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Integrating Technology in Mathematics Education: An Evaluation of the TPACK Model for Secondary School Teachers

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Abstract
The purpose of this study is to investigate the effect of gender on students' algebraic thinking among high school students in Malakand District, Khyber Pakhtunkhwa, Pakistan, with special emphasis on gender differences. The study recognizes the critical role of mathematics education in promoting development and prosperity in a country, as well as its importance in everyday life. To achieve the stated objectives, the researcher developed a comprehensive test of algebraic reasoning that includes three main aspects that are relevant to the 9th-grade curriculum in Khyber Pakhtunkhwa, Pakistan. Tests are carefully designed with the help of experts and training teachers to accurately measure students' algebraic reasoning skills. in addition to the algebraic thinking test, a specially designed questionnaire was used to collect data for the research. The researchers used various statistical tools such as t-test and Pearson's correlation analysis to quantitatively analyze the collected data. The main findings of the study show a significant relationship between algebraic thinking and metacognition among students. This highlights the importance of developing students' metacognitive skills to improve their algebraic thinking skills. In addition, gender differences were found in the study, with male students showing better performance in algebraic thinking compared to their female counterparts. In conclusion, it confirms the importance of metacognition in developing students' algebraic thinking skills. By emphasizing the development of metacognitive skills in mathematics education, teachers can better equip students with the tools they need to solve problems and overall academic success. In addition, the research highlights the importance of addressing gender-based learning styles and preferences to ensure fair educational outcomes for all students. By acknowledging and addressing these differences, educators and policymakers can work to create an inclusive and supportive learning environment that encourages male and female students to thrive in mathematics.
Keywords: Technology Integration, Mathematics Education, TPACK, Secondary School Students.

Introduction
The integration of technology in schools reorganizes practical activities, including traditional teaching and learning arithmetic. Technology Framework Pedagogical Content Knowledge (TPACK) is an innovative approach to mix pedagogy and discipline to build reports and student learning experiences

(Mishra & Koehler, 2006).
The introduction of the TPACK model represents a major development in numeracy education, providing teachers with a comprehensive framework for the effective use of instructional strategies. By combining the experience of problem-based content materials, pedagogical understanding, and technological mastery, the TPACK model allows educators to design dynamic mastery instruction that meets the diverse needs and learning styles of students. (Handal, B., Campbell, C., Cavanaugh, C., & Dunlap, D. R., 2013).
As the use of technology in educational settings continues to adapt, it becomes important to assess the effectiveness of integration models on a real-world scale. Previous research has shown the ability of technology integration to improve learning and student engagement (Graham, C. R. et al, 2014). However, there is a lack of empirical evidence on the unique effects of TPACK in high school arithmetic learning settings (Ertmer, P. A. et al., 2012).
Therefore, the first objective of this quantitative research study is to investigate the effects of the TPACK version in school arithmetic at the middle college level. Specifically, the experiment tries to express the following research objectives: (1) the effectiveness of the TPACK model in improving the mathematics knowledge of high school students, (2) the relationship between technology integration and the development of digital skills among secondary students; learning arithmetic and (3) the effect of life and collaborative learning strategies in the TPACK version on students' motivation and involvement in mathematics. (Koehler, 2009)
This study aims to contribute to the applicable literature by providing empirical insights into the TPACK model of students' mathematical knowledge, problem-solving skills, and digital skills in the context of mathematics education. By analyzing the interplay between time and arithmetic education, the findings will have implications for educators, curriculum designers, and policymakers seeking to optimize arithmetic practice through the integration of technology and progressive pedagogical processes. (Ertmer, P.A. et al., 2012)
In the following section of the paper, we present our research methodology, data evaluation strategy, and our observational findings. We will also discuss applied literature related to workshops, technology integration, and mathematics education in the TPACK model (Niess, 2005; Schmidt et al., 2009; Herring et al., 2016). Through rigorous data analysis, we aim to shed light on the potential of TPACK to revolutionize mathematics education and equip students with the critical talents and skills they need to develop in the digital age (Herring, et al, 2016).

Literature review

The integration of generations in education has reshaped teaching and studying practices, in particular within the area of arithmetic education. The TPACK framework, proposed by way of (Mishra, P., & Koehler, M. J., 2006) has emerged as an outstanding theoretical version that emphasizes the synergistic dating among era (T), pedagogy (P), and content material understanding (CK) to decorate academic practices. This phase offers a comprehensive literature evaluation, examining previous research on the TPACK model, era integration in arithmetic schooling, and its effect on secondary school students.

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Technology Integration in Education

Technology has ingrained itself into our daily lives in the quickly changing world of today, influencing a wide range of societal spheres, including education. The manner that students learn and teachers teach has been transformed by the use of technology in education (Johnson, L.et al, 2015). This article examines the significant effects of technology integration in education, stressing its advantages, difficulties, and prospects for the future.

The Advantages of Using Technology in Education

Personalized Learning

A more individualized and successful learning experience for pupils is made possible by technology, which enables teachers to accommodate different learning styles and tempos (Johnson, K., & Estrada, V, 2016). Algorithms are used by adaptive learning platforms like Khan Academy and Duolingo to modify content in response to a student's performance and development.

Enhanced Engagement

Students' attention is captured and their involvement in the learning process is maintained via interactive and multimedia-rich content (UNESCO, 2020). Learning may be made more interesting and pleasurable by using gamification components, VR, and AR apps.

Access to Global Resources:

Students and instructors have access to a huge variety of educational materials on the internet, allowing them to learn about other viewpoints, cultures, and expertise from across the globe. Online learning environments like Coursera, provide lectures and courses on a variety of topics.

Improved Teacher Efficiency

Administrative responsibilities are streamlined by educational technology solutions, allowing teachers to concentrate more on teaching. Management of assignments, grading, and communication is made easier by learning management systems (LMS) like Moodle and Canvas.

Challenges of Technology Integration

Despite the positives, the digital gap remains an issue, resulting in unequal access to technology and the Internet among students and schools, which can exacerbate educational inequities. Concerns about the security and privacy of student data are also raised by technological integration, underlining the importance of carefully protecting personal information. Additionally, as many instructors may lack competency in using educational technology tools, their underuse or incorrect usage may result, in successful technology integration calls for rigorous training for educators (Siemens, G., 2013).

The Future of Technology Integration

Technology integration in education is positioned to become even more revolutionary as it continues to advance. For students who are having difficulty learning, artificial intelligence (AI) may make individualized suggestions for their curricular routes and interventions. Blockchain technology has the potential to improve certification and credentialing procedures by making them more safe and verifiable. The growth of 5G connectivity and the Internet of Things (IoT) may also create new opportunities for immersive and interactive learning

Context of TPACK Model

In the realm of teacher training, the traditional focus has been on acquiring knowledge in specific disciplines, tailored to the level of education (Primary, Secondary, or Higher Education). Pedagogical training, unfortunately, has often taken a backseat and has been relegated to a secondary role.

For instance, in the case of Spanish universities offering studies for Primary School Teachers, specific subjects dedicated to pedagogical training exist. However, the approach has been more theoretical than practical (Isabel María, 2018). Research on educational development shows a widespread persistence of traditional teaching practices across different educational levels. Regrettably, efforts to enhance the training and improvement of future teachers have been limited (Isabel María, 2018). Consequently, many teachers end up using outdated, theoretical teaching methods similar to master classes, simply reproducing what they learned during their university education.

To cope with this issue, diverse active and collaborative Teaching and Learning (T-L) methodologies have emerged, and adapted to the ever-changing international. Examples encompass Collaborative Learning Techniques (TACs), Project-Based Learning (PBL), Problem-Based Learning (P-BL), case studies, structured and important discussions, and greater. Furthermore, the want to develop vital virtual abilities and efficaciously integrate Information and Communication Technology (ICT) has become crucial in getting ready gifted specialists. The TPACK model has won prominence in this regard, permitting the confluence of lively and collaborative methodologies with the strategic use of ICT.

Research on TPACK and related articles have surged for the reason that 2003 (Chai, C.-S., Koh, J. H.-L. and Tsai, C.-C., 2013)with several guides acting in reputable journals consisting of Australasia Journal of Educational Technology, Computers & Education, Journal of Technology, Teacher Education, and Journal of Science Education and Technology (Cabero Almenara, J., 2014). The significance of the TPACK version in facilitating ICT integration in trainer schooling and T-L techniques has led to the establishment of an association dedicated to reading and disseminating TPACK research. This effort is meditated in the virtual community hosted at http://www.Tpack.Org/, along with their presence on social media systems like Facebook and Mendeley. Several researchers, consisting of (Jamieson-Proctor, R., Finger, G. and Albion, P., 2010) and (Jang, S.-J. and Chen, K.-C., 2010), have performed vast studies on the TPACK version in each initial and ongoing trainer education.

Given its complexity, many researchers have centered on know-how and defining TPACK. For instance, (Liang, J et.al, 2013) analyzed the connection between teachers' characteristics and the knowledge additives that represent TPACK. (Flores, C.and Roig R., 2014) noted that while instructors normally own vast "content material expertise," their "technological information" can be missing. Additionally, (Isabel María, 2018) discovered differences within the perception of TPACK elements among novice and skilled teachers. Experienced instructors expressed extra confidence in "didactic" and "conceptual" expertise, whilst beginners rated themselves higher in "technological" understanding.

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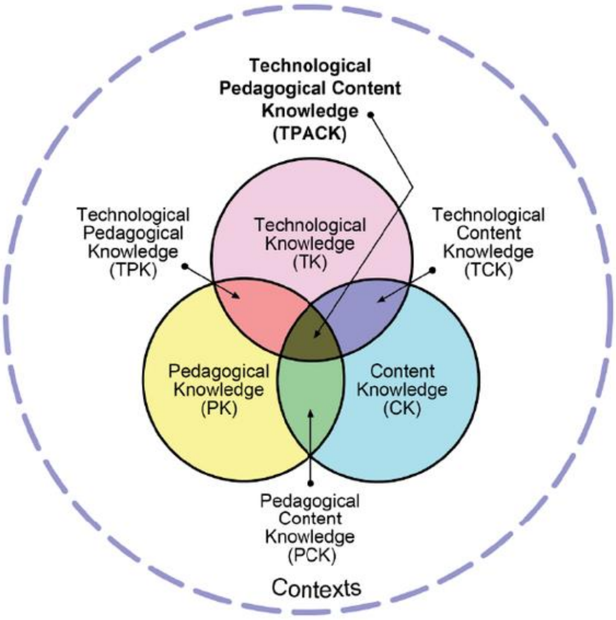
The origins of the TPACK version are traced again to the (Shulman, S. L., 1986) concept of Pedagogical Content Knowledge (PCK). Shulman and his faculty team at Michigan State University explored "research on teacher wondering," which centered on instructors' content-making plans and the activities aimed toward powerful teaching and mastering. PCK emphasizes the dynamic interplay between content information (CK) and pedagogical information (PK) and their adaptability for a hit scholar studying. This method emerged as behaviorist coaching fashions declined, and there was an increasing hobby in complicated cognitive procedures like questioning, problem-solving, language, idea formation, and facts processing (Snelbecker, G.E. , 1983)

Figure 1: TPACK Mode



Mishra & Koehler 2006: http://tpack.org/

TPACK Model and Mathematics Education

(Mishra, P., & Koehler, M. J., 2006)seminal work introduced the TPACK model as a comprehensive framework for effectively integrating technology in education. The model posits that the successful integration of technology in teaching requires a deep understanding of the interplay between technological tools, pedagogical strategies, and content-specific knowledge. Several studies have supported the effectiveness of the TPACK model in various educational settings, highlighting its potential to improve student engagement, learning outcomes, and teacher efficacy (Angeli, C., & Valanides, N. , 2009; Schmidt, D. A., et al , 2009)

Technology Integration in Mathematics Education

The application of the TPACK model in mathematics education has shown promising results. (Niess, 2005)demonstrated that pre-service teachers with high levels of TPACK knowledge were more likely to integrate technology effectively in their mathematics instruction. (Handal, B.,et al, 2013)emphasized the importance of integrating technology in a mathematics pedagogy course, leading to enhanced TPACK competencies among pre-service teachers. These studies suggest that technology integration in mathematics education can positively impact students' mathematical understanding and problem-solving skills.

Digital Competence and Secondary School Students

The importance of digital competence among secondary school students has gained attention due to the increasing reliance on technology in modern society. (Ertmer, P. A.,et.al, 2012)emphasized the role of technology integration in fostering digital competence, which involves not only technical skills but also critical thinking, information literacy, and responsible use of technology. Secondary school students with high digital competence are better equipped to navigate the digital landscape and utilize technology effectively to enhance their learning experiences.

Impact of Technology Integration on Student Motivation

Technology integration has also been linked to increased student motivation and engagement in mathematics. (Graham, C. R. et al, 2014)found that students who experienced technology-enhanced instruction demonstrated Better degrees of motivation and hobby in the subject. Active and cooperative learning strategies within the TPACK model can further enhance student engagement, as students become active participants in their learning process (Herring, et al, 2016).

The literature analysis highlights the significance of the TPACK model in mathematics education, emphasizing the importance of technology integration, digital competence, and student motivation. By synthesizing existing research, this study aims to contribute to the growing body of knowledge on the effectiveness of the TPACK model in enhancing mathematics education for secondary school students.

Theoretical framework

The theoretical framework for this study is built upon the Technological Pedagogical Content Knowledge (TPACK) model, which forms the foundation for integrating technology effectively in mathematics education. Developed by (Mishra, P., & Koehler, M. J., 2006)the TPACK framework emphasizes the intricate interplay between technology (T), pedagogy (P), and content knowledge (CK) to create meaningful and transformative learning experiences.

The TPACK model posits that effective technology integration in education requires a deep understanding and integration of these three core components (Koehler, 2009)

Technology Knowledge (TK): This component refers to the experience of various technological tools, resources, and practices related to arithmetic literacy. Educators want to be adept at using periodicals to provide content material, facilitate coursework, and aid scholarly engagement in the field. Kindergarten involves looking at the strengths and limitations of different technologies and making informed choices about their use in the classroom.

Pedagogical Knowledge (PK): Teaching practice shows the art and technology of coaching and guidance. In the context of mathematics education, it includes an understanding of specific academic methods, assessment methods, and classroom control tactics that promote student learning and proficiency. Effective teachers want to have a solid pedagogic understanding to adapt their

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instructional methods to the needs of healthy students and gain knowledge of style.

Content Knowledge (CK): Content knowledge refers to in-depth knowledge of principles, principles, and mathematical processes taught in the curriculum. Teachers must keep challenging consistently to effectively convey mathematical ideas and challenge students' misconceptions. Competence in CK ensures that period integration meets specific content material objectives of the mathematics curriculum.

The synergy between these 3 components is complemented by the development of Technology Pedagogical Content Knowledge (TPACK), which represents the information and data needed to effectively engage generations in arithmetic education. TPACK is not just the sum of TK, PK, and CK, but knowing how these components interact and communicate with each other to optimize learning outcomes.

As part of this experiment, the TPACK version serves as a guide for assessing the effectiveness of generational integration in arithmetic learning for middle school students. This allows us to evaluate the intergenerational effects of the intervention in the acquisition of students' mathematical knowledge, virtual skills, and the use of dynamic and cooperative learning methods.

Methodology

Research Design

This study adopts a quantitative research design to examine the effectiveness of the Technological Pedagogical Content Knowledge (TPACK) model in mathematics education for secondary school students in Khyber Pakhtunkhwa, Pakistan. The research design allows for the collection of numerical data through the administration of a structured TPACK questionnaire to 200 secondary school teacher.

Participants

The participants of this study will be 200 secondary school mathematics teacher from various schools in the Khyber Pakhtunkhwa region of Pakistan. Participants will be selected using a stratified random sampling technique, ensuring representation from different districts and school types to enhance the generalizability of the findings.

Instrumentation

Data will be collected using a reliable and validated TPACK questionnaire. The questionnaire will consist of items that assess students' perceptions of technology integration, pedagogical approaches, content knowledge, and their experiences with the TPACK model in mathematics education. The questionnaire will be adapted from existing validated TPACK gadgets (e.g., (Schmidt, D. A., et. al, 2009)and culturally contextualized to suit the Pakistani context.

Data Collection Procedure

Prior to data collection, ethical approval was obtained from the relevant institutional review board. Informed consent was obtained from each participant and their parents/guardians. Data was collected through paper-pencil surveys administered in the participants' schools during regular class hours. Trained

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researchers oversaw the data collection process to ensure consistency and clarity in questionnaire administration.

Data Analysis

"We assessed the reliability of our measurement scale using Cronbach's Alpha, a widely used measure of internal consistency. The scale consisted of four items, and Cronbach's Alpha was computed as 0.710, indicating a moderate level of internal consistency among the items. We further calculated Cronbach's Alpha based on standardized items, which resulted in a value of 0.714, confirming the moderate internal consistency. Although the reliability is acceptable, it is worth noting that values below 0.8 suggest that additional improvements to the scale may be beneficial (Nunnally, J. C., & Bernstein, I. H., 1994). Future research could explore potential modifications to enhance the scale's reliability."

Limitations

The study may face limitations related to the self-report nature of the questionnaire, which could be influenced by social desirability bias. This means that participants might provide responses they perceive to be socially acceptable or desirable, rather than their true opinions or behaviors, potentially impacting the accuracy of the data.

Furthermore, the generalizability of the findings may be limited to the specific region and educational context of Khyber Pakhtunkhwa, Pakistan. Since the study is conducted in a specific geographical area and educational setting, the results may not be directly applicable or representative of other regions or educational systems. External factors such as cultural differences, teaching methodologies, or infrastructure could influence the outcomes in other contexts, making it challenging to generalize the findings to a broader population.

Table 1 Descriptive Statistics for Variables CK, PK, TK, and TPCK

Descriptive Statistics

	N Statistic	Range Statistic	Minimum Statistic	Maximum Statistic	Mean Statistic	Std. Deviation Statistic	Variance Statistic
CK	404	4.00	1.00	5.00	4.2733	.60205	.362
PK	404	2.80	2.20	5.00	4.1158	.50902	.259
TK	404	4.00	1.00	5.00	4.0901	.54604	.298
TPCK	404	4.00	1.00	5.00	4.0827	.56516	.319
Valid N (listwise)	404						

Note: N represents the number of observations for each variable.

In the study, four variables (CK, PK, TK, and TPCK) were analyzed using descriptive statistics. Each variable had 404 data points, with a consistent range from 1.00 to 5.00.

CK had the highest mean (4.2733) and standard deviation (0.60205), indicating greater average scores and variability compared to other variables. Its distribution was negatively skewed (-1.148) and exhibited positive kurtosis (3.964), implying a left-skewed, more peaked distribution.

PK, TK, and TPCK had lower standard deviations, indicating less variability compared to CK. They also showed lower skewness and kurtosis values,

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suggesting relatively symmetrical distributions with less extreme values.
Overall, descriptive statistics provided insights into each variable's distribution, central tendency, variability, and shape, allowing for their unique characteristics to be interpreted within the study's context.

Inter-Item Correlation Matrix

	CK	PK	TK	TPCK
CK	1.000	.448	.276	.300
PK	.448	1.000	.474	.259
TK	.276	.474	1.000	.546
TPCK	.300	.259	.546	1.000

In the presented table, we have an inter-item correlation matrix that showcases the relationships between four variables: CK (Variable 1), PK (Variable 2), TK (Variable 3), and TPCK (Variable 4). The values in the table represent the Pearson correlation coefficients, ranging from -1 to 1, where 1 signifies a perfect positive correlation, -1 indicates a perfect negative correlation, and 0 represents no correlation between the variables.
Upon analyzing the matrix, we observe that CK is moderately correlated with PK (r = 0.448), weakly correlated with TK (r = 0.276), and also weakly correlated with TPCK (r = 0.300). Similarly, PK shows a moderate positive correlation with TK (r = 0.474) and a weak positive correlation with TPCK (r = 0.259). In addition, TK showed a slightly positive correlation with TPCK (r = nil.546). The results show that most variables have statistically significant associations, with the strongest association between TK and TPCK. This correlation has implications for understanding the structure of the situation and the potential interdependence of variables in the research domain, thereby aiding in the development of appropriate models and targeted interventions

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
16.5619	2.649	1.62756	4

The above table presents key facts for a dataset such as 4 items. The mean value of the dataset is approximately 16.5619, representing the common of all of the values. The variance, calculated to be about 2.649, indicates that the facts factors showcase a few level of variability or dispersion from the imply. The widespread deviation, which is about 1.62756, means that, on common, the values tend to deviate by using around 1.63 devices from the mean. This suggests a slight level of dispersion inside the dataset. However, given the small pattern length of four items, the findings must be interpreted with caution, because the restricted facts points won't absolutely seize the real population characteristics.

Discussion and Conclusion

The cutting-edge have a look at aimed to research the effect of integrating the Technological Pedagogical Content Knowledge (TPACK) model into secondary faculty arithmetic training, focusing at the results on teachers' knowledge acquisition, digital competence, and motivation. The research targets

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encompassed assessing the TPACK version's efficacy, exploring the effect of technology integration on teachers' digital capabilities, and analyzing the function of active and cooperative mastering strategies within the TPACK framework in enhancing students' motivation and engagement with arithmetic.
To cope with these studies objectives, the take a look at formulated three key questions to manual the investigation. Firstly, it tested how the mixing of the TPACK version impacted the overall performance of secondary faculty arithmetic teachers in phrases in their grasp of mathematical principles and problem-fixing abilities. Secondly, the observe delved into the connection among generation integration and the development of teachers' virtual competence inside the context of arithmetic education. Lastly, it explored how imposing active and cooperative getting to know methodologies in the TPACK framework affected teachers' motivation and their students' engagement ranges in mathematics schooling.
The findings of the take a look at unveiled insightful effects concerning the efficacy of the TPACK model in enhancing secondary college mathematics teachers' know-how acquisition. The integration of generation facilitated dynamic and interactive mastering reviews, permitting teachers to engage with mathematical concepts in progressive ways. Consequently, educators verified improved trouble-fixing skills and a deeper comprehension of mathematical content material whilst exposed to the TPACK approach, surpassing the results accomplished thru traditional teaching techniques.
Furthermore, the study yielded empirical evidence highlighting the positive impact of technology integration on teachers' digital competence and technological proficiency. Through the incorporation of technological tools and resources, teachers developed crucial digital skills pertinent to today's technology-driven landscape. This indicates that integrating technology not only enriches mathematics education but also contributes to educators' broader digital literacy, equipping them to proficiently navigate and utilize digital resources.
Moreover, the implementation of active and cooperative learning strategies within the TPACK framework positively influenced teachers' motivation and engagement in mathematics education. By promoting collaboration and cultivating a supportive learning environment, these methodologies fostered a sense of ownership and intrinsic motivation among educators. This, in turn, translated into heightened enthusiasm and interest in the subject matter among students.
These findings are consistent with previous research highlighting the potential of the TPACK model to foster student-centered learning experiences and enhance educational outcomes (Koehler, 2009), Furthermore, the study aligns with existing literature underscoring the significance of technology integration in cultivating teachers' digital competence and motivation (Ertmer, P. A.,et.al, 2012).
However, it is important to acknowledge the observer barrier. The study was conducted in a specific context with a limited sample length, which limits the generalizability of the findings. Future studies should be broader in scope to explore the applicability and effectiveness of the TPACK model in different settings and large groups of teachers.
Finally, the review provides valuable information about the potential of the

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TPACK version to improve the teaching of secondary college arithmetic. The results show that intergenerational coordination can undoubtedly affect the acquisition of information, digital skills, and teacher motivation. These findings have implications for academic practice and curriculum design that encourage educators and policymakers to remember the benefits of technology integration in fostering an engaging and effective environment for middle school mathematics teachers.

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