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TECHNOLOGICAL PEDAGOGICAL AND CONTENT KNOWLEDGE OF TEACHERS AND SENIOR SECONDARY STUDENT NUMERATION PERFORMANCE

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Abstract
This research investigated how the Technological, Pedagogical, and Content Knowledge (TPACK) of Mathematics teachers affected the academic performance of senior secondary students in numeration. The study utilized an analytical survey research design and focused on a population consisting of 16 Senior Secondary School (SSS) three Mathematics teachers and 2975 SSS three students from all the public senior secondary schools in the Ahoada East L.G.A. of Rivers State. The sample of 16 SSS three Mathematics teachers and 353 students constituted the sample for this study. The study employed a census sampling method to select 16 Mathematics teachers from SSS three levels, while a simple random sampling technique was used to select the student sample. Data was collected using the Teachers TPACK Self-Assessment Questionnaire (T2PACK – SAQ) and Numeration Performance Test (NPT). The reliability coefficients obtained for T2PACK – SAQ and NPT were 0.71 and 0.76, respectively. The research was guided by four research questions and two hypotheses. The research questions were answered using mean and standard deviation, with a mean criterion of 2.50. The hypotheses were tested using an independent sample t-test at a significance level of 0.05. The findings revealed that TPACK has a positive impact on attitudes towards technology use in Mathematics education and enhances effective teaching and learning of Mathematics. Additionally, it was observed that Mathematics teachers possess a high level of TPACK, and students taught numeration by teachers with high TPACK achieved significantly better results compared to those taught by teachers with low TPACK. However, the gender difference was not significant. As a result of this research, one of the key recommendations is for teachers to incorporate the TPACK framework into their Mathematics instruction to enhance student achievement. Furthermore, it is suggested that the Nigerian Educational Research and Development Council (NERDC) consider integrating the TPACK framework into the secondary school Mathematics curriculum, recognizing its beneficial impact on Mathematics education.

Keywords: Technology, Pedagogy, Content, Knowledge, Numeration, Performance

Introduction
The integration of Information and Communication Technology (ICT) into education has brought about significant changes to the teaching and learning process in the 21st century. Particularly, ICT has reshaped education, with a profound impact during the COVID-19 pandemic in 2019. The pandemic led to disruptions in education due to measures like school closures and social distancing. However, the negative consequences of these measures were significantly mitigated through the adoption of ICT. Electronic learning (e-learning) emerged as a crucial solution, allowing education to continue amidst the challenges posed by the pandemic.

E-learning is simply defined as learning through electronic devices without the conventional face-to-face classroom contact between the teacher and the learners. George and Zalmon (2019) described e-learning as an ICT-based and technology-driven instructional strategy. Distance learning, virtual learning and online learning are terms used to describe e-learning. During the COVID-19 pandemic, every educational institution resorted to e-learning platforms to continue rendering their educational services to society. Learning institutions without e-learning systems and facilities before the outbreak of COVID-19 either shut down completely or began e-learning services during the pandemic. Undoubtedly, educational institutions will inevitably face the hurdle of ensuring sufficient access to e-learning resources and having the necessary personnel equipped with technological, pedagogical, and content knowledge. This deficiency can have a detrimental impact on students' academic achievements. As evidenced by a study conducted by Ojimba et al. in 2022, the COVID-19 pandemic had a negative influence on the academic performance of high school students, particularly in the domain of Mathematics.

To address this issue, they suggested the implementation of novel teaching methods to counteract the detrimental impact of the pandemic on the teaching and learning of Mathematics.

TPACK, which stands for Technological, Pedagogical, and Content Knowledge, is an innovative instructional framework. It combines a teacher's understanding of technology, pedagogy (teaching methods), and subject matter content, emphasizing how these elements interact within the teaching and learning process. Zalmon and Wonu (2022) define TPACK as a comprehension that arises from the interplay among technological, pedagogical, and content knowledge. Essentially, the TPACK framework posits that effectively integrating technology into education requires a deep understanding of technology, teaching methods, and subject matter, as well as the synergies among them.

There is a growing call to incorporate the TPACK framework into the teaching of Mathematics and other sciences, driven by the favourable outcomes it has demonstrated in Mathematics instruction. Utilizing the TPACK framework in Mathematics education holds the promise of yielding positive learning results. It can stimulate creativity, kindle interest in learning, cultivate motivation, nurture problem-solving abilities, enhance communication, encourage collaboration, inspire innovation, and foster critical thinking skills. The primary goal of this research is to expand upon the current knowledge base regarding the effects of incorporating the TPACK framework into the field of Mathematics education. More specifically, it seeks to explore the relationship between Mathematics teachers' grasp of technology, pedagogy, and subject matter knowledge and the academic achievements of high school students in the area of numeration, which deals with the study of numbers and numerical concepts.

Statement of the Problem

The emergence of the COVID-19 pandemic though pathetic and deadly exposed the technological gap and deficiencies in the Nigerian educational system. The pandemic forced the closure of numerous public institutions in the country due to a lack of access to information and communication technologies. Government COVID-19 control measures mandated the shutdown of all educational institutions that traditionally relied on in-person classroom teaching. However, some schools with e-learning platforms continued to operate via those platforms. The effects of the COVID-19 pandemic on education especially Mathematics education is unimaginable.

Technologies have the potential to support Mathematics education in an era of global pandemic and provide opportunities for effective communication between teachers and students. The solution to the education challenge isn't solely reliant on technology itself; instead, it hinges on how effectively technology is blended into teaching methods and educational materials. Therefore, this study aims to explore how educators' understanding of technology, pedagogy, and subject matter influences the academic performance of high school students in the realm of numerical concepts.

Aim and Objectives of the Study

The study aims to investigate the influence of Mathematics teachers' Technological Pedagogical and Content Knowledge (TPACK) on senior secondary student performance in numeration. The specific objectives of the research are as follows:

1. Ascertain the implications of the TPACK framework to the teaching and learning of Mathematics.
2. Assess the extent of the Mathematics teacher's perceived knowledge of the TPACK framework.
3. Determine the influence of teachers' TPACK framework on students' performance in numeration.
4. Find out the influence of teachers' TPACK framework on the male and female students' performance in numeration.

Research Questions

The study was directed by four research inquiries:

1 What are the implications of the TPACK framework for the teaching and learning of Mathematics?

2 What is the extent of a Mathematics teacher's perceived knowledge of the TPACK framework?

3 What is the difference between the numeration performance of students taught by teachers with high and low knowledge of TPACK?

4 What is the difference between the numeration performance of the male and female students taught by teachers with high knowledge of TPACK?

Hypotheses

The study established and subsequently examined two null hypotheses at a significance level of 0.05 to guide the research.

H_{01}: There is no significant difference between the numeration performance of students taught by teachers with high and low knowledge of TPACK.

H_{02}: There is no significant difference between the numeration performance of the male and female students taught by teachers with high knowledge of TPACK.

Methodology

In this study, we employed an analytical survey research design. The study's population included 16 Mathematics teachers in senior secondary school class three and 2,975 students in senior secondary school class three, comprising 1,519 male and 1,456 female students. These individuals were drawn from 16 public senior secondary schools within the Ahoada East L.G.A. of Rivers State (Rivers State Senior Secondary Schools Board, 2021). To ensure comprehensive coverage, we used a census sampling technique to select all the teachers since their number was manageable. For the student sample, we calculated the sample size using Taro Yamene's formula, resulting in a sample of 353 students. These students were chosen using a stratified random sampling technique. The research instruments employed for data collection included the Teachers TPACK Self-Assessment Questionnaire (T^2PACK – SAQ) and the Numeration Performance Test (NPT). The T^2PACK – SAQ contained 33 items, evaluating teachers' self-assessment across seven TPACK domains: 5 items related to technology knowledge, 3 items for content knowledge, 5 items for pedagogical knowledge, 4 items assessing pedagogical content knowledge, 5 items measuring technological content knowledge, 3 items for technological pedagogical knowledge, and 8 items gauging technological pedagogical and content knowledge. The survey questionnaire utilized a four-point Likert scale for rating, which included options such as "Strongly Disagree" (SD), "Disagree" (D), "Agree" (A), and "Strongly Agree" (SA), corresponding to weightings of 1, 2, 3, and 4, respectively. To ensure the validity of the instruments, three Mathematics Educators reviewed and validated them. The reliability of the instruments was assessed using the Cronbach alpha method, resulting in reliability coefficients of 0.71 for the T^2PACK – SAQ and 0.75 for the NPT. To gather data, a direct approach was employed, with the instruments administered to the respondents and collected immediately for subsequent analysis. Mean and standard deviation were employed to address the research questions, with a mean criterion set at 2.50. Additionally, for hypothesis testing, an independent t-test was conducted at a significance level of 0.05.

Results

Research question one: What are the implications of the TPACK framework to the teaching and learning of Mathematics?

Table 1: Descriptive Analysis of the implications of the TPACK framework to the teaching and learning of Mathematics

	Implication of TPACK	Mean	SD	Remark
1.	The TPACK framework promotes a favourable mindset towards utilizing technology in the teaching and learning of Mathematics.	3.30	1.02	Agreed
2.	TPACK contributes to the improvement and facilitation of effective Mathematics instruction and learning.	3.17	0.87	Agreed
3.	TPACK assists in keeping Mathematics teachers informed about various technologies and teaching methodologies, thereby enhancing the effectiveness of Mathematics education.	3.17	0.79	Agreed
4.	TPACK encourages a comprehension of how to blend content knowledge, pedagogical skills, and technology to enhance Mathematics instruction and learning.	3.03	0.89	Agreed
5.	TPACK is necessary for quality instruction in Mathematics.	3.40	0.77	Agreed
6.	Students taught with the TPACK framework develop an interest in learning Mathematics.	3.20	0.89	Agreed
7.	TPACK enhances the performance of students in Mathematics.	3.13	0.90	Agreed
8.	TPACK promotes the retention of mathematical concepts among students.	3.43	0.57	Agreed
	Total	**3.23**	**0.84**	**Agreed**

Table 1 displays the consensus among Mathematics teachers on the positive impact of TPACK. They endorsed that TPACK fosters a positive attitude towards technology use in Mathematics education (Mean=3.30, SD=1.02), enhances the effectiveness of teaching and learning in Mathematics (Mean=3.17, SD=0.87), updates teachers on various technologies and pedagogical approaches (Mean=3.17, SD=0.79), facilitates the integration of content, pedagogy, and technology for effective Mathematics instruction (Mean=3.03, SD=0.89), is vital for delivering high-quality Mathematics education

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(Mean=3.40, SD=0.77), sparks student interest in Mathematics (Mean=3.20, SD=0.89), improves student performance in Mathematics (Mean=3.13, SD=0.90), and aids in the retention of mathematical concepts among students (Mean=3.43, SD=0.57).

Research question two: What is the extent of a Mathematics teacher's perceived knowledge of the TPACK framework?

Table 2: Descriptive statistics on the extent of Mathematics teacher's perceived knowledge of the TPACK framework

	Technological Knowledge (TK)	**Mean**	**SD**	**Remark**
1	I possess the skills to effectively address my technical challenges.	2.43	1.04	Disagreed
2	I can quickly grasp and adapt to technological concepts.	2.87	1.22	Agreed
3	I stay informed about significant advancements in new technologies.	3.13	0.86	”
4	I know a wide range of diverse technologies.	3.17	0.87	”
5	I possess technical abilities, expertise, and proficiencies.	3.03	0.93	”
	Total	**2.93**	**0.98**	**Agreed**
	Content Knowledge (CK)	**Mean**	**SD**	**Remark**
1.	Sufficiently knowledgeable in Mathematics subject.	2.67	1.03	Agreed
2.	Apply mathematical thinking in real-life problem-solving.	3.10	0.92	”
3.	Uniquely and strategically develops my understanding of Mathematics.	2.90	0.76	”
	Total	**2.89**	**0.90**	**Agreed**
	Pedagogical Knowledge (PK)	**Mean**	**SD**	**Remark**
1.	Possesses evaluation skills for effective evaluation of student performance in Mathematics.	3.40	0.77	Agreed
2.	Adaptation and application of relevant learning theories to Mathematics teaching and learning.	2.93	0.74	”
3.	Knowledgeable in employing innovative and conventional teaching methods and materials in Mathematics instruction.	3.30	0.79	”
4.	Evaluate students' comprehension through various assessment methods.	2.43	0.97	Disagreed
5.	Highly proficient in Mathematics classroom control and management for enhanced learning.	2.80	0.55	Agreed
	Total	**2.97**	**0.76**	**Agreed**
	Pedagogical Content Knowledge (PCK)	**Mean**	**SD**	**Remark**
1.	Choosing suitable teaching methods to facilitate students' understanding and learning in Mathematics.	2.23	0.77	Disagreed
2.	Employment of mathematical games and software in teaching Mathematics.	2.90	0.61	Agreed
3.	Use of computers in demonstrating Mathematics concepts.	2.87	0.51	”
4.	Integrating ICT in Mathematics instruction.	2.90	0.61	”
	Total	**2.73**	**0.63**	**Agreed**
	Technological Content Knowledge (TCK)	**Mean**	**SD**	**Remark**
1.	Knowledgeable in technologies for teaching and learning Mathematics.	2.80	0.48	Agreed
2.	Knowledgeable in simulations and mathematical modelling using appropriate software technologies.	2.83	0.38	”
3.	Knowledgeable in mathematical games technologies applied in Mathematics teaching and learning.	2.83	0.53	”
4.	Knowledgeable in mathematical software used in Mathematics instruction.	2.70	0.65	”

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5.	Knowledgeable in the use of e-learning platforms and gadgets for effective Mathematics classroom instructional delivery.	2.77	0.57	”
	Total	**2.79**	**0.52**	**Agreed**
	Technological Pedagogical Knowledge (TPK)	**Mean**	**SD**	**Remark**
1.	I can select technologies that improve the instructional methods employed in Mathematics education.	3.17	0.87	Agreed
2.	I can utilize suitable technologies to enhance the educational resources used in Mathematics instruction.	3.17	0.79	”
3.	My teacher training program has provided me with ample chances to attain the necessary technological, pedagogical, and content knowledge needed for successful Mathematics teaching.	3.30	1.02	”
	Total	**3.24**	**0.93**	**Agreed**
	Grand Mean	**2.92**	**0.79**	**Agreed**

Table 2 provides an overview of Mathematics teachers' perceived levels of familiarity with the TPACK framework. The data indicates that there is a high degree of comfort with various aspects of TPACK, including technological knowledge (Mean=2.93, SD=0.98), content knowledge (Mean=2.89, SD=0.90), pedagogical knowledge (Mean=2.97, SD=0.76), pedagogical content knowledge (Mean=2.73, SD=0.63), technological content knowledge (Mean=2.79, SD=0.52), technological pedagogical knowledge (Mean=3.24, SD=0.93), and the overarching technological pedagogical content knowledge (Grand Mean=2.92, SD= 0.79).

Research question three: What is the difference between the numeration performances of students taught by teachers with high and low knowledge of TPACK?

Table 3: Descriptive statistics (mean and standard) on the Difference between the numeration performance of students taught by teachers with high and low knowledge of TPACK

Teachers' TPACK	n	Mean	SD	Difference
High	189	62.43	9.23	9.23 (0.991)
Low	153	53.20	8.97	

Table 3 displays the contrast in numeration performance among students instructed by teachers possessing either high or low levels of TPACK knowledge. The table shows that students taught by teachers with high TPACK performed better in numeration (M=62.43, SD=9.23) than students taught by teachers with low TPACK (M=53.20, SD=8.97). The difference between their mean performance is (Mean =9.23, SD=0.991).

Research question four: What is the difference between the numeration performance of the male and female students taught by teachers with high knowledge of TPACK?

Table 4: Descriptive statistics (mean and standard) on the difference between the numeration performance of the male and female students taught by teachers with high knowledge of TPACK

Sex of students	n	Mean	SD	Difference
Male	102	62.57	9.47	0.280 (1.350)
Female	87	62.29	88.99	

Table 4 illustrates the variation in numeration performance between male and female students when taught by teachers with a strong grasp of TPACK. The table shows that male students taught by teachers with high TPACK slightly performed higher (M=62.57, SD=9.47) than female students taught by teachers with high TPACK (M=62.29, SD=8.99). The difference between their mean performance is (Mean =0.280, SD=1.350).

H_{01}: There is no significant difference between the numeration performances of students taught by teachers with high and low knowledge of TPACK.

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Table 5: Summary of t-test on the difference between the numeration performances of students taught by teachers with high and low knowledge of TPACK

TRACK	n	Mean	SD	Difference	df	t-test	Sig.
High	189	62.43	9.23	9.23 (3.47)	340	9.312	0.000
Low	153	53.20	8.97				

Table 5 presents compelling evidence of a substantial disparity in the mean performance scores of students who received instruction from teachers with a high TPACK compared to those taught by teachers with a low TPACK. This difference was found to be statistically significant (t(0.05, 340)=9.312, sig=0.000). Consequently, we reject the null hypothesis and accept the alternative hypothesis at the 0.05 significance level.

H_{02}: There is no significant difference between the numeration performance of the male and female students taught by teachers with high knowledge of TPACK.

Table 6: Summary of t-test on the difference between the numeration performance of the male and female students taught by teachers with high knowledge of TPACK

Sex	n	Mean	SD	Difference	df	t-test	Sig.
Male	102	62.57	9.47	0.280 (1.350)	187	0.207	0.836
Female	87	62.29	8.99				

Table 6 reveals that there is no substantial difference in the mean performance of male and female students when they are taught by teachers with a strong TPACK ($t_{(0.05,187)}$=0.207, sig=0.836). Consequently, we reject the null hypothesis two and accept the alternative hypothesis at the 0.05 significance level.

Discussion

Table 1 presents the mean scores and standard deviations concerning the perceived implications of the TPACK framework on the teaching and learning of Mathematics. The data in the table indicate that Mathematics teachers widely agreed on several positive impacts of TPACK. They acknowledged that TPACK fosters a positive attitude towards the utilization of technology in Mathematics education and promotes effective teacher knowledge encompassing various technologies, pedagogy, and content essential for effective Math instruction. TPACK was also seen as a facilitator of a deeper understanding of how to integrate content, pedagogy, and technology for optimal Mathematics teaching and learning outcomes. Furthermore, the study found consensus among teachers that TPACK is crucial for delivering high-quality Mathematics instruction, sparking students' interest in the subject, enhancing their performance, and aiding in the retention of mathematical concepts. These findings resonate with research conducted by Akturk and Ozturk (2019), which similarly highlighted the positive influence of the TPACK framework on student Mathematics achievement.

In Table 2, the mean scores and standard deviations shed light on the Mathematics teachers' perceived levels of the TPACK framework. The table reveals that these teachers exhibited a high degree of proficiency in various aspects of TPACK, including technological, content, pedagogical, pedagogical content, technological content, technological pedagogical, and the integration of technological pedagogical and content knowledge. These findings are consistent with a study conducted by Irwanto et al. (2022), which also reported a high level of perceived TPACK among teachers.

In Table 3, we can see the mean scores and standard deviations that highlight the differences in numeration performance among students taught by teachers with varying levels of TPACK knowledge. The table clearly illustrates that students who were taught by teachers possessing a strong TPACK achieved higher scores in numeration compared to their counterparts who had teachers with lower TPACK knowledge. This study's findings underscore the positive influence of teachers' TPACK on student performance in numeration, which aligns with prior research by Kosoko-Oyedeko and Adeyinka (2017). Their study similarly noted differences in pupil performance when ICT was employed in teaching Christian Religious Education, as opposed to when it was not utilized.

In Table 4, a comparison was made between the numeration performance of male and female students who were taught by teachers possessing a strong TPACK. It was observed that male students slightly outperformed their female counterparts, but this difference in their average performance did not have statistical significance. This outcome aligns with the research conducted by Akturk and Ozturk (2019), where they also found no statistically significant gender-based differences in any of the TPACK scale subscales.

Conclusions

This research investigated how the technological, pedagogical, and content knowledge possessed by Mathematics teachers impacts the academic performance of senior secondary students in numeration. The findings of the study revealed that Mathematics teachers exhibit a strong TPACK, which plays a significant role in improving students' performance in Mathematics.

Recommendations

1. The Nigerian Educational Research and Development Council (NERDC) should consider incorporating the TPACK framework into the secondary school Mathematics curriculum due to its evident benefits for Mathematics instruction and learning.
2. Mathematics teachers with low technological pedagogical and content knowledge should develop themselves accordingly to become relevant and useful in this twenty-first century.
3. To enhance student performance, educators should incorporate the TPACK framework into their Mathematics teaching and learning approaches.
4. The male and the female students should be taught with the TPACK framework to guarantee gender equity in Mathematics learning in secondary schools.
5. It is advisable for both government authorities and school administrators to periodically arrange professional development programs for educators. These programs should aim to enhance teachers' understanding of the technological, pedagogical, and content aspects of Mathematics instruction.

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