.984	
PK	1-5	11-15	-3.3984*	1.07195	.011	11-15y >1-5y
		16 above	-2.0490	1.12640	.426	
		6-10	-.5119	1.22793	1.000	
PCK	1-5	11-15	-1.8211	1.10497	.609	
		16 above	-1.3333	1.16110	1.000	
		6 -10	1.9167	1.51820	1.000	
TPK	1-5	11-15	.9715	1.36617	1.000	
		16 above	1.6078	1.43557	1.000	
		6 -10	.1310	1.38317	1.000	
TCK	1-5	11-15	.2364	1.24467	1.000	
		16 above	-3.3081	1.30790	.075	
		6 -10	-2.6786*	.96624	.038	6-10 >1-5years
TPACK	1-5	11-15	-4.1429*	.86948	.000	11-15>1-5years
		16 above	-6.8193*	.91365	.000	16 ab >1-5years
	6-10	11-15	-1.4643	.97094	.803	
		16 above	-4.1408*	1.01069	.000	16ab>6-10y
	11-15	16 above	-2.6765*	.91862	.025	16abo >11-15years

5. Discussion

The findings of the current study align with previous research conducted by [21,22,23,37] who discovered statistically significant differences between male and female teachers in terms of their knowledge levels with respect to Technological Pedagogical Content Knowledge (TPACK) constructs. The results indicate that male teachers demonstrated statistically significant means across all TPACK constructs. [22] specifically concluded that gender plays a critical role in the development of the TPACK framework for science teachers in Turkey. This finding may also be applicable to the current study, as male teachers exhibited higher mean scores than their female counterparts across all TPACK constructs.

Conversely, the results of this study contradict the findings of [17,38,56,57], who reported that female science teachers scored higher means than their male counterparts in all non-technological components of the TPACK framework (Pedagogical Knowledge (PK), Content Knowledge (CK), and Pedagogical Content Knowledge (PCK). These studies also concluded that female teachers exhibited lower confidence in all technological-related constructs Technological Knowledge (TK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and Technological Pedagogical Content Knowledge (TPACK) compared to their male counterparts.

In terms of the influence of teaching experience on science teachers' TPACK constructs, the findings revealed a statistically significant impact on the Pedagogical Knowledge (PK) construct. The study found that teachers with 11 to 15 years of teaching experience had the highest mean value in the PK construct of the TPACK framework, compared to those with fewer years of teaching experience. This suggests that teachers with 11 to 15 years of teaching experience possess more PK than their counterparts with 1 to 5 years of experience. This finding is consistent with the research conducted by [18,55], who also found a statistically significant difference in science teachers' PK and PCK constructs based on teaching experience.

Although the current study indicated that the PK construct was significant in relation to teaching experience, the PCK construct was not found to be significant. Previous studies [58,59,60], have suggested that veteran teachers generally exhibit lower TK constructs, but higher levels in the remaining TPACK constructs. The present study also revealed that teachers with more than six years of teaching experience have higher TPACK constructs, which is statistically significant. Specifically, teachers with 6 to 10 years of teaching experience exhibited more TPACK than those with 1 to 5 years of experience. Furthermore, teachers with more than 16 years of experience demonstrated even higher TPACK than those with 1 to 5 years of experience. These findings are consistent with [38] who also found that teachers with more teaching experience (six years and above) exhibited higher TPACK constructs than those with less teaching experience (1 to 5 years).

6. Conclusion

Science teachers' TPACK based on gender suggest that the male science teachers have higher TPACK knowledge than the female science teachers do and the difference is statistically significant. On teaching experience and TPACK, the result suggests that TPACK generally was high among teachers who have taught for more than six years and above.

7. Recommendations

It is also being recommended that for teachers' TPACK framework development programmes the organizers should be paying more attention to gender. Thus, it may be useful for organizers to separate the males form the females and run separate programme for each group (male and female). Since they exhibit different levels of TPACK framework constructs.

The study suggests that teaching experience significantly influences the development of TPACK among science teachers. It recommends providing targeted support and professional development opportunities, especially to teachers in their first five years. The study found that substantial growth in TPACK occurs after six years of teaching. Therefore, such support could speed up TPACK development in early-career teachers, improving their ability to incorporate technology effectively in their teaching methods.

References

[1] A. P. Gilakjani and S. M. Ahmadi, "The relationship between L2 reading comprehension and schema theory: A matter of text familiarity," *Int. J. Inf. Educ. Technol.*, vol. 1, no. 2, pp. 142–149, 2017.

[2] S. Shehzadi, Q. A. Nisar, M. S. Hussain, M. F. Basheer, W. U. Hameed, and N. I. Chaudhry, "The role of digital learning toward students' satisfaction and university brand image at educational institutes of Pakistan: a post-effect of COVID-19," *Asian Educ. Dev. Stud.*, 2020.

[3] I. Montiel, J. Delgado-Ceballos, N. Ortiz-de-Mandojana, and R. Antolin-Lopez, "New ways of teaching: using technology and mobile apps to educate on societal grand challenges," *J. Bus. Ethics*, vol. 161, pp. 243–251, 2020.

[4] F. Tilya, "IT and educational policy in the sub-Saharan African region," in *J. Toews, M. D. Subramanyam, and J. M. Rowan (Eds.) Knockdown and mortality of adults of eight species of stored-product beetles exposed to four surfaces treated with spinosad*, *J. Econ. Entomol.*, vol. 96, no. 6, pp. 1967–1973, 2003.

[5] D. Agyei and J. Voogt, "Developing technological pedagogical content knowledge in pre-service mathematics teachers through teacher design," *Australas. J. Educ. Technol.*, vol. 28, no. 4, pp. 547–564, 2012.

[6] J. O. Ejemeyovwi, E. S. Osabuohien, and E. I. Bowale, "ICT adoption, innovation and financial development in a digital world: empirical analysis from Africa," *Transnatl. Corp. Rev.*, vol. 13, no. 1, pp. 16–31, 2020.

[7] T. T. Okoli and D. D. Tewari, "Investigating the policy implications of financial technology shocks on macroeconomic stability: evidence from emerging African economies," *Afr. J. Dev. Stud.*, vol. 10, no. 3, p. 123, 2020.

[8] S. O. Oloruntoba, E. B. Ishola, and I. K. Ekanade, "Globalization, Poverty, and Development in Africa: Looking Past to the Future," in *Challenges of Globalization and Prospects for an Inter-civilizational World Order*, Springer, Cham, pp. 725–748, 2020.

[9] Curriculum Research and Development Division, *Teaching syllabus for science (Junior High School)*, Ministry of Education, Ghana Education Service, 2007.

[10] M. A. Adarkwah, "I'm not against online teaching, but what about us?: ICT in Ghana Post Covid-19," *Educ. Inf. Technol.*, vol. 26, pp. 1665–1685, 2020.

[11] K. Mangesi, *ICT in Education in Ghana. Survey of ICT and Education in Africa: Ghana Country Report*, pp. 1–9, 2007.

[12] C. Angeli and N. Valanides, "Epistemological and methodological issues for the conceptualization, development, and assessment of ICT–TPCK: Advances in technological pedagogical content knowledge (TPCK)," *Comput. Educ.*, vol. 52, no. 1, pp. 154–168, 2009.

[13] K. Kereluik, P. Mishra, and M. J. Koehler, "On learning to subvert signs: Literacy, technology and the TPACK framework," *California Reader*, vol. 44, no. 2, 2011.

[14] M. J. Koehler, P. Mishra, and K. Yahya, "Tracing the development of teacher knowledge in a design seminar: Integrating content, pedagogy and technology," *Comput. Educ.*, vol. 49, no. 3, pp. 740–762, 2007.

[15] C. S. Chai, J. H. L. Koh, C. C. Tsai, and L. S. Tan, "Modelling primary school pre-service teachers' Technological Pedagogical Content Knowledge (TPACK) for meaningful learning with information and communication technology (ICT)," *Comput. Educ.*, vol. 57, no. 1, pp. 1184–1193, 2011.

[16] M. Niess, "Mathematics teachers developing technology, pedagogy and content knowledge (TPACK)," in *Society for Information Technology & Teacher Education International Conference*, AACE, pp. 5297–5304, 2008.

[17] T. C. Lin, C. C. Tsai, C. S. Chai, and M. H. Lee, "Identifying science teachers' perceptions of technological pedagogical and content knowledge (TPACK)," *J. Sci. Educ. Technol.*, vol. 22, no. 3, pp. 325–336, 2013.

[18] S. J. Jang and Y. Chang, "Exploring the technical pedagogical and content knowledge (TPACK) of Taiwanese university physics instructors," *Australas. J. Educ. Technol.*, vol. 32, no. 1, 2016.

[19] K. Açıkgül and R. Aslaner, "Effects of Geogebra supported micro teaching applications and technological pedagogical content knowledge (TPACK) game practices on the TPACK levels of prospective teachers," *Educ. Inf. Technol.*, vol. 25, no. 3, pp. 2023–2047, 2020.

[20] M. Y. Mai and M. S. G. Hamzah, "The development of an assessment instrument of Technological Pedagogical Content Knowledge (TPACK) for primary science teachers in Malaysia," *J. Pendidik. Sains Mat. Malays.*, vol. 7, no. 1, pp. 93–104, 2017.

[21] A. Erdogan and I. Sahin, "Relationship between math teacher candidates' technological pedagogical and content knowledge (TPACK) and achievement levels," *Procedia-Soc. Behav. Sci.*, vol. 2, no. 2, pp. 2707–2711, 2010.

[22] S. J. Jang and M. F. Tsai, "Exploring the TPACK of Taiwanese secondary school science teachers using a new contextualized TPACK model," *Australas. J. Educ. Technol.*, vol. 29, no. 4, 2013.

[23] P. Luik, M. Taimalu, and R. Suviste, "Perceptions of technological, pedagogical and content knowledge (TPACK) among pre-service teachers in Estonia," *Educ. Inf. Technol.*, vol. 23, no. 2, pp. 741–755, 2018.

[24] A. S. North and J. M. Noyes, "Gender influences on children's computer attitudes and cognitions," *Comput. Hum. Behav.*, vol. 18, no. 2, pp. 135–150, 2002.

[25] M. Sáinz and M. López-Sáez, "Gender differences in computer attitudes and the choice of technology-related occupations in a sample of secondary students in Spain," *Comput. Educ.*, vol. 54, no. 2, pp. 578–587, 2010.

[26] S. Appiah and J. Mfum-Appiah, "Appraisal of Religious and Moral Education (RME) Curriculum: Pedagogical Knowledge Practices in Junior High Schools (JHSs) in Ghana," 2019.

[27] S. A. Gyamfi, "Pre-service teachers' attitude towards information and communication technology usage: A Ghanaian survey," *Int. J. Educ. Dev. Using ICT*, vol. 13, no. 1, 2017.

[28] C. E. Yalley, "Investigating the technological pedagogical content knowledge of social studies teachers in the senior high schools in the Kumasi Metropolis," Doctoral dissertation, Univ. Cape Coast, 2016.

[29] M. Koehler and P. Mishra, "What is technological pedagogical content knowledge (TPACK)?" 2009.

[30] D. A. Schmidt, E. Baran, A. D. Thompson, P. Mishra, M. J. Koehler, and T. S. Shin, "Technological pedagogical content knowledge (TPACK): The development and validation of an assessment instrument for preservice teachers," *J. Res. Technol. Educ.*, vol. 42, no. 2, pp. 123–149, 2009.

[31] C. J. Wang, "Facilitating the emotional intelligence development of students: Use of technological pedagogical content knowledge (TPACK)," *J. Hosp. Leisure, Sport Tourism Educ.*, vol. 25, p. 100198, 2019.

[32] P. A. Harris, R. Taylor, R. Thielke, J. Payne, N. Gonzalez, and J. G. Conde, "Research electronic data capture (REDCap)—A metadata-driven methodology and workflow process for providing translational research informatics support," *J. Biomed. Inform.*, vol. 42, no. 2, pp. 377–381, 2009.

[33] K. Holt, *Right-wing alternative media*. Routledge, 2019.

[34] D. Oner, "A virtual internship for developing technological pedagogical content knowledge," *Australas. J. Educ. Technol.*, vol. 36, no. 2, pp. 27–42, 2020.

[35] N. Nazari, Z. Nafissi, and M. Estaji, "The impact of an online professional development course on EFL teachers' TPACK," *J. Lang. Horizons*, vol. 4, no. 1, pp. 59–86, 2020.

[36] D. Petko, "Quo vadis TPACK? Scouting the road ahead," in *Proc. 1349–1358*, Assoc. Adv. Comput. Educ. (AACE), 2020.

[37] S. Bulut, "Investigating perceptions of preservice mathematics teachers on their technological pedagogical content knowledge (TPACK) regarding geometry," Master's thesis, Middle East Tech. Univ., 2012.

[38] T. Altun, "Examination of classroom teachers' Technological, pedagogical, and content knowledge based on different variables," *Croat. J. Educ. Hrvat. časopis za odgoj obrazovanje*, vol. 15, no. 2, pp. 365–397, 2013.

[39] Y. Dong, C. S. Chai, G. Y. Sang, J. H. L. Koh, and C. C. Tsai, "Exploring the profiles and interplays of pre-service and in-service teachers' technological pedagogical content knowledge (TPACK) in China," *J. Educ. Technol. Soc.*, vol. 18, no. 1, pp. 158–169, 2015.

[40] M. Ozudogru and F. Ozudogru, "Technological pedagogical content knowledge of mathematics teachers and the effect of demographic variables," *Contemp. Educ. Technol.*, vol. 10, no. 1, pp. 1–24, 2019.

[41] K. H. Cheng, "A survey of native language teachers' technological pedagogical and content knowledge (TPACK) in Taiwan," *Comput. Assist. Lang. Learn.*, vol. 30, no. 7, pp. 692–708, 2017.

[42] G. Bas and C. Senturk, "An evaluation of Technological Pedagogical Content Knowledge (TPACK) of in-service teachers: A study in Turkish public schools," *Int. J. Educ. Technol.*, vol. 5, no. 2, pp. 46–58, 2018.

[43] E. D. De Leeuw, "To mix or not to mix data collection modes in surveys," *J. Off. Stat.*, vol. 21, no. 5, pp. 233–255, 2005.
[44] O. M. Mugenda and A. G. Mugenda, *Research methods dictionary*, 2012.
[45] A. C. Edmondson and S. E. McManus, "Methodological fit in management field research," *Acad. Manag. Rev.*, vol. 32, no. 4, pp. 1246–1264, 2007.
[46] P. Ghauri, K. Grønhaug, and R. Strange, *Research methods in business studies*. Cambridge Univ. Press, 2020.
[47] E. A. Codling, M. J. Plank, and S. Benhamou, "Random walk models in biology," *J. R. Soc. Interface*, vol. 5, no. 25, pp. 813–834, 2008.
[48] R. M. Groves, F. J. Fowler Jr, M. P. Couper, J. M. Lepkowski, E. Singer, and R. Tourangeau, *Survey methodology*. John Wiley & Sons, 2011.
[49] M. J. Salganik and D. D. Heckathorn, "Sampling and estimation in hidden populations using respondent‐driven sampling," *Sociol. Methodol.*, vol. 34, no. 1, pp. 193–240, 2004.
[50] K. A. Owusu, L. Conner, and C. Astall, "Assessing New Zealand high school science teachers' technological pedagogical content knowledge," *J. Comput. Math. Sci. Teach.*, vol. 34, no. 3, pp. 345–373, 2015.
[51] T. C. Lam and M. Kolic, "Effects of semantic incompatibility on rating response," *Appl. Psychol. Meas.*, vol. 32, no. 3, pp. 248–260, 2008.
[52] J. D. Creswell, "Mindfulness interventions," *Annu. Rev. Psychol.*, vol. 68, no. 1, pp. 491–516, 2017.
[53] M. Field and M. Golubitsky, *Symmetry in chaos: A search for pattern in mathematics, art, and nature*. Soc. Ind. Appl. Math., 2009.
[54] J. Pallant, *A step by step guide to data analysis using the SPSS program*, 2010.
[55] K. Bingimlas, "Investigating the level of teachers' knowledge in Technology, Pedagogy, and Content (TPACK) in Saudi Arabia," *South Afr. J. Educ.*, vol. 38, no. 3, 2018.
[56] H. Oz, "An investigation of preservice English teachers' perceptions of Mobile Assisted Language Learning," *Engl. Lang. Teach.*, vol. 8, no. 2, pp. 22–34, 2015.
[57] F. Karaca, "An investigation of preservice teachers' Technological Pedagogical Content Knowledge based on a variety of characteristics," *Int. J. High. Educ.*, vol. 4, no. 4, pp. 128–136, 2015.
[58] Y. Chang, M. F. Tsai, and S. J. Jang, "Exploring ICT use and TPACK of secondary science teachers in two contexts," *US-China Educ. Rev.*, vol. 4, no. 5, pp. 298–311, 2014.
[59] M. I. Jordan, "On statistics, computation and scalability," 2013.
[60] M. H. Lee and C. C. Tsai, "Exploring teachers' perceived self-efficacy and technological pedagogical content knowledge with respect to educational use of the World Wide Web," *Instr. Sci.*, vol. 38, no. 1, pp. 1–21, 2010.