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A Conceptual Paper on Assessing the Competency of Primary Mathematics Teachers in Integrating Artificial Intelligence Tools into Teaching and Learning

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Abstract

Malaysian Mathematics education is evolving in line with global digital transformation, positioning artificial intelligence (AI) as an emerging technology with the potential to further enhance the teaching and learning process, which requires teacher's competency for effective integration. However, existing literature indicates that no study has specifically explored primary Mathematics teacher's competency in integrating AI into teaching and learning in the Malaysian context, highlighting the need for such research. Thus, this conceptual paper elaborates the conceptual framework for exploring the competency levels of primary school teachers in integrating AI tools into the teaching and learning of Mathematics, based on the Technological Pedagogical Content Knowledge (TPACK) model and the Malaysian Teacher Standards (SGM 2.0). This paper further analyses the issues, concepts, and objectives of the forthcoming study through a review of literature from various disciplines. This study may serve as a reference and foundation for future large-scale and comprehensive research aimed at assessing and exploring the competency levels of Mathematics teachers at the national level.

Keywords: AI in Education, Mathematics Teacher's Competency, Primary Mathematics Education, Technological Pedagogical Content Knowledge (TPACK), Standard Guru Malaysia (SGM 2.0)

Introduction

Mathematics education serves as the foundation for a nation's development, particularly in driving advancements in science and technology (Cotic, 2024). Since the 1970's and up to the implementation of the National Education Blueprint 2013-2025, the teaching and learning of Mathematics in Malaysia has undergone significant transformations (OECD, 2024), in terms of approaches, content and implementation strategies. The 2027 School Curriculum is poised to replace the current curriculum and it is designed to cultivate a generation that is digitally fluent, to promote active learning among students, and to equip them with the skills necessary to compete at the global level (Kementerian Pendidikan Malaysia, 2023), an

aspiration that is further reinforced by Strategic Core 2 of the Ministry of Education Malaysia's Strategic Plan (2024-2030) and the objective of the Digital Education Policy (DPD). The Fourth Industrial Revolution (4IR), underpinned by foundational technologies such as Artificial Intelligence (AI), is presently transforming the global landscape (UNESCO, 2021), with the education sector anticipated to undergo significant and accelerated integration of these technologies within the next five years (Unit Perancang Ekonomi, 2021).

Despite allocating approximately 3.6% of its GDP to education in 2023, which is higher than most ASEAN countries (World Bank, 2025), Malaysia continues to face declining student performance in Mathematics education that does not correspond with the level of investment made (Kementerian Pendidikan Malaysia, 2023). Technological proficiency is a key element in mastering Mathematics, as it supports more effective and higher order thinking in the learning process (Kementerian Pendidikan Malaysia, 2017). The benefits of digital transformation cannot be fully realised if educators are not empowered and teaching practices are not fundamentally transformed (European Union, 2020); (UNESCO, 2023). Therefore, there is an urgent need to explore the integration of this emerging technology into Mathematics education in Malaysia, as it has demonstrated positive impacts including personalisation of learning (Alvarez, 2024); (Li et al. 2025), automation of teaching tasks (Morris, Holmes and Choi, 2024); (Chan et al. 2025); (Zatti & Kalinke, 2024), enhancing student's engagement (Inoferio et al. 2024); (Torres-Pena et al. 2024); (Rumbelow and Coles, 2024), support for students with special educational needs (Rizos, Foykas and Georgakopoulos, 2024) and enhance conceptual understanding in Mathematics (Wardat et al. 2023); (Bagno, Dana-Picard and Reches, 2024); (Yunianto et al. 2024).

Therefore, it is imperative to explore how well teachers can integrate artificial intelligence (AI) tools into mathematics teaching and learning, as scholars have pointed out the potential benefits of AI in education sector, while the Malaysian government has also invested significantly in this area. Identifying the level of teacher's competencies is essential not only for effective policy implementation but also for ensuring that students benefit from personalised learning experiences, enhanced engagement and improve conceptual understanding in matematics. Furthermore, the findings will provide the Ministry of Education Malaysia with evidence-based insights to design targeted professional development programmes, thereby empowering teachers to harness AI effectively in their classrooms. In doing so, this study will contribute to bridging the gap between national aspirations for digital transformation in education and the actual readiness of mathematics teachers.

Problem Statement

The National 4IR Policy aims to ensure that all teachers are trained to integrate 4IR technologies including AI into teaching and learning (Unit Perancangan Ekonomi, 2021). Similarly, one of the key objectives of the DPD is to empower educators to integrate digital technologies within the educational landscape (Kementerian Pendidikan Malaysia, 2023). However, findings from the digital competency screening of teachers under the Digital Education Strenthening Programme (PPP) during the 12th Malaysia Plan (RMKe-12) in 2021 revealed that 57.9% teachers were still at basic competency level (Kementerian Pendidikan Malaysia, 2023). Kementerian Pendidikan Malaysia (2023) reported that 90% of Mathematics teachers in Malaysia rarely or never used computers in the teaching and learning process.

This outcome underscores the urgent need to conduct a more in-depth investigation into teacher's digital competency, particularly among Mathematics teachers, while also taking into account the influence of AI as an educational technology. Teacher's competency levels must be identified in order to strengthen the use of digital technologies in the teaching and learning of Mathematics (Geraniou et al. 2024; UNESCO, 2018). The Ministry of Education Malaysia (MOE) has set a timeline from 2023 to 2025 to enhance teacher's competency levels through the implementation of training programmes aimed at improving educator's digital competencies (Kementerian Pendidikan Malaysia, 2023). Morover, teacher's competency and autonomy in the use of AI must be strengthened through continuous professional development in order to enhance the quality of education (UNESCO, 2023). Therefore, there is a need for research to validate existing KPM initiatives and gather updated data on Mathematics teacher's competency in integrating AI, to support the effective implementation of continuous professional development programmes.

Furthermore, based on a literature review conducted up to 2025, there appears to be no local study that specifically focuses on the competency levels of primary school Mathematics teachers in the use of AI. Most existing studies either encompass all subjects (Saharuddin, Nasir & Mahmud, 2025; Chear & Norman, 2024) or focus on subjects other than Mathematics, such as Malay Language (Rani, Roslan & Wahid, 2025) and English Language (Zulkarnain & Md Yunus, 2023). Over the past five years, a number of studies have explored the use of technology in teaching and learning (Ab Aziz & Maat, 2021; Chandrasegaran & Maat, 2023; Hoon & Ibrahim, 2024; Jafar et al. 2020; Jalil & Siew, 2023; Kuppusamy & Norman, 2021; Lau & Roslinda Rosli, 2020; Lim et al. 2024; Mat Adam, Raja Maamor Shah & Adnan, 2022; Mahmud & Mahmud, 2022; Mohamad Sidek & Mahmud, 2024; Osman & Maat, 2022; Ravendran & Daud, 2020). However, local studies have generally placed limited emphasis on AI as a component of digital technology, in contrast to international studies, which have given more focused attention to AI as a critical element in digital innovation. This is supported by findings from a systematic literature review by Awang, Yusop and Danaee (2025), which analysed 32 articles on the current practices and future direction of artificial intelligence in mathematics education, and found that none of these articles originated from Malaysia. Therefore, there is a significant need to explore the competency levels of Malaysian primary school Mathematics teachers in integrating AI into the teaching and learning process.

Purpose of Research and Research Question

This conceptual paper elaborates the conceptual framework for exploring the competency levels of primary school teachers in integrating AI tools into the teaching and learning of Mathematics, based on the Technological Pedagogical Content Knowledge (TPACK) model and the Malaysian Teacher Standards (SGM 2.0). Specifically, through the conceptual framework, the future study will examine the extent to which primary Mathematics teacher's technological knowledge, including Technological Knowledge (TK), Technological Pedagogical Knowledge (TPK), and Technological Content Knowledge (TCK), influences their competency in utilising AI in instructional practice. Moreover, teacher's competency will be comprehensively assessed across four key dimensions outlined in SGM 2.0: knowledge orientation, instructional practice, community engagement, and personal qualities. In addition, differences in competency levels will be analysed based on demographic factors. As such, research questions that will be addressed are:

I. How can the technological knowledge of primary school Mathematics teachers be conceptualised based on the elements of Technological Knowledge (TK), Technological Content Knowledge (TCK), and Technological Pedagogical Knowledge (TPK)?
II. How can teacher competency in integrating AI be assessed conceptually through the four dimensions of the Malaysian Teacher Standards 2.0 (knowledge orientation, instructional practice, community engagement, and personal qualities)?
III. What is the conceptual relationship between Mathematics teachers' technological knowledge (TPACK) and their competency levels as described by the Malaysian Teacher Standards 2.0 (SGM 2.0)?
IV. What demographic factors should be conceptually considered when assessing primary school Mathematics teachers' competency levels in integrating AI?

Significance of The Research

This study may serve as a foundational reference for future research by providing a conceptual framework. The future study is expected to provide comprehensive data to key stakeholders such as the Ministry of Education Malaysia (MOE), State Education Departments (JPN), District Education Offices (PPD), schools, and non-governmental organisations in planning policies, programmes, and activities for primary school Mathematics teachers in order to continuously enhance their competency in integrating AI into teaching and learning. The future study will also provide an overview of the competency levels of Mathematics teachers in Malaysia in integrating AI into teaching and learning, in comparison with those in more developed countries. This study may also serve as a reference and foundation for future large-scale and comprehensive research aimed at assessing and exploring the competency levels of Mathematics teachers at the national level.

Limitation

This study does not include the ethical values dimension outlined in the SGM 2.0 model when exploring the competency levels of primary school Mathematics teachers in integrating AI. The researcher also excludes Content Knowledge (CK), Pedagogical Knowledge (PK), and Pedagogical Content Knowledge (PCK) from the TPACK model. These exclusions are made to ensure that the study remains specifically focused on identifying teacher competency levels and to avoid an overly broad scope that might divert from the primary objectives of the research.

Theoritical Overview

The two models to be utilised by the researcher in this study are the Technological Pedagogical Content Knowledge (TPACK) model and the Malaysian Teacher Standards 2.0 (SGM 2.0).

Technological Pedagogical Content Knowledge (TPACK)

Shulman (1986) introduced the concept of Pedagogical Content Knowledge (PCK), which represents the integration of content knowledge and pedagogical knowledge. Subsequently, Mishra and Koehler (2006) expanded this framework by incorporating technological knowledge, resulting in the Technological Pedagogical Content Knowledge (TPACK) model, which integrates content knowledge, pedagogical knowledge, and technological knowledge. This framework identifies three core components, namely Technological Knowledge (TK),

Pedagogical Knowledge (PK), and Content Knowledge (CK), along with four intersecting components, which are Technological Content Knowledge (TCK), Pedagogical Content Knowledge (PCK), Technological Pedagogical Knowledge (TPK), and Technological Pedagogical Content Knowledge (TPACK) (Mishra and Koehler, 2006). The TPACK framework is presented as follows.

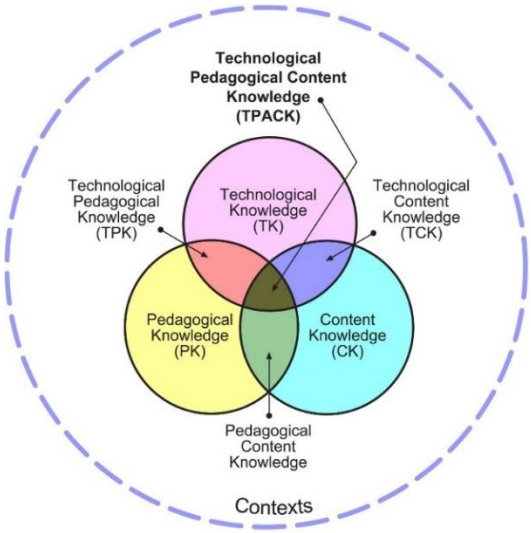

Figure 1: The TPACK Framework and Its Knowledge Components (Koehler and Mishra, 2009)

a) Technological Knowledge (TK)

According to Mishra and Koehler (2006), Technological Knowledge (TK) refers to the knowledge and skills required to effectively utilise technology, and this domain of knowledge must evolve in accordance with technological advancements. It requires teachers to be proficient in using technology and capable of identifying the most appropriate technological tools to achieve specific teaching and learning objectives (Li and Nugraha, 2025). Specifically, with Technological Knowledge (TK), Mathematics teachers are able to identify AI tools such as Wolfram Alpha, Symbolab, GeoGebra, Photomath, Mathway, ChatGPT, intelligent tutoring software, and automated assessment platforms, along with their features and how these tools can be effectively utilised in the teaching and learning of Mathematics.

b) Technological Content Knowledge (TCK)

Technological Content Knowledge (TCK) refers to the understanding of how technology and content are interrelated. According to Mishra and Koehler (2006), teachers must not only master the subject content they teach but also understand how that content can be enriched and transformed through the effective use of technology. TCK involves knowledge of how to use technology to represent, investigate, and create content in various ways, without necessarily considering the teaching aspects (Chai, Hwee, and Tsai, 2013).

c) Technological Pedagogical Knowledge (TPK)

According to Kiray, Celik, and Colakoglu (2018), Technological Pedagogical Knowledge (TPK) refers to general knowledge about how the use of technology influences teaching and learning. More specifically, TPK involves understanding the existence, components, and capabilities of various technologies as they are applied in instructional settings, as well as recognising how teaching may change as a result of the use of specific technologies (Mishra

and Koehler, 2006). This knowledge explores how technology can be effectively integrated into teaching practices to enhance the overall learning experience (Li and Nugraha, 2025).

Malaysian Teacher Standards (SGM 2.0)

The Malaysian Teacher Standards 2.0 (SGM 2.0) is a guideline document for educators outlining the quality standards that teachers are expected to achieve and the ethical values they are expected to uphold in order to demonstrate professionalism in their teaching practice. Generally, SGM 2.0 consists of two main components, which are the Competency Dimensions and Teaching Ethics. The Competency Dimensions component outlines the knowledge, skills, and values that teachers should attain, while the Teaching Ethics component describes the moral principles and ethical values that should be practised by professional educators (Kementerian Pendidikan Malaysia, 2023). There are four main domains under the Competency Dimensions: Knowledge Orientation, Instructional Practice, Community Engagement, and Personal Qualities. The SGM 2.0 framework is presented as follows.

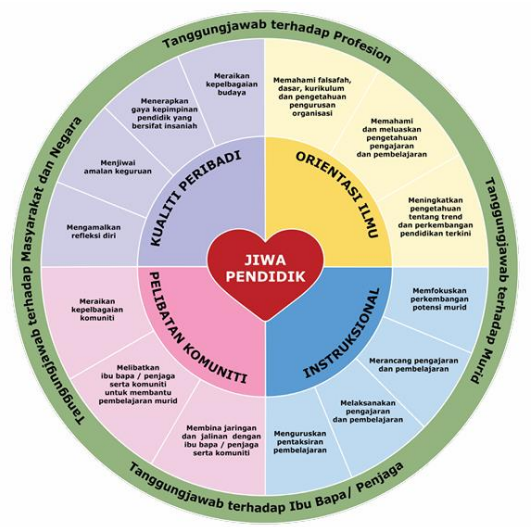

Figure 2. The SGM 2.0 Framework (Kementerian Pendidikan Malaysia, 2023)

According to SGM 2.0, there are four domains within the competency component that teachers are required to integrate into their teaching and learning practices.

a) Knowledge Orientation

A teacher who is competent in the domain of knowledge orientation should possess a thorough understanding of educational philosophy, policies, curriculum, and organisational management; deepen and expand knowledge in the teaching and learning process; and continuously update their understanding of current trends and developments in education.

b) Instructional Practice

A professional teacher, in terms of the instructional domain, should focus on the development of student's potential, plan and implement teaching and learning activities, and manage learning assessment effectively.

c) Community Engagement

An educator who is competent in the domain of community engagement should build networks and partnerships with parents or guardians and the wider community, involve them in supporting student learning, and embrace the diversity of the community.

d) Personal Qualities

Within the domain of personal qualities, a teacher should engage in self-reflection, embody the values of the teaching profession, demonstrate a humane and ethical leadership style, and embrace cultural diversity.

Discussion of The Literature Review

Technological Pedagogical Content Knowledge (TPACK)

The Technological Pedagogical Content Knowledge (TPACK) framework, proposed by Mishra and Koehler (2006), is a widely recognised model for examining digital competency among teachers (Tzafilkou, Perifanou and Economides, 2023). TPACK provides a conceptual framework for understanding the domains of knowledge related to the effective use of digital technology within educational contexts (Li et al. 2024). According to Mishra, Warr, and Islam (2023), the TPACK framework is technology agnostic, as it focuses on the integration of technological tools with content and pedagogy, rather than on the specific tools themselves. This characteristic makes the framework suitable for exploring teacher's competency in the use of AI tools. In the context of primary Mathematics education, the TPACK framework can serve as a guide for implementing meaningful learning experiences (Huang et al. 2024). It also plays a role in guiding teachers to effectively integrate digital technologies while supporting the development of Mathematical skills (Li et al. 2024). Several previous studies have demonstrated that the TPACK framework can be effectively utilised to explore the integration of technology in the teaching and learning of Mathematics (Bahador, Othman dan Saidon, 2017), (Sampar dan Mohamed, 2023), (Jalil dan Moi, 2023), (Kholid, 2023). In addition, according to Mishra, Warr, and Islam (2023), publications employing the TPACK framework as a primary research model have increased from only 29 works in 2008 to a total of 2,941 publications by June 2023, comprising 1,984 journal articles, 29 books, 354 book chapters, and 574 dissertations. This trend clearly demonstrates that the TPACK framework is highly suitable for identifying the competency levels of primary school Mathematics teachers in integrating AI into teaching and learning. However, Kholid et al. (2023) claim based on their systematic literature review, that no researchers have yet applied the TPACK framework specifically within the scope of AI.

Malaysian Teacher Standards (SGM 2.0)

The Malaysian Teacher Standards 2.0 (SGM 2.0) was officially introduced by the Ministry of Education Malaysia in 2023 as a guideline for identifying and determining competency levels in terms of values, skills, and knowledge (Kementerian Pendidikan Malaysia, 2023; Ling et al. 2023). This document is an enhancement of the original Malaysian Teacher Standards published in 2009, and its content is based on the Southeast Asia Teacher Competency Framework (SEA-TCF). According to Makhsin, Teoh, and Ismail (2022), SGM 2.0 is a comprehensive framework that is well-suited to the context of 21st-century education. Several studies have employed the SGM 2.0 model as the foundation for investigating teacher's competency levels (Yakob and Hong, 2022; Ling et al. 2023; Makhsin, Teoh and Ismail, 2022; Nadmilail, Matore and Maat, 2022; Sariff and Hamid, 2024). However, research

employing this model remains limited in Malaysia, particularly in the context of Mathematics education and the integration of AI.

Conceptual Model Development

Mathematics teacher's knowledge in the technological components of TPACK (TK, TPK and TCK) is used as the independent variable, while teacher's competency levels serve as the dependent variable. Based on the questionnaire measuring these three TPACK dimensions, researcher can identify the initial level of teacher's competency (high, medium, low). SGM 2.0 is not a separate dependent variable, rather it provides additional dimensions to evaluate the dependent variable identified by TPACK. Once reasearcher identify teacher's competency level using TPACK, researcher will further analyse this compentency in greater depth using SGM 2.0 dimensions (knowledge orientation, instructional practice, community engangement and personal qualities). This step allows researcher to clarify and pinpoint specific strengths and area for improvement. The SGM 2.0 framework is used to evaluate Mathematics teacher's competency based on its four competency dimensions. Through this framework, the future research able to determine the extent to which teacher's technological knowledge influences their competency levels and to evaluate the strengths and weaknesses of both competent and less competent teachers based on the four dimensions of SGM 2.0. This is important because while the TPACK framework is capable of assessing teachers from technical and pedagogical perspectives, the SGM 2.0 dimensions are necessary to evaluate teachers in terms of attitude, values, and professional engagement, all of which support the effective integration of AI in the teaching and learning of Mathematics. The integration of the TPACK model and the SGM 2.0 framework offers the potential to identify and assess the competency levels of primary school Mathematics teachers in effectively integrating AI tools into teaching and learning. Demographic variables such as gender, teaching experience, and educational background will be analysed to determine the extent to which these factors differentiate teacher's competency levels in AI integration. The conceptual framework of the study is constructed as follows.

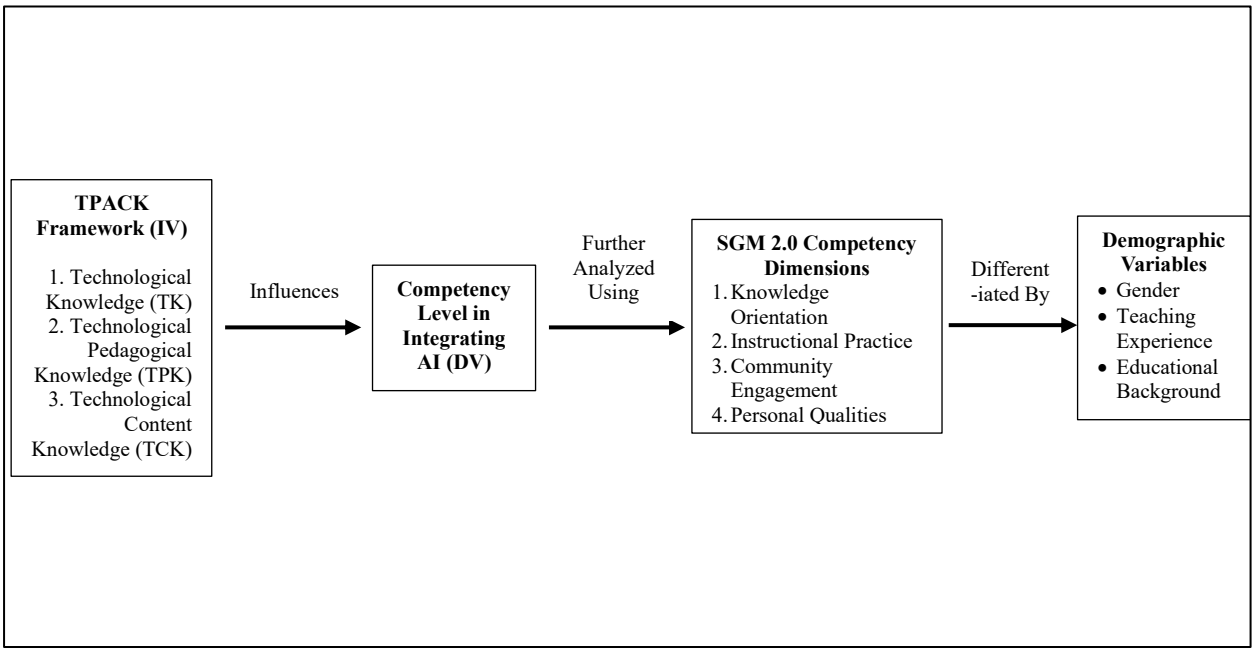

Figure 3. Conceptual Framework of the Study: TPACK–SGM 2.0

Source: TPACK Model (Koehler & Mishra, 2009) and SGM 2.0 Model (Kementerian Pendidikan Malaysia, 2023)

Conclusion

In the era of rapid digital transformation in Mathematics education, AI holds significant potential for integration into teaching and learning practices (Cotic, 2024). Furthermore, previous studies have shown that AI technologies have the capacity to transform and elevate the quality of education (Li and Nugraha, 2025). However, teacher's digital competency is a critical element in effectively integrating this technology within the field of education. Accurate data on teacher's competency in integrating AI into teaching and learning can not only assist stakeholders in organising programmes for in-service and pre-service teachers, but also serve as a foundation for developing policies and curricula that are appropriate and aligned with national context. Therefore, this study serves as a step towards realising that aspiration.

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