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Application of Technological Pedagogical Content Knowledge (TPACK) in Teaching and Learning for Mathematics Teachers

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Abstract

This paper presents a comprehensive literature review related to Malaysian mathematics primary school teachers' integration of technology and the acquisition of Technological Pedagogical Content Knowledge (TPACK). TPACK is a framework to describe the complex intersection of knowledge that teachers need to integrate the elements of technology into their teaching practices. This paper also explores the current state of research in this area and identifies research gaps for future investigations. The literature highlights some deep and significant understanding of teachers' perceptions of TPACK, teaching practices based on TPACK and the impacts of TPACK on students' outcomes. The findings suggest that more studies should be done to investigate the levels of TPACK knowledge among teachers and how this might impact students' engagement, motivation and understanding of mathematical concepts. Further research is needed to provide insights for future research and education policy development. Overall, this paper serves as a foundation for future studies and strategies to improve mathematics education through the integration of TPACK knowledge among Malaysian primary school teachers.

Keywords*:* TPACK, Mathematics, Primary Schools

Introduction

The integration of technology in schools has become a significant focus in recent years. In addition, technology adaptation has become inevitable in the teaching and learning of Mathematics to enable learners to understand, explore and solve Mathematical problems (MOE, 2021). Sierra et al (2023) acknowledge that teachers today have an extensive range of sophisticated technology available to them and they must acquire adequate knowledge and training in using technology such as knowing how to integrate technology into teaching practices using the TPACK framework. Aligned with the strategic and operational initiatives in the ICT Transformation Plan 2019-2023, the adoption of ICT and digital capabilities prepares students with adequate knowledge, Higher Order Thinking Skills (HOTS), leadership skills, multilingual skills, spiritual and moral ethics (MOE, 2013). The third aspiration in the ICT

transformation Plan also acknowledges that it is vital to implement technology to support education trends.

Consequently, the Malaysian education system has been impacted by several curricula revamps and transformations to equip quality education. The Ministry of Education Malaysia (MOE) has therefore developed and elevated the application of Information and Communication Technology (ICT) for educational practice (MOE, 2013). Shift 7 in Malaysia Education Blueprint 2015-2023 stressed the leverage of ICT to scale up the teaching and learning value across Malaysia. This is also applied to the teaching and learning of Mathematics in primary school. According to the Ministry of Education Malaysia (2018), skills that should be developed among students include using mathematical tools and Information and Communications Technology (ICT). Technology-using skills include being able to use and care for mathematics tools like abacuses, calculators, computers, educational software, websites, and educational packages. Many studies have examined the effects of using technology based on teachers' perceptions and students' outcomes (MOE, 2020). Overall, the use of technology can enhance students' engagement, motivation, and conceptual understanding in learning mathematics.

Technological improvements have significantly enhanced educational access. It improves communication and collaboration opportunities and serves as a powerful tool to improve education in a variety of ways, including making it easier for teachers to develop instructional materials and enabling new ways to learn and communicate (Kuang & Bai, 2019). Several studies have also investigated the issues related to the adoption of technology in the classroom, particularly in mathematics instruction. According to Amedu and Hollebrands (2022), some of the prominent and growing issues include curriculum development, workload, insufficiency of training and preparatory programmes, and resource allocation. Hence, this paper will explore Technological Pedagogical and Content Knowledge (TPACK), focusing on the context of mathematics in Malaysian primary classrooms.

Literature Review

Technology In the Malaysian Primary Education System

Integration of technology in education has become a necessity due to the development of the Fourth Industrial Revolution (IR 4.0) and the use of the Internet of Things (IoT). This is to enable students to understand, explore, and solve problems in various disciplines, including Mathematics subject (MOE, 2021). Muhazir and Renawati (2020) stated that today's teachers have various technologies such as tools, hardware, software, and applications available for use during the teaching and learning process. In line with the strategic initiatives and operations in the Ministry of Education Malaysia's ICT Transformation Plan 2019-2023, the use of ICT and digital capabilities can equip students with knowledge, high-level order thinking skills (HOTS), leadership skills, multilingual skills, spiritual and moral ethics (MOE, 2019). Overall, quality education can be achieved through the integration of technology in teaching and learning. The third aspiration in the ICT Transformation Plan also emphasises the importance of implementing technology to support educational development (MOE, 2019).

The integration of technology in Malaysian primary schools has evolved over the years. This has been driven by many factors such as educational initiatives to improve the quality of teaching and learning experiences among primary school pupils, government policies and advancements in technology infrastructure. There have been many policies and initiatives to

promote technology integration such as the Smart School Initiative 1BestariNet (Zeeshan et al., 2022). These initiatives aim at providing schools with access to technology resources as well as to support teachers in integrating technology into their teaching and learning practices.

Besides, the Malaysian education system has also undergone curriculum alignment and transformation to provide quality education. Referring to the content of the primary school Mathematics curriculum, teachers are advised to apply various types of technology to enhance students' understanding and encourage them to be active learners (MOE, 2021). Past studies have discussed the effectiveness of technology integration as a supportive tool in Mathematics education, offering new experiences to both teachers and students (Chin et al., 2022). Parrot and Leong (2018) also found that technology can assist teachers in creating a learning environment that focuses on visualising abstract ideas as well as organising and analysing data. Shift 7 in Malaysia Education Blueprint 2015-2023 stressed the leverage of ICT to scale up the teaching and learning value across Malaysia. With the Internet's worldwide reach and the availability of smart gadgets that can connect to it, a new era of education may be available to everyone and everywhere effectively and efficiently. In short, technological improvements have significantly enhanced educational access.

However, there are studies found that teachers still lack the knowledge and skills to integrate technology in the classroom (Lee et al., 2006). Furthermore, a quantitative study conducted by Chin et al (2022) also found that 50% of the study's respondents expressed the need for improvement in teaching technology skills compared to other skills such as management, communication, and instructional planning. Other than that, a study conducted by Poobalan and Safwan (2022) has indicated that primary school Mathematics teachers face several constraints in implementing the use of technology, such as lack of technological resources, time constraints, and limited knowledge regarding the latest technology for instructional purposes. Thus, research should be conducted in order to address these challenges.

Mathematics in Primary School

Every Malaysian student has the right to go through a minimum of six years of primary school education. Mathematics plays an important role within the Standard-Based Curriculum for Primary School, necessitating its inclusion in the educational journey of all kids who are enrolled in the National Education System (MOE, 2018). Similar to the mathematics curricula of several nations, the Malaysian Primary Mathematics Curriculum has seen a shift in its pedagogical approach, transitioning from a predominant emphasis on skills and computation to a greater focus on comprehending and applying fundamental mathematical concepts (Curriculum Development Centre, 2003). The mathematics curriculum for primary school now has been designed to provide students with the understanding of the concept of numbers, basic calculation skills, simple mathematical ideas and applying mathematical knowledge, to solve problems and overcome challenges faced in daily life and the 21st century challenges (MOE, 2018). The curriculum is designed to build a strong foundation in mathematics and gradually introduce more advanced topics as students progress through the primary grades
Nevertheless, learning Mathematics has become one of the most difficult subjects for students to succeed in (Mamat & Abdul Wahab, 2022). Based on past studies, various causes prevent students from mastering the subject. According to Zainuddin & Rashidi (2010), the difficulty in learning Mathematics is due to a lack of proficiency in mental coordination using numbers and concepts. One of the main factors affecting the capacity of students to

comprehend mathematics, students always think that mathematics is difficult and unrelated to real-world problems (Mazana et al., 2019). Some of them also show difficulty in using mental strategies and providing visualisation in Mathematics learning (Miller & Mercer, 1997).

In mathematics education, technology facilitates learners to visualise abstract ideas as well as organise and analyse data, so that learners can focus on decision-making, reflection, reasoning, and problem-solving (National Council of Teachers of Mathematics, 2000). However, integrating technology in teaching Mathematics has become an issue especially among Mathematics educators in Malaysia (Law & Mahmud, 2021). Educators have a critical role in tackling important issues in mathematics education, particularly in integrating technology into teaching and learning processes to provide valuable learning resources. Considering the era of rapid technological advancement and the widespread use of ICT, the use of technology in the teaching and learning of mathematics is something that deserves attention (Puteh & Rohaidah, 2017). The theory referred to is the Technological Pedagogical Content Knowledge (TPACK) theory.

Technological Pedagogical Content Knowledge (TPACK)

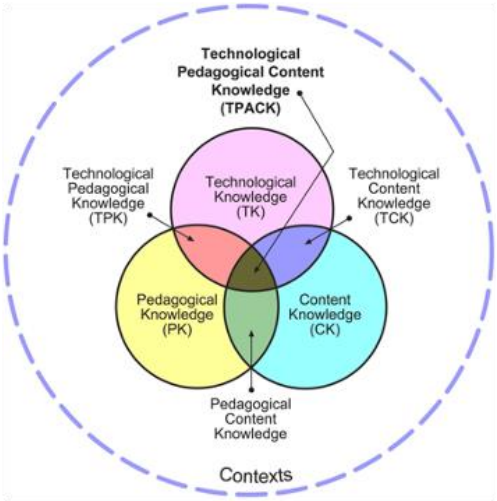

Figure 1: Component of TPACK model (Mishra & Koehler, 2006)

In 2005, Punya Mishra and Matthew J. Koehler officially proposed the TPACK framework (Technological Pedagogical Content Knowledge). This framework is crucial for effective teaching through the integration of technological elements (Mishra & Koehler, 2006). Later, Thompson & Mishra (2008) added "And" for easier recall and pronunciation, making it TPACK. TPACK is a new framework formed by integrating the technological knowledge component into Shulman's PCK framework (Pedagogical Content Knowledge) (Shulman, 1987). TPACK is a novel teaching framework that combines content knowledge, teaching methods, and technology and explores the extent to which the relationships and interactions among these three elements influence teachers' professionalism (Mishra & Koehler, 2009). Teachers must understand the elements contained in PCK to effectively integrate technology into teaching (Cox, 2009). According to Miswan et al (2014), the TPACK framework provides educators with guidance on "What to teach?", "How to teach?" and "What types of technology?" can be integrated into the teaching and learning process.

The core idea of the TPACK framework is the interaction between three types of knowledge: (a) technological knowledge; (b) pedagogical knowledge; and (c) content knowledge. Then, these three types of knowledge overlap to form four related types of knowledge which are Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TPK), Technological Content Knowledge (TCK) and Technological Pedagogical and Content Knowledge (TPACK).

The following is the explanation of each TPACK component

Content Knowledge
Content Knowledge refers to teachers' understanding of the subject topic such as theories, concepts and others to be learned or taught. (Schmidt, Mishra & Koehler, 2009)

Pedagogical Knowledge
Pedagogical Knowledge refers to the methods, techniques, steps and procedures used in classroom teaching and learning (Koehler & Mishra, 2006)

Technological Knowledge
Technological Knowledge refers to the knowledge of computer system operation and hardware, as well as the ability to use basic software. This involves having the technical and software skills necessary to modify or develop new educational materials using technology (Koehler & Mishra, 2006)

Pedagogical Content Knowledge (PCK)
Pedagogical Content Knowledge (PCK) refers to the outcome of integrating content and pedagogy to grasp how specific elements of a subject can be structured, adapted, and delivered for teaching. PCK is demonstrated by understanding the organisation of content elements to enhance the teaching process (Koehler & Mishra, 2006)

Technological Content Knowledge (TPK)
Technological Content Knowledge (TPK) refers to the knowledge of how technology can be innovatively used to create teaching methods for specific content (Koehler & Mishra, 2006)

Technological Content Knowledge (TCK)
Technological Content Knowledge (TCK) refers to the understanding of how technology can generate new representations of specific information in implementing teaching methods (Koehler & Mishra, 2006)

Technological Pedagogical and Content Knowledge (TPACK)
Technological Pedagogical and Content Knowledge (TPACK) refers to the knowledge of incorporating technology into teaching methods within a specific subject area, as described by (Schmidt et al., 2009). TPACK can be described as a fusion of content knowledge, pedagogy, and technology.

TPACK is the theory about how technology is used in teaching and learning (Mishra & Koehler, 2006). According to Ling et al (2021), many studies have been conducted to examine the integration of technology in Mathematics teaching using the TPACK framework.

Past Related Studies

No	Title	Authors	Year	TPACK	Mathematics Subject	Primary School	Data Analysis	Country
1	Level Of Technological Pedagogical Content Knowledge (TPACK) Among National Secondary School Teachers In Kuala Lumpur	Zulkurnain, N. F. N., Nor, M. Y. M., & Rahman, M. R. A.	2021	/	/		Quantitative	Malaysia
2	Technological Pedagogical Content Knowledge in the Mathematics Classroom	Guerrero, S.	2010	/				USA
3	Exploring Mathematics Teachers' Perception of Technological Pedagogical Content Knowledge	Ting, L. L. & Hsiao, F. L.	2015	/	/	/	Quantitative	Taiwan
4	Technological Pedagogical Content Knowledge (TPACK) in Teaching 21st Century Skills in the 21st Century Classroom	Shafie, H., Abd Majid, F., & Shah Ismail	2019	/			Quantitative	Malaysia
5	Pengetahuan Teknologi Pedagogi Kandungan (PTPK) Dalam Kalangan Guru Matematik Sekolah Rendah	Khor, M. T., & Lim, H. L.	2014	/	/	/	Quantitative	Malaysia (Seberang Perai Tengah)
6	Pengetahuan Teknologi Pedagogi Kandungan Guru Matematik Sekolah Menengah	Jalil, N. A. A., & Siew, N. M.	2023	/	/		Quantitative	Malaysia (Pantai Barat Sabah)
7	Technological Pedagogical Content Knowledge, Commitment and Motivation of Physics Teachers to Implement Online Teaching and Learning during COVID-19 Pandemic	Juwait, S., Siew, N. M., & Madjapuni, M. N.	2022	/			Quantitative	Malaysia (Sabah)
8	Primary Science Teachers' Perception of Technology Pedagogical and Content Knowledge (TPACK) in Malaysia	Mai, M. Y., & Hamzah, M.	2016	/		/	Qualitative	Malaysia (Selangor & Perak)
9	The Technological Pedagogical Content Knowledge (TPACK) among Mathematics	Noor Ariani, D., Saad, N. S., Yusuf, Q., & Dalle, J.	2014	/	/	/	Quantitative	Banjarmasin, Indonesia

	Teachers In Primary Schools							
10	Primary Mathematics School Teachers' Technological, Pedagogical, Content Knowledge and Learner's Achievement.	Patalinghug, J. T., & Arnado, A. A.	2022	/	/	/	Quantitative	Butuan City, Philippines
11	Do The Teachers' Technological Pedagogical and Content Knowledge (TPACK) Influence the Mathematical Skills of Elementary School Students?	Arora, R., & Pany, S.	2021	/	/		Quantitative & Qualitative	Punjab, India
12	The Technological Pedagogical Content Knowledge (TPACK) Competence of Vocational High School Teacher	Maknun, J.	2022	/			Quantitative	Indonesia
13	Science Teachers Perceptions of Technological Pedagogical Content Knowledge (TPACK) in Urban Area	Safriana, Irfan, A., & Fitri, Z.	2022	/			Quantitative	Indonesia
14	Maker Math: Exploring Mathematics through Digitally Fabricated Tools with K-12 In-Service Teachers	Harron, J. R., Jin, Y., Hillen, A., Mason, L., & Siegel, L.	2022	/	/	/	Qualitative	USA
15	Investigation of Primary School Teachers' Professional Competencies and Technological Pedagogical Content Knowledge (TPACK) Competencies	Zhakiyanova, Z., Zhaitapova, A., Orakova, A., Baizhekina, S., Shnaider, V., & Nametkulova, F.	2023	/		/	Quantitative	Kazakhstan

The above articles explored 15 studies related to the concept of TPACK in various educational contexts ranging from the year 2010 to 2023. The participants in the studies came from different backgrounds involving teachers and students from secondary and primary levels of education. Some of the key findings of these studies include a significant portion of the studies, specifically 7 out of 15, have a primary focus on the primary school level of education.

Next, a substantial majority, 8 out of 15 studies place an emphasis on the intersection of TPACK and Mathematics. Based on the research methodology, the majority of the reviewed articles, 12 out of 15 employ a quantitative research approach, one study relies on a qualitative research approach which offers a deeper understanding of TPACK and one

research utilises a mixed-method approach. From the global scope, the studies above showcase a diverse geographical distribution. Six studies were conducted in Malaysia, one originates respectively from Taiwan, Kazakhstan, India, and the Philippines and two in the USA. Hence, this representation exhibits the application of TPACK in different educational settings. Below are some literature reviews on the articles selected.

Firstly, Harron et al (2022) explored the use of digitally fabricated tools in mathematics education with K-12 in-service teachers. The study involved nine teachers from elementary, middle, and high schools who participated in workshops focused on creating and utilising these tools. The study focused on the impacts of these tools in mathematics. However, there are some limitations of this study such as the need for a larger sample size. This particular study only involved nine teachers which limits the generalizability of the findings. Hence, a larger sample would provide a more representative sample of primary school teachers and find a more comprehensive understanding of the impact of digitally fabricated tools, particularly in mathematics.

Next, a study by Maknun (2022) examined vocational teachers' TPACK competence in Malaysia. The findings of the study provided insights into the TPACK competence of vocational school teachers and contributed to the understanding of effective teaching strategies in vocational schools. However, this study primarily focuses on the TPACK competence of teachers, so it would be valuable to explore the impact of TPACK on student outcomes. Investigating the relationship between teachers' TPACK competence and student achievement or engagement will provide insights into the effectiveness of TPACK in improving learning outcomes in vocational schools.
The study conducted by Patalinghug and Arnado (2022) focused on the TPACK of primary mathematics school teachers and its impact on learners' achievement. This descriptive-correlational design found that the TPACK of primary mathematics teachers has a strong relationship with learners' achievement. By examining the variables and their relationships, this study shed light on the factors that contribute to the successful teaching and learning of mathematics. There is a research gap in this study in which there is a need to explore the specific components of TPACK that have the greatest influence on learners' achievement. This may help to identify the specific areas where teachers may need additional support and training to enhance their instructional practices.

Based on the above studies, the research gaps identified include the need for further research on instructional strategies based on teachers' TPACK in the primary mathematics education context and the exploration of challenges in implementing TPACK knowledge in mathematics teaching and learning using different sample sizes and research approaches. Addressing these research gaps would contribute to a deeper understanding of effective and workable teaching practices and integration of different means of technology in mathematics education for primary school.

Conclusion

To conclude, this paper has reviewed the literature on the background of technological integration in the Malaysian primary school system, policies and initiatives taken by the Ministry of Education Malaysia, the Technological Pedagogical Content Knowledge (TPACK) framework which includes teachers' perceptions of TPACK, teaching practices based on TPACK and the impacts of TPACK on students' outcomes. The findings suggest that more

studies should be done to investigate teachers' TPACK and how this might impact students' engagement, motivation and understanding of the subject of mathematics. The review also highlights the importance of understanding teachers' TPACK knowledge and its impact on mathematics instructions. For example, Maknun (2022) and Patalinghug and Arnado (2022) contributed to the findings and understanding of effective teaching strategies as the impacts of TPACK knowledge among teachers. Overall, the literature review also points out the need for further research in several areas. These include exploring instruction strategies to improve TPACK knowledge, investigating the impacts of TPACK on the teaching and learning of mathematics, as well as to find out the challenges and opportunities of technology integration in teaching mathematics in the Malaysian primary school context. As a conclusion, this paper showcases a comprehensive overview of the current state of research TPACK in various contexts as well as focusing on TPACK among Malaysian primary mathematics teachers. The findings underscore the importance of TPACK knowledge and technology integration to create meaningful and effective teaching and learning for the students.

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