The Development of Mathematics Teachers' Proficiency Framework for Sustainable and Standardised Assessment in Southeast Asia (SEA)

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Abstract
No education can exceed the quality of its teachers. This statement indicates that teachers' competence is important in the education system. A professional teacher must have specific knowledge and skills, which are related to pedagogy, content, and technology in providing good quality mathematics teaching and learning in the 21st century. The knowledge and skills need to be improved from time to time to fit the recent issues suitable for advancing technology information and global society. An assessment framework and tools for mathematics teachers' proficiency are needed, considering the importance of assessing mathematics teachers' knowledge for sustainable improvement. This study aims to develop a rigorous region-wide teacher proficiency assessment framework to evaluate mathematics teachers' knowledge. This research is an ongoing project funded by the Ministry of Education, Culture and Technology of Indonesia which involved two lecturers, two analysts, and seven researchers. The method used in the study is the ADDIE instructional design of which steps are Analysis, Design, Development, Implementation, and Evaluation. This paper produced an assessment framework with the twelve sub-indicators for Pedagogical Content Knowledge (PCK), six for Technological Content Knowledge (TCK), and ten for Technological Pedagogical Knowledge (TPK), which cover mathematics teachers' proficiency components. By using this framework, it is expected that an assessment test for mathematics teachers in Southeast Asia can be developed in the near future.

Keywords: Mathematics Teachers, Teachers Proficiency Framework, Assessment Framework, TPCK

Introduction

A professional teacher must have specific knowledge and skills to provide high-quality mathematics teaching and learning in the 21st century. There are at least two knowledge areas that need to be accomplished by mathematics teachers regarding the content and pedagogy, which will then be conveyed to students. In the teaching and learning practice, content and pedagogical knowledge are two pieces of knowledge that are not mutually exclusive. For this reason, having knowledge of standalone content and general pedagogical strategies was not enough to grasp the knowledge of good teachers.

As we are now living in the digital era, In the digital era, the use of ICT has become prevalent (Chai et al., 2013) and even becomes one of the most critical components in the classroom (Ozudogru & Ozudogru, 2019). Consequently, teachers are intended to master technology, specifically the technology to be integrated into the learning process. In line with the content and pedagogical knowledge, technological knowledge must combine with the content and pedagogical in the learning process. Thus, to become ready to facilitate students in mathematics teaching and learning to develop 21st century skills, teachers must keep evaluating and maintaining their knowledge and skills regarding the content, pedagogy, and technology.

The teachers' knowledge and skills need to be improved occasionally to fit the recent issues suitable for advancing technology, information and global society. Handal et al. (2013) emphasized the two main reasons teachers' competence in integrating technology in the teaching and learning process needs to be evaluated. First, ensuring the quality of teaching is as essential as ensuring the students have novel technologies exposure in the classroom. Second, evaluating the teacher's competence in integrating the technologies into the teaching and learning process can be a strategic way to provide the appropriate teacher professional development programs.

There is a need to assess mathematics teachers' knowledge for their sustainable improvement. Moreover, there are various types of research regarding the assessment of teachers' knowledge, specifically on TPCK. However, the researches that have done had various focus areas and different perspectives. Most research used questionnaires or self-report instruments to measure the TPCK (Handal et al., 2013; Malubay & Daguplo, 2018; Pamuk et al., 2015; Schmidt et al., 2014). Scherer et al. (2017) also had measured the technology-dimensions in the Technological, Pedagogical, and Content Knowledge (TPACK) using questionnaires or self-report. Baier & Kunter (2020) developed a knowledge-based instrument to measure the TPK on the TPCK model, or it called as using the cognitive perspective to assess the teachers' TPK. Thus, the researcher teams considered developing the teachers' proficiency framework, envisioned for sustainable and standardized assessment for primary school teachers and junior high school mathematics teachers within Southeast Asia (SEA) countries.

Theoretical Framework

No education can exceed the quality of its teachers. This statement indicates that teachers' competence is essential in the education system. It is supported by the statement of Tican & Deniz (2019) that is teachers should be qualified enough to support the development of 21st century skills in education. The teachers' competencies are related to the content, pedagogy and technology in order to be able to provide a good quality of 21st century learning. In other words, to deliver the appropriate 21st century learning competently, a teacher needs to know and use technology to be used to teach specific content subjects in a classroom effectively. In the educational research filed, there is Technological Pedagogical Content Knowledge (TPCK) framework to understand the teacher knowledge needed to effectively integrate technology in teaching and learning (Mishra & Koehler, 2006).

The TPCK framework was then renamed to TPACK to make it easier to remember and represented a more integration of technology, pedagogy, and content knowledge (Schmidt et al., 2014). This framework consists of seven components as depicted in the picture below.

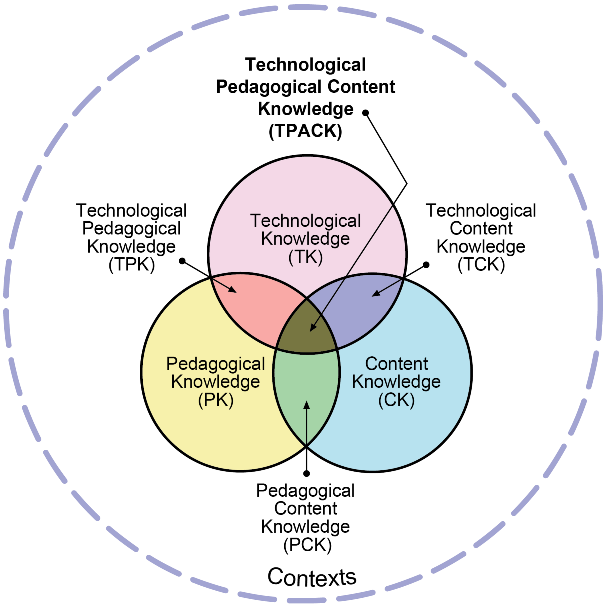

Figure 1. TPACK framework from tpack.org

In TPACK framework, there are there basic components – content (C), pedagogy (P), technology (T); its interrelated knowledges - pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK); and all three interplay knowledge – technological pedagogical content knowledge (TPCK) (Mishra & Koehler, 2006). This framework emphasized more on the complex interrelation between the components, rather than treated separately on each three basic knowledges for having a good teaching.

One of the basic components is content knowledge (CK). Mishra & Koehler (2006) stated that the content knowledge (CK) was the knowledge of the content that a teacher will convey to the students. Besides the content knowledge, a teacher must also understand about the ways to deliver the teaching and learning processes that involve how students learn, how to manage the classroom, how to develop lesson plans and how to assess the student. This knowledge then is called pedagogical knowledge (PK) (Mishra & Koehler, 2006).

The intersection of content and pedagogy is the Pedagogical Content Knowledge (PCK). It is argued that it is not good enough for teacher to teach particular subject matter using the knowledge of contents and general pedagogy knowledge (Shulman, 1986). A good teacher must have a knowledge on how to teach a particular subject. With the same notions with Shulman, Mishra & Koehler (2006) mentioned that PCK is a specific content knowledge that focuses on the applicability of the content to be delivered for students.

PCK as the intersection of content knowledge and pedagogy, Pamuk et al (2015) mentioned that it is also a specific part of pedagogical knowledge that focus on the teaching strategies that incorporate appropriate conceptual representations to address learner difficulties and misconceptions. Further, PCK claimed as teacher competence to foster meaningful understanding on a specific content (Depaepe et al., 2013). Some experts also mentioned that PCK is not only related to content and teaching, but also knowledge of contents and students (Hill et al., 2008; Marks, 1990) as well as knowledge of curriculum (An et al., 2004; Hill et al., 2008; Lannin et al., 2013). Specifically for mathematics teachers in SEA, SEAMEO RECSAM (2013) mentioned that a teacher with professional teaching and learning process includes the knowledge of mathematical task and discourse; planning for learning processes; implementing teaching strategies; monitoring, assessment, and evaluation; and reflection of teaching and learning.

Besides content and pedagogy, in this digital era teachers need to master technology to be integrated in the mathematics classroom. Mishra & Koehler (2006) defined the Technological Knowledge (TK) as knowledge about standard technologies, such as a ruler, chalk and blackboard, and more advanced technologies, such as the computer and internet, that involves the skills to operate software tools such as word processors, spreadsheets, browsers, and e-mail. The nature of TK must be updated since the technology is constantly changing in the shift time.

In line with the content and pedagogical knowledge, the technological knowledge must combine with the content and pedagogical in the learning process. Mishra and Koehler (2006) then defined technological content knowledge (TCK) as the knowledge about how technology and content are reciprocally related. On the other hand, TCK can also be defined as the knowledge and skills to select and use technology to support content or concept (Harris & Hofer, 2009; Koehler et al., 2013; Lux et al., 2011; Pamuk et al., 2015). In the context of mathematics teachers, SEAMEO RECSAM (2013) also mentioned that a professional specifically in teaching mathematics, a teacher must have the knowledge of how particular technology supports a mathematics concept, and the knowledge of use of ICT to model context and solve problems.

Mishra and Koehler (2006) also define technological pedagogical knowledge (TPK) as knowledge of how various technologies are used in teaching and learning settings and knowledge of how teaching might change as the result of using a particular technology. On the other hand, TPK means the knowledge related to how to integrate technology about enhancing the pedagogical practices (Heitink et al., 2017; Lux et al., 2011; Pamuk et al., 2015). Since, pedagogical practices are related to the process to support students' learning, Sahin (2011) mentions that teachers that have TPK means they have knowledge in using computer applications to support students' learning.

The intersection between PCK, TCK, and TPK that are defined as TPACK (Technological Pedagogical Content Knowledge) should be mastered by teachers to be a good teacher in compounding content, pedagogy and technology representing an efficient teaching and learning process through technology (Handal et al., 2013). Mishra & Koehler (2006) described in details regarding the TPACK as follows:

> TPCK is the basis of good teaching with technology and requires an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes

> concepts difficult or easy to learn and how technology can help redress some of the problems that students face; knowledge of students' prior knowledge and theories of epistemology; and knowledge of how technologies can be used to build on existing knowledge and to develop new epistemologies or strengthen old ones. (p.1029)

By having the TPACK, a teacher will teach a subject matter with the suitable pedagogical methods and technologies (Schmidt et al., 2014).

Many researchers had worked on assessing the teachers' perception of their content, pedagogy and technology understanding. Some of them were using surveys on the TPCK domain and required a long time study (Schmidt et al., 2014). Furthermore, (Kabakci Yurdakul et al., 2012) also had developed a TPACK deep scale to gather the information about blending technology, pedagogy and content knowledge in the teaching and learning process. However, the TPACK framework consisted of seven components in it. In this connection the researchers needed to define which components that could effectively reflect the mathematics teacher's proficiency.

Methodology

This research is a part of the project on developing a rigorous region-wide instrument to measure mathematics teachers' proficiency in Southeast Asia. This paper will report on the main question: *how to develop Mathematics Teachers' Proficiency Framework for Sustainable and Standardised Assessment in Southeast Asia (SEA)?*

This study used the ADDIE instructional design of which steps are Analysis, Design, Development, Implementation, and Evaluation. It involved two lecturers, two analysts, and seven researchers during the assessment framework development processes. The process on developing the assessments framework consisted of the following phases:

Analysis

The process of developing the theoretical and methodological assessment frameworks began using the collaborative inquiry approach aimed to systematically examine the existing teachers' standards either in international or national level from several resources. This process administered using the online meeting platform in order to facilitate the experts on mathematics teachers and education from Malaysia, Australia and the Ministry of Education, Research and Technology of Indonesia to discuss and brainstorms the existing standards of professional mathematics teachers in Southeast Asia.

Design

After getting the notions and advisors from the expert on defining the standards of professional mathematics teachers, the research teams were grouped into three teams – TPK teams, PCK teams, and TCK teams. Each team consisted of three experienced researchers on mathematics education and teacher professional development field to further review the literature regarding the TPK, TCK, and PCK.

Develop

The TPK teams, PCK teams, and TCK teams then defined the appropriate indicator and sub indicator of each domain of teachers' proficiency. Furthermore, the researcher teams also collaboratively defined the most possible and appropriate type of questions that can represent the evidence of each indicator or sub indicators.

Implementation

The researchers invited the experts from Malaysia and Australia to share the initial draft of the assessment framework via online meeting platform. The online discussion sessions aimed to provide the room to describe the work done by the researchers and to confirms the ideas from the researchers.

Evaluation

Right after the implementation phase, the researcher teams send the initial draft of the assessment framework to validate the construct and get feedback from experts. This phase involved two experts on mathematics education and teacher professional development from university and a regional institution.

Result and Discussion

Developing the theoretical and methodological assessment framework

The domain of the assessment framework of mathematics teachers' proficiency pointed on the three main domains as depicted in the picture below.

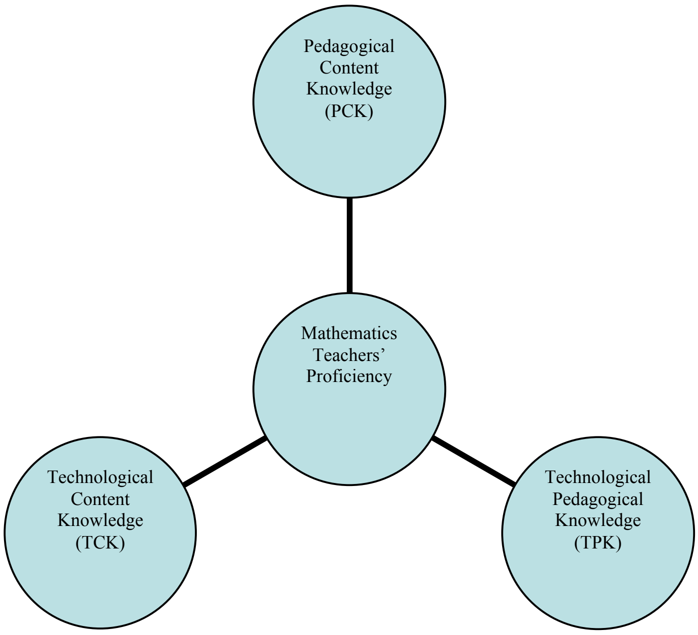

Figure 2. Mathematics Teachers Proficiency Domains

On the domain of PCK, 9 articles had been reviewed to break down the indicators reflecting the knowledge of pedagogy and subject matter content. The results are described on the following table.

Table 1. Summary of literature review on PCK

Reference	Definitions
SEARS-MT (SEAMEO RECSAM, 2013)	Professional teaching and learning standards consist of 1. Mathematical task and discourse 2. Planning for learning processes 3. Implementing teaching strategies 4. Monitoring, assessment, and evaluation 5. Reflection of teaching and learning

Shulman (1987)	1. knowledge of learners and their characteristics 2. knowledge of educational context 3. knowledge of educational ends, purposes and values, and their philosophical and historical bases. 4. content knowledge 5. general pedagogical knowledge 6. curriculum knowledge
An et al. (2004)	1. knowledge of content 2. knowledge of curriculum 3. knowledge of teaching
Lannin et al. (2013)	1. knowledge of curriculum for math 2. knowledge of instructional strategies for math 3. knowledge of student understanding within mathematics 4. knowledge of assessment for math
Marks (1990)	1. knowledge of student understanding 2. knowledge of subject matter for instructional purposes. 3. knowledge of media for instruction 4. knowledge of instructional processes
Pamuk et al. (2013)	1. Determining the teachability of the content 2. Understanding content related difficulties and easiness 3. Organizing and teaching content according to students' levels and contextual factors. 4. Developing alternative strategies for components of teaching (i.e.) assessment, classroom management, motivation, individual differences) 5. Knowledge of teaching methods for different types of subject matters 6. Knowledge of representing and formulation of the content 7. Enriching teaching and understanding with examples, analogies, representations.
Shulman (1986)	1. Knowledge of instructional strategies and representations 2. knowledge of students' (mis)conceptions
Depaepe et al. (2013)	1. common content knowledge 2. specialized content knowledge 3. horizon content knowledge
Hill et al. (2008)	1. Knowledge of content and students (KCS) 2. knowledge of content and teaching (KCT) 3. knowledge of curriculum

Based on the above literature review result, the indicators for PCK domain were identified on the following table.

Table 2. General indicators for Pedagogical Content Knowledge (PCK)

Knowledges	**General Indicator**
Pedagogical Content Knowledge (PCK)	Knowledge of mathematical task and discourse Knowledge of instructional strategies Knowledge of assessment and evaluation Knowledge of reflection of teaching and learning

Within the Southeast Asia context, there is the SEA-BES Common Core Regional Learning Standards (CCRLS) in Mathematics which provide the mathematics contents strands for mathematics activity in primary and junior high school (Mangao et al., 2017)

Table 3. Mathematics Strands based on SEA BES CCRLS in Mathematics

Key Stage	Mathematics Strands
Key Stage 1 covers Grades 1 to 3	Numbers and Operations Quantity and Measurement Shapes, Figures and Solids Pattern & Data Representations
Key Stage 2 covers Grades 4 to 6	Extension of Numbers and Operations Measurement and Relations Plane Figures & Space Solids Data Handling and Graphs
Key Stage 3 covers Grades 7 to 9	Numbers and Algebra Relations and Functions Space and Geometry Statistics and Probability

Since the assessment framework will be implemented for primary and junior high school mathematics teachers, then the specific mathematics content will be based on all those three key stages on table 3.

On the domain of TCK, 5 main articles had been reviewed to break down the indicators reflecting the knowledge of content and technology. The results are described on the following table.

Table 4. Summary of literature review on TCK

Reference	Definition
SEARS-MT (SEAMEO RECSAM, 2013)	a. Knowledge of how particular technology supports a mathematics concept b. Knowledge of use of ICT to model context and solve problems
Koehler et al., (2013)	a. Knowledge of the way the subject matter (or the kinds of representations that can be constructed) can be changed by the application of particular technologies. b. Knowledge of which specific technologies are best suited for addressing subject-matter learning in their domains. c. Knowledge of how the content dictates or perhaps even changes the technology—or vice versa.
Pamuk et al., (2013)	a. Transformation of the content b. Organization of the content c. Make unobservable content more explicit (observable) d. Emerging different perspectives on the content e. Communicating with particular content f. Representation of the subject matter with technology g. Use of technology to support varied representations

	h. Use of technology to ensure flexibility navigating across representations i. Data collection and analysis

Harris & Hofer, (2009)	a. Knowledge to select technologies to communicate particular content. b. Knowledge to use technologies to communicate particular content.
Lux et al., (2011)	a. Knowledge to select affordable technology to support the content. b. Knowledge to select appropriate technology based on types of content ideas. c. Knowledge to improve the quality content representation using technology

Finally, as for Technological Content Knowledge (TCK), there are two general indicators and six sub indicators as shown on Table 1.

Table 5. General Indicators for Technological Content Knowledge (TCK)

Knowledges	General Indicator
Technological Content Knowledge (TCK)	Knowledge of how particular technology supports a mathematics concept Knowledge of use of ICT to support mathematical activities

Furthermore, there are six main articles that had been reviewed to define the element of TPK. The summary of the literature review process is as follows.

Table 6. Summary of literature review on TPK

Reference	Definition
SEARS-MT (SEAMEO RECSAM, 2013)	**Dimension 1: Professional Knowledge** a. Knowledge of ICT **Dimension 2: Professional Teaching and Learning Process** a. Planning for Learning Process b. Implementing teaching strategies c. Monitoring, assessment, and evaluation d. Reflection of teaching and learning **Indicator** a. Knowledge of motivational and engagement levels of students for learning mathematics b. Knowledge of strategies for supporting creativity and innovation c. Knowledge of strategies for developing students' higher order thinking skills in mathematics

	d. Knowledge for making complex relations between representations of core topics e. Knowledge of ICT integration in teaching and learning 1234 f. Knowledge of how to use ICT to model context and solve problems g. Engage and enrich students in mathematical thinking through discourse h. Communicate thinking through various means of representation and reasoning i. Plan for an effective and safe learning environment to cater to the diversity of all students j. Use of effective communication and promotion of classroom discussion k. Develop and use a range of appropriate assessment tasks and strategies l. Analyze students' learning through assessment
Australian Professional standards for teachers (Dyson et al., 2018)	a. Demonstrate knowledge and understanding of strategies for differentiating teaching to meet the specific learning needs of students across the full range of abilities. b. Implement teaching strategies for using ICT to expand curriculum learning opportunities for students. c. Demonstrate knowledge of a range of resources, including ICT, that engage students in their learning. d. Demonstrate an understanding of the relevant issues and the strategies available to support the safe, responsible and ethical use of ICT in learning and teaching. e. Demonstrate an understanding of the purpose of providing timely and appropriate feedback to students about their learning.
Koh & Sing (2011)	a. Knowledge of how to use technology to construct different forms of knowledge b. Knowledge of how to use technology to plan and monitor students' learning
Cox (2008)	a. Technological pedagogical knowledge is an understanding of the application of technology without reference to a specific content

Lux et al. (2011)	a. Knowledge of how to integrate technology into teaching and learning in order to help students achieve specifics pedagogical goals and objectives b. Knowledge to adapt technologies to better support teaching and learning c. Knowledge to reconfigure technology and apply it to meet instructional needs
Pamuk et al.(2015)	a. TPK is knowledge about enhancing pedagogical practices, components (teaching, assessment, motivation etc.) with the implementation of technology into teaching and learning activities b. Knowledge of how to use technologies to assess students' learning c. Knowledge of how to use technologies to identify differences among students d. Knowledge of how to use technology to advance teaching and students' learning e. Knowledge of how to use technology to bring students' individual differences (learning preferences, content background, academic level) into the classroom

In connection to the above literature review on TPK, then it was defined the general indicator of TPK on this assessment framework as follows.

Table 7. General indicators for Technological Pedagogical Knowledge (TPK)

Knowledges	General Indicator
Technological Pedagogical Knowledge (TPK)	Knowledge of how to use ICT to plan for and implement joyful and meaningful teaching and learning Knowledge of how to use ICT to provide joyful and meaningful monitoring, assessment and evaluation. Knowledge of how to use ICT to reflect of teaching and learning

The assessment framework developed referred to SEARS – MT, which includes standards for teachers in the Southeast Asian region. In addition, for the content components covered by TCK and PCK, we used The SEAMEO Basic Education Standards (SEA-BES) and the Common Core Regional Learning Standards (CCRLS) in Mathematics. At SEA BES CCRLS in Mathematics, standard mathematics learning content has been provided for countries in Southeast Asia.

Reviewing and finalizing the assessment framework

The framework was reviewed by the two experts from Australia and Malaysia. Each expert gives reviews on indicators, sub indicators and descriptions on each component of TPK, PCK and TCK. The review results on the TCK component mentioned that all content domains are covered and linked to the applicable technology. The same result goes to the TPK component. All sub indicators and descriptions covered the technological and pedagogical knowledge domains. Then, for the PCK component, one reviewer gave the additional comment to include the mathematical content to the sub indicators. The feedback has been followed up by providing the content or mathematics for every sub indicator.

In previous research, many instruments have been developed to measure TCK, PCK, or TPK. this study adopts a cognitive perspective, meaning that the teacher's attribute can be measured separately from actual classroom teaching by means of questionnaires or tests (Depaepe et al., 2013). This assessment framework will be then followed up by developing the knowledge-based test as the assessment tools.

Conclusion

After all the phases of the development, it was produced an assessment framework with the twelve sub-indicators for Pedagogical Content Knowledge (PCK), six for Technological Content Knowledge (TCK), and ten for Technological Pedagogical Knowledge (TPK), which cover mathematics teachers' proficiency components. The author plan by using this framework, it will be carried out the development of an assessment test for mathematics teachers in Southeast Asia in the near future.

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