# Measuring Mathematics Teacher Educators' Knowledge of Technology Integrated Teaching: Instrument Development

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This study describes the construction of a questionnaire instrument to measure mathematics teacher educators' knowledge for technology integrated mathematics teaching. The study was founded on a reconceptualisation of the generic Technological Pedagogical Content Knowledge framework in the specific context of mathematics teaching. Steps in the development of the questionnaire were; consideration of the context in which the questionnaire would be used, comparison of proposed items with and existing instrument, expert review, and pilot testing. The process described provides a model for other researchers interested in adapting generic tools for mathematics specific use.

The Technological Pedagogical Content Knowledge (TPCK) framework (Mishra & Koehler, 2006), renamed TPACK (Thompson & Mishra, 2007), was articulated to describe teachers' knowledge of technology integrated teaching. The framework has been introduced to explain the knowledge base needed for teachers to teach effectively with technology. It stems from the notion that technology integration benefits from a careful alignment of content, pedagogy and the potential of the technology (Niess, 2005). Teachers who want to integrate technology in their teaching practice, therefore, need to be competent in technology, pedagogy and content. Mishra and Koehler (2006) went further arguing that effective technology integration in teaching also requires knowledge defined by the relationships and interplays between knowledge of technology, pedagogy and content as indicated in Figure 1.

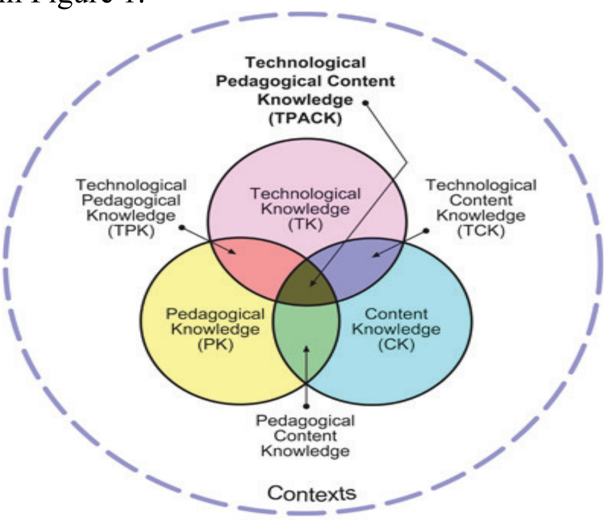


*Figure 1.* TPACK framework (source: Koehler & Mishra, 2009).

As indicated in Figure 1, the interplay between technology, pedagogy and content give rise to i) Pedagogical Content Knowledge (PCK) which refers to knowledge of pedagogy that is appropriate to the teaching of specific content; ii) Technological Content Knowledge (TCK) which refers to an understanding of the teacher that technology and content influence each other for effective learning; iii) Technological Pedagogical

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Knowledge (TPK) which is the understanding of how teaching changes when particular technologies are used, and finally where all three intersect, iv) Technological Pedagogical Content Knowledge (TPACK) referring to the knowledge needed by teachers to understand the pedagogical approaches that use technologies in systematic ways to teach content.

## Measuring TPACK

Instruments to measure teachers' knowledge of technology integrated teaching have been developed using the TPACK framework in diverse fields of study and a variety of contexts (e.g., Abbitt, 2011; Albion, Jamieson-Proctor, & Finger, 2010; Graham, Cox, & Velasquez, 2009; Koehler & Mishra, 2005; Schmidt et al., 2009). One example of a questionnaire instrument to measure teachers' TPACK was described by Koehler and Mishra (2005). In that USA study, 4 faculty members and 13 student participants responded to questions about individual and group perceptions of elements of the TPACK. The questionnaire instrument comprised 33 Likert scale items and 2 open-ended questions and was primarily designed to determine the level of participants' TPACK.

A literature review study (encompassing 34 journal articles, 52 papers published in conference proceedings, two book chapters, two doctoral dissertations, and one report) on instruments developed to measure TPACK in the context of pre-service teacher preparation programs by Abbitt (2011), showed the importance of using quantitative and qualitative approaches to understanding TPACK. Quantitative methods (e.g., closed response questionnaire items) can provide efficient measures whereas qualitative approaches (e.g., open response questionnaire items) can provide further insight into respondents' thinking. Examples of instruments include that of Albion et al. (2010) who described the development and empirical validation of an instrument to measure and audit the TPACK capabilities of final year teacher education students at two universities in Queensland, Australia. They found that the teaching with technology audit questionnaire was a valid, reliable and multi-dimensional instrument. Graham et al. (2009) used a self-report questionnaire and performance assessment strategies for measuring TPACK confidence of in-service teachers. The instrument addressed technology related elements of the TPACK framework using a total of 31 items specific to science.

The examples described above illustrate the effort that has been made to develop valid and reliable instruments which can measure teachers' TPACK. All were developed based on the generic definitions of the TPACK framework (Mishra & Koehler, 2006). The authors of the present study, however, argue the importance of understanding and explaining the use of the TPACK framework specific to mathematics teaching. They were also interested in an instrument that could be used with mathematics teacher educators (MTEs) – a group whose knowledge has been under-researched (Zazkis & Zazkis, 2011). This paper reports the development of an instrument to measure MTEs' TPACK. The development process, detailed in the following sections entailed conceptualising the TPACK framework for mathematics teaching, consideration of context, comparison with an existing instrument, expert review, and pilot testing.

## Instrument Development

Various studies have illustrated procedures for developing reliable and valid instruments to measure a given construct (e.g., Colton & Covert, 2007; Liang et al., 2008). Colton and Covert (2007) recommended an iterative process involving constant revision.

They recommended eight cyclic steps: identifying the purpose and focus of the study; obtaining feedback from stakeholders to clarify the purpose and focus; identifying the research methodology and type of instrument to use for data collection; beginning to formulate items or questions; pre-testing items with content experts and potential respondents; making revisions based on feedback; piloting and revision; and finally administering the instrument. They indicated that instrument development ought to be a systematic yet creative activity requiring continual refinement and revision. Liang et al. described five phases to develop an instrument to evaluate pre-service teachers (PSTs) views on the nature of science. These were, i) selection of standards and literature based items, ii) pilot tests and interviews, iii) expert review, iv) further revision and v) comparison with existing instruments. This study drew on both Colton and Covert's iterative process for instrument development, and the instrument development phases of Liang et al. (2008). The process used is indicated in Figure 2.

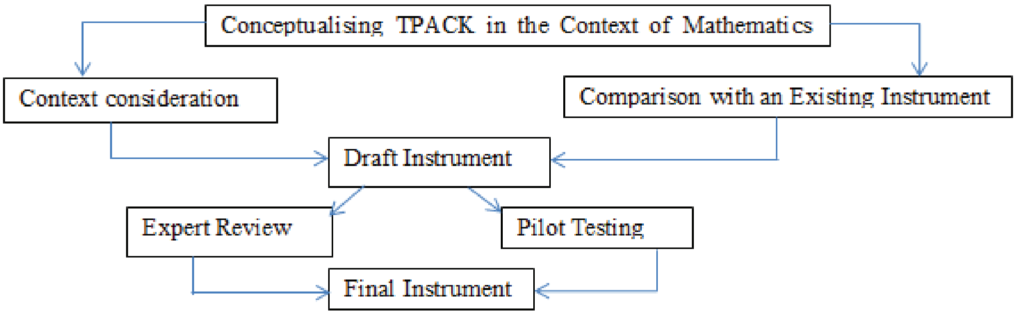


*Figure 2.* Process of developing an instrument to measure mathematics teacher educators' TPACK.

This study included context analysis, literature review (to conceptualise TPACK in the context of mathematics teaching), expert review, and a pilot test to develop the instrument to measure MTEs' TPACK.

## Development of an Instrument to Measure Mathematics Teacher Educators' TPACK

This section explains each stage of the development process as shown in Figure 2.

### *Conceptualising TPACK in the Context of Mathematics Teaching*

The need to specify TPACK in relation to mathematics teaching in order to provide a sharper lens than the generic TPACK framework alone and to understand better the knowledge required for teachers of mathematics to use technology in their teaching was the starting point. Researchers in mathematics education have conceptualised the knowledge needed to teach mathematics in various ways (e.g., Ball, Thames, & Phelps, 2008; Chick, Baker, Pham, & Cheng, 2006; Rowland, Huckstep, & Thwaites, 2005). However, Ball et al.'s (2008) framework with its emphasis on mathematical knowledge suited our purpose of developing a mathematics specific framework for technology integrated teaching. Hence Ball et al.'s (2008) Mathematical Knowledge for Teaching (MKT) and the TPACK framework (Mishra & Koehler, 2006) were used as bases for understanding technology integrated mathematics teaching. The TPACK framework was restructured by refocussing three new components for teaching mathematics using technology (Technology Knowledge (TK), Specialised Pedagogy Knowledge (SPK) and Specialised Mathematics Knowledge (SMK) as in indicated in Figure 3. The definitions of each of the knowledge types arising from interplay of the various components are provided in Table 1.

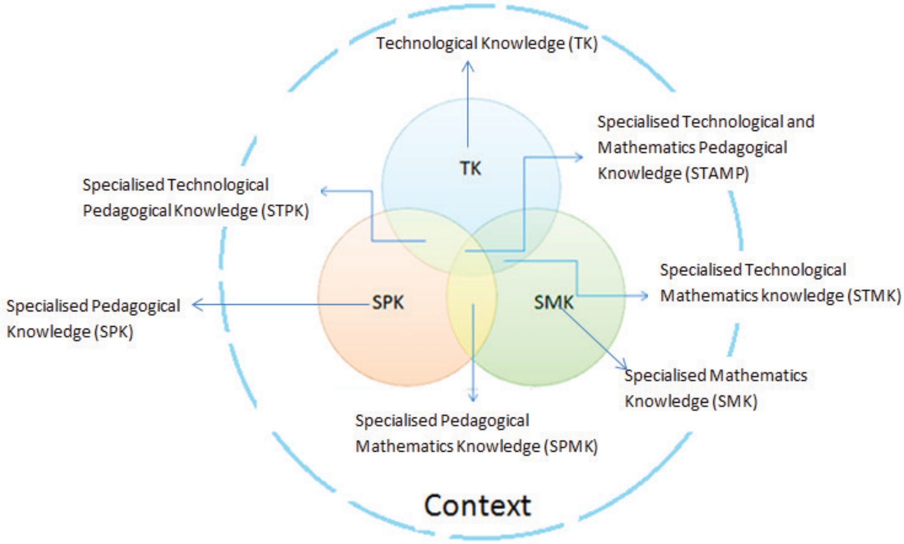


Figure 3. Knowledge required in teaching mathematics with technology.

Table 1
*Knowledge required in teaching mathematics using technology*

| Component | Definition |
|---|---|
| SMK | Actual mathematics concepts and specialised mathematics knowledge required for teaching. |
| SPK | Knowledge of various instructional strategies and the knowledge required to understand the nature of the target students to teach mathematics. |
| TK | Various technologies, ranging from low-tech technologies to digital technologies. |
| STMK | Teaching effective mathematics cementing the special content knowledge of mathematics with the application of technology. |
| STPK | Anticipating what students are likely to think and find confusing and addressing this with the application of technology and selected pedagogy. |
| SPMK | Pedagogical knowledge that fits with the mathematical concepts. |
| STAMPK | The application of technology for effective mathematics learning of students. |

*Consideration of context*

The context in which an item is presented has an influence on the way respondents interpret and answer it (Colton & Covert, 2007). The instrument was designed to measure MTEs' knowledge of technology integrated mathematics teaching in the context of initial teacher education in Ethiopia. This is in contrast to more common uses of the TPACK framework with pre-service and in-service teachers. The items needed to be in relation to MTEs (Colton & Covert, 2007). For example, there were items which referred to how teacher educators can be models for their PSTs in the use of technology in their teaching (e.g., "I can provide leadership in helping PSTs and others to teach ICT integrated mathematics with teaching approaches”). Similarly, the wording of each item was linked to MTEs teaching primary PSTs of mathematics. The wording of items was considered carefully to ensure that they would be understood by Ethiopian MTEs.

*Comparison with an Existing Instrument*

A number of studies (e.g., Agyei & Voogt, 2012; Chai, Koh, & Tsai, 2010; Koh, Chai, & Tsai, 2010) have described the construction of instruments based on Schmidt et al.’s (2009) questionnaire to measure teachers’ TPACK. For example, Agyei and Voogt (2012) adapted items from Schmidt et al. (2009) to address the integration of spread sheets in mathematics teaching, and Chai et al. (2010) adapted the same questionnaire to examine PSTs’ TPACK perceptions before and after their ICT course. Koh et al. (2010) used an adaptation of Schmidt et al.’s (2009) questionnaire, based on review of the items by experts who are specialised in ICT, to examine Singaporean PSTs’ TPACK. There were thus precedents for basing a new instrument on that of Schmidt et al. (2009)

Schmidt et al.’s (2009) instrument was used as a frame by redefining the TPACK framework from the perspective of teaching mathematics with technology and modifying the underpinning theories in understanding TPACK in relation to mathematics teaching. For example, in the definition of CK Mishra and Koehler’s (2006) TPACK framework was reconceptualised to account for the distinctive nature of CK needed to teach mathematics, as described by Ball et al. (2008) and defined as “Specialised Mathematical Knowledge” (SMK). This specialised knowledge assisted in the designing of items related to Content Knowledge (CK) later (SMK) of mathematics teachers in the TPACK framework. Table 2 shows examples of how items related to TK were modified (e.g., one item became four) while Table 3 provides examples of modified CK items (e.g., three items became two).

Table 2
*Modification of items for the Technological Knowledge (TK) construct of TPACK*

| Schmidt et al. (2009) item | New items included | Justification |
|---|---|---|
| I know about technologies that I can use for understanding and doing mathematics. | 1. I can use a wide range of technologies to teach maths.<br>2. I can select technologies to use in my classroom that enhance what I teach.<br>3. I can’t think of teaching maths without the use of technology.<br>4. I know how to cement the knowledge needed to teach maths with the application of technologies. | The item in Schmidt et al. (2009) was only one which makes it difficult to measure teacher’s TCK in an item; hence there was a need to include more items. In addition, the special type of knowledge needed for mathematics teachers should be measured while influenced by the application of technology. |

As a result, the definition for each of the newly conceptualised technology integrated mathematics teaching components was compared with the items included in Schmidt et al. (2009). Based on the comparison, some items were revised, included or even discarded based on the new conceptualisation of TPACK, the context, and participants in the study.

Table 3
*Modification of items for the Content Knowledge (CK) construct of TPACK*

| Schmidt et al. (2009) item | Modified item | Justification |
|---|---|---|
| 1. I have sufficient knowledge about maths.<br>2. I can use a mathematical way of thinking.<br>3. I have various ways and strategies of developing my understanding of maths. | 1. I have a mathematical knowledge unique to teaching.<br>2. I understand the difference between the knowledge required for teaching mathematics and common knowledge for mathematics. | According to Ball et al., (2008) teaching mathematics demands a special kind of knowledge different from knowing mathematics called Specialised content knowledge; hence this has to be addressed in the questionnaire. |

### *Creating a Draft Instrument*

The definitions in Table 1, context considerations, and comparison with an existing instrument were used to construct the draft instrument for measuring MTE's knowledge for technology integrated mathematics teaching. Additional items were constructed to measure each of the constructs that appear in the modified framework (Figure 3) when SMK is influenced by the application of technology and selection of a particular pedagogy (namely SPMK, STMK, and STAMPK). For example, there was a need for items that can measure MTEs' content knowledge unique to teaching mathematics (Ball et al., 2008). Examples are provided in Table 2. An effort was made to show how this knowledge might interact with the application of technology (i.e. STMK component). As consequence, the STMK component was stated as "I know how to cement the knowledge needed to teach mathematics with the application of technologies". In a similar fashion a total of 41 items were constructed requiring responses on 5-point Likert scales from Strongly Disagree to Strongly Agree. Open-ended questions were added to invite participants to explain their experience in relation to each of the items. The qualitative (open-ended questions) and the quantitative items (Likert type) helped to ensure the validity of the instrument by ensuring that it elicited evidence relating to the constructs intended to be measured (Colton & Covert, 2007).

The draft questionnaire also asked respondents to provide information about their experience of teaching at teachers' college and school level, their access to various technologies, and the frequency with which they used these, and their confidence to undertake a range of tasks involving the use of technology.

### *Expert Review*

The review aimed to pinpoint ways to define and operationalise the constructs and indicate whether each item seemed likely to measure what it was intended to (Liang et al., 2008). Two experts in mathematics education reviewed the questionnaire and several changes were made. Table 4 shows examples of the kinds of improvements made such as adaptations to explicitly address MTEs' work, and splitting 'double-barrelled' items.

In addition, there were recommendations by the experts to add two open-ended items asking participants for such things as an example of how they have successfully used technology in their teaching of PSTs. As a result, more open-ended items (making a total of 9 such items) were included in the questionnaire which could offer detailed and rich information about teachers' knowledge on TPACK.

Table 4
*Examples of improved items based on expert review*

| Original item | Expert reviewed items | Justification |
|---|---|---|
| I know about technologies that I can use for understanding and doing mathematics (TCK). | I know about technologies that I can use to PSTs' understanding of mathematics. | The audience was not addressed. There is a need to address the audience. |
| I can anticipate mathematical concepts what students will find confusing and solve with appropriate teaching method (PCK). | I can anticipate mathematical concepts that PSTs will find confusing.<br>I can prevent PSTs' learning difficulties with appropriate teaching method. | The item was complex; it contained more than one item. There was a need to split and develop two more items for understanding and misconceptions |

### *Pilot Test*

After the instrument was reviewed by content experts, a pilot test with a small group of Australian MTEs (5 responses were obtained) was conducted. The pilot-test assisted in addressing problems that might occur during administration. Furthermore, this step was essential in checking that the items were such that the instrument was to fulfil its purpose, and that it w as unlikely that participants in the study would misunderstand (Colton & Covert, 2007). The pilot testing revealed that some items were vague and too broad. As a result, several items were modified. The pilot testing was, also helpful in identifying unambiguous and understandable items (Colton & Covert, 2007). For example one open-ended question read "In your opinion, what are the challenges to use technology into your teaching of pre-service teachers?" In relation to this item, one respondent commented "*so many*". This indicated that the question was too broad and hence, there was a n eed to modify the question to focus on a particular issue.

The final instrument comprised, in addition to items seeking demographic data, closed response items asking about the accessibility and frequency of use of several specific technologies, types of social media, and software packages, all chosen for their likely relevance in the context of the study and each accompanied by a prompt for respondents to list others, 41 Likert type items measuring aspects of TPACK followed by space to expand upon or clarify any of these responses, and nine open response questions.

## Conclusion

This paper has described the procedure used to develop an instrument to measure MTEs' knowledge for technology integrated mathematics teaching. It is acknowledged that the fact that the pilot test sample differed from the target population is one limitation of the study. The study emphasised the importance of conceptualising the TPACK framework in the context of mathematics teaching to develop a valid and reliable instrument. It provides an approach that might be useful for researchers in other curriculum areas interested in to increase emphasis on de veloping an instrument based on s ubject specific definitions of TPACK to measure its constructs.

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