Journal Pre-proof

Describing increasing proficiency in teachers' knowledge of the effective use of digital technology

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Please cite this article as: Saubern R., Urbach D., Koehler M. & Phillips M., Describing increasing proficiency in teachers' knowledge of the effective use of digital technology, *Computers & Education* (2020), doi: https://doi.org/10.1016/j.compedu.2019.103784.

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Title
Describing increasing proficiency in teachers' knowledge of the effective use of digital technology

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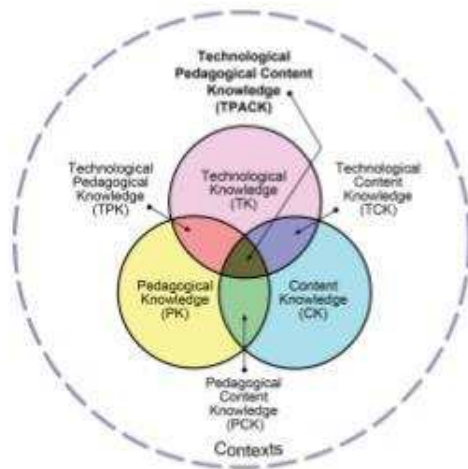East Lansing MI 48824
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Highlights
- Examines what it means for teachers to have more or less Technological Pedagogical Content Knowledge (TPACK).
- A partial credit Rasch analysis is conducted on evidence of practicing teachers' TPACK Confidence and TPACK Usefulness.
- Person-item maps are generated showing the relationship between respondent ability and item difficulty.
- Person-item maps are used to develop construct maps which qualitatively describe increasing proficiency in the constructs.

Abstract
This paper aims to contribute to the theoretical framing of Technological Pedagogical Content Knowledge (TPACK) by exploring how a measurement approach can be used to address the need to improve the prescriptive value of the framework. Building on and extending the work described in Saubern, Urbach, Koehler and Phillips (2019), this paper describes the development of an empirically derived qualitative description of increasing proficiency in TPACK Confidence and TPACK Usefulness. Using the results of a partial credit Rasch analysis of survey responses, five bands of proficiency in TPACK Confidence and five bands of proficiency in TPACK

Usefulness were delineated and described. The study found that teachers at higher levels of TPACK proficiency more strongly believe in the value of using technology to facilitate deep thinking and learning and are more confident to use technology to support and facilitate deeper thinking and learning in and across curriculum areas than teachers with lower levels of proficiency. By providing a description of lower and higher proficiency and an inferred typical order of acquisition, the resulting construct maps can be used by researchers to help develop and test hypotheses about teachers' acquisition of TPACK and improve the validity and precision of TPACK survey tools and by teacher educators to better understand and evaluate the TPACK of student teachers and inform the development of teacher education curricula.

Graphical Abstract

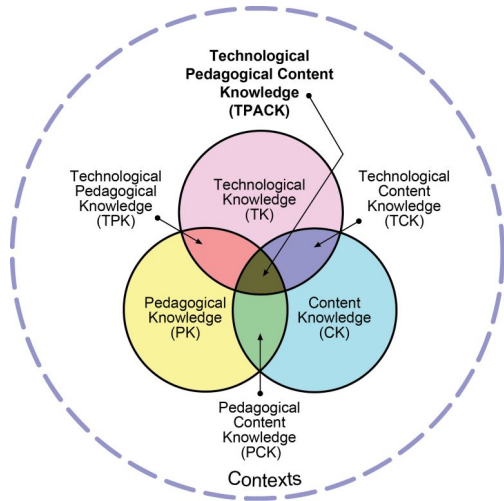Reproduced by permission of the publisher, © 2012 by tpack.org

Keywords
Teacher professional development
Educational technology
Technological, pedagogical, and content knowledge (TPACK)

TPACK Confidence	Band	Description
↑	Teachers in **Band 5** are typically… 12% of respondents	… **extremely confident** that they have the knowledge, skills and abilities to support students' use of ICT to actively construct knowledge that integrates curriculum areas, actively construct their own knowledge in collaboration with their peers and others, analyze their knowledge, synthesize their knowledge, develop deep understanding about a topic of interest relevant to the curriculum area/s being studied, plan and/or manage curriculum projects, engage in sustained involvement with curriculum activities and facilitate the integration of curriculum areas to construct multidisciplinary knowledge.
	Teachers in **Band 4** are typically… 21% of respondents	… **beginning to be extremely confident** that they have the knowledge, skills and abilities to support students' use of ICT to actively construct knowledge that integrates curriculum areas, actively construct their own knowledge in collaboration with their peers and others, develop deep understanding about a topic of interest relevant to the curriculum area/s being studied and plan and/or manage curriculum projects and **very confident** that they have the knowledge, skills and abilities to support students' use of ICT to analyze their knowledge, synthesize their knowledge, engage in sustained involvement with curriculum activities and facilitate the integration of curriculum areas to construct multidisciplinary knowledge.
	Teachers in **Band 3** are typically… 32% of respondents	… **very confident** that they have the knowledge, skills and abilities to support students' use of ICT to actively construct knowledge that integrates curriculum areas, actively construct their own knowledge in collaboration with their peers and others, analyze their knowledge, synthesize their knowledge, develop deep understanding about a topic of interest relevant to the curriculum area/s being studied, plan and/or manage curriculum projects, engage in sustained involvement with curriculum activities and facilitate the integration of curriculum areas to construct multidisciplinary knowledge.
	Teachers in **Band 2** are typically… 25% of respondents	… **beginning to be very confident** that they have the knowledge, skills and abilities support students' use of ICT to develop deep understanding about a topic of interest relevant to the curriculum area/s being studied and plan and/or manage curriculum projects and **moderately confident** that they have the knowledge, skills and abilities to support students' use of ICT to actively construct knowledge that integrates curriculum areas, actively construct their own knowledge in collaboration with their peers and others, analyze their knowledge, synthesize their knowledge, engage in sustained involvement with curriculum activities and facilitate the integration of curriculum areas to construct multidisciplinary knowledge.

1. Introduction

What teachers know has long been an area of interest for researchers in education (Fenstermacher, 1994; Loughran, 2010). Efforts to distinguish the knowledge of teachers from other content experts led to the conceptualization of a knowledge base for teaching (Shulman, 1987; Shulman, 1986). Shulman argued that teachers draw on a wide range of knowledge types, describing seven kinds of knowledge ranging from knowledge of the subject content to knowledge of learners and their characteristics (Shulman, 1987). Amongst these, Shulman singled out pedagogical content knowledge (PCK) as the form of knowledge that most clearly distinguishes the expert teacher from the content expert as it:

> represents the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of students, and presented for instruction. (Shulman, 1987, p. 8)

In the context of research on teacher professional development and the impact of increasing use of digital technologies in education, Mishra and Koehler (2006, 2007) built on Shulman's PCK framework to develop the Technological Pedagogical Content Knowledge (TPACK) framework. TPACK describes the factors that contribute to successful teaching with technology and is intended to support and promote understanding of technology integration in education from theoretical, pedagogical and methodological perspectives (Mishra & Koehler, 2006). TPACK has proven a popular and useful framework for researchers investigating teachers' understanding of the effective use of technology in teaching and learning (Kessler & Phillips, 2019). However, aspects of the TPACK framework, like the PCK framework that preceded it, have been the subject of critique, investigation and development. In particular, researchers have examined the integrative and transformational quality of the TPACK construct, TPACK components and component boundaries, TPACK measurement approaches, the relationship between TPACK and PCK and the prescriptive value of the framework (Angeli & Valanides, 2009; Archambault & Crippen, 2009; Archambault & Barnett, 2010; Cavanagh & Koehler, 2013; Chai, Koh, & Tsai, 2010; Graham, 2011; Koehler, Shin, & Mishra, 2012; Phillips & Harris, 2018; Scherer, Tondeur, & Siddiq, 2017).

This paper aims to contribute to the theoretical framing of TPACK by exploring how a measurement approach can be used to address the need to improve the prescriptive value of the framework. An analysis of data collected using an established TPACK survey tool was used to develop an empirically derived qualitative description of increasing proficiency in TPACK in the form of a construct map (Cavanagh & Koehler, 2013; Wilson, 2003; Wilson, 2004). By providing a description of lower and higher proficiency and an inferred typical order of acquisition, these construct maps can be used by researchers to help develop and test hypotheses about teachers' acquisition of TPACK, improve the validity and precision of TPACK survey tools and interrogate and reflect on the framing of the construct in a fine-grained way (Archambault & Barnett, 2010; Cavanagh & Koehler, 2013; Graham, 2011). Teacher educators can use construct maps to better understand where teacher education students are in the development of their TPACK, establish goals and next steps for learning and more broadly to inform the development of teacher education curriculum.

1.1 The Technological Pedagogical Content Knowledge (TPACK) framework

In considering the knowledge base for teaching, Shulman (1987; 1986) singled out pedagogical content knowledge (PCK) for special attention as it "identifies the distinctive bodies of knowledge for teaching" (Shulman, 1987, p. 8). PCK is a kind of specialist knowledge of teachers which combines pedagogical knowledge, that is, "broad principles and strategies of classroom management and organization that appear to transcend subject matter" (Shulman, 1987, p. 8), and content knowledge of particular subjects to generate an understanding of "how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction" (Shulman, 1987, p. 8). PCK can be represented as a Venn diagram shown as an overlap between pedagogical knowledge and content knowledge (figure 1).
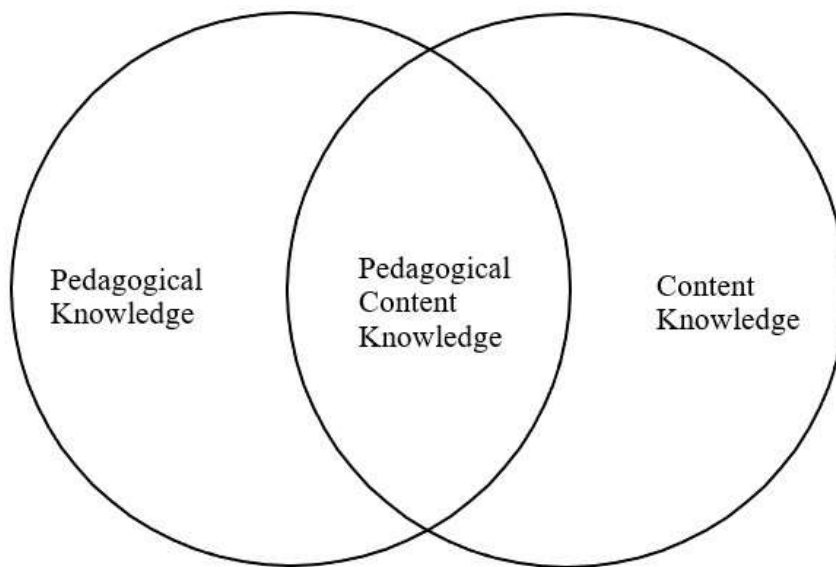
Figure 1: Pedagogical Content Knowledge

In an attempt to understand how the increasing use of digital technologies in schools might impact on the development of teachers' professional knowledge, Mishra and Koehler (2006, 2007) expanded Shulman's PCK framework through the addition of a third knowledge domain, technological knowledge (TK), by which they meant a continuously developing state of knowledge about technology which goes beyond understanding of how to use and apply technology to achieve goals to include problem solving, communicating and interacting with technology (Koehler & Mishra, 2009). The resulting TPACK framework (figure 2) describes the interaction of three core areas of teacher knowledge, pedagogical knowledge (PK), content knowledge (CK) and technological knowledge (TK), interacting to create four additional subdomains:
- Pedagogical Content Knowledge (PCK): described by Shulman (1987; 1986)

- Technological Pedagogical Knowledge (TPK): the understanding of technology that teachers bring to particular pedagogical tasks and how teaching and learning are affected by the use of particular technology in particular ways (Koehler & Mishra, 2009).
- Technological Content Knowledge (TCK): knowledge of the technology that relates to the subject area of instruction, in particular "an understanding of the manner in which technology and content influence and constrain one another" (Koehler & Mishra, 2009, p. 65).
- Technological Pedagogical Content Knowledge (TPACK): an "emergent form of knowledge" dynamically combining all three core knowledge areas and the basis of effective teaching using technology (Mishra & Koehler, 2007). It incorporates understandings of how concepts can be represented using technology, how particular pedagogical approaches can make use of particular technologies to teach particular content, understanding of how technology can be used to address what is difficult or easy to learn in particular content areas, knowledge of how students see and understand the use of technology for learning and of how to build and develop these understandings (Koehler & Mishra, 2009).
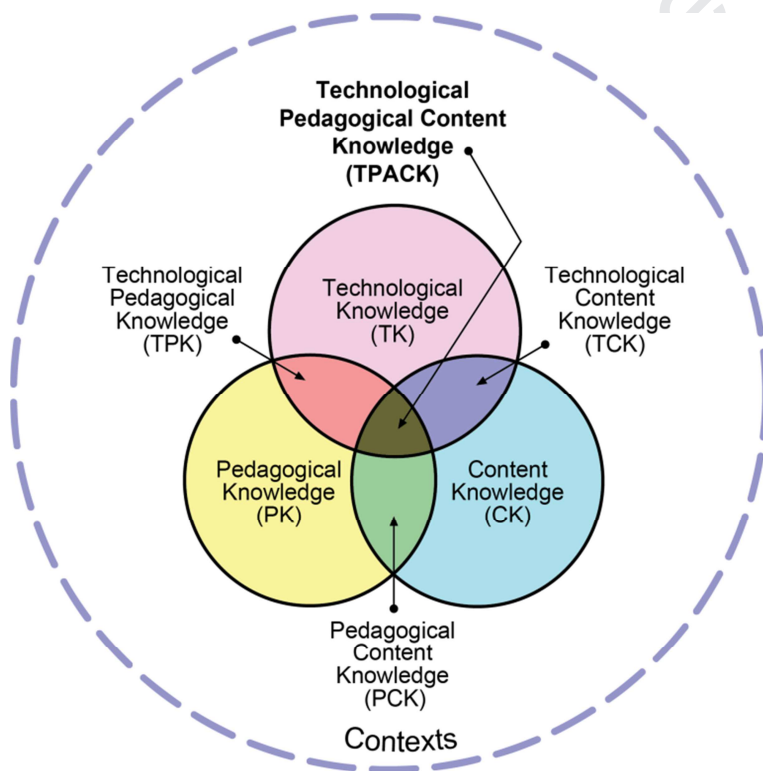
Figure 2: Technological Pedagogical Content Knowledge (TPACK) framework. Reproduced with permission of the publisher, © 2012 by tpack.org

The TPACK framework has had a substantial influence on research investigating the effective use of educational technology, particularly in relation to teacher education and teacher

professional development. A recent paper at a major teacher education conference reported that the TPACK framework has been used in over 3200 publications across a diverse range of educational contexts and content areas (Kessler & Phillips, 2019). A number of studies have examined the TPACK of pre-service teachers to inform the design of initial teacher education programs (Agyei & Keengwe, 2014; Deng, Chai, So, Qian, & Chen, 2017; Finger et al., 2013a; Mouza, Yang, Pan, Ozden, & Pollock, 2017; Tondeur, Scherer, Siddiq, & Baran, 2017; Valtonen et al., 2017) and to identify teacher professional learning needs and evaluate the efficacy of in-service teacher education (Brinkley-Etzkorn, 2018; Chung-Yuan, Meng-Jung, Yu-Hsuan, & Liang, 2017; Gill & Dalgarno, 2017; Heitink, Voogt, Fisser, Verplanken, & van Braak, 2017; Jääskelä, Häkkinen, & Rasku-Puttonen, 2017; Liang, Chai, Koh, Yang, & Tsai, 2013; Rienties, Brouwer, & Lygo-Baker, 2013; Stoilescu, 2015). Other researchers have used the framework in identifying profiles of teachers with different skills and orientations, investigating relative strengths and weaknesses of teachers in relation to different aspects of TPACK and investigating differences between groups of teachers in relation to demographic qualities such as age, gender and length of service (Alrwaished, Alkandari, & Alhashem, 2017; Handal, Campbell, Cavanagh, Petocz, & Kelly, 2013; Jaikaran-Doe, 2016; Roig-Vila, Mengual-Andres, & Quinto-Medrano, 2015; Tondeur et al., 2017). Researchers have also critically examined and evaluated the TPACK framework itself to understand its strengths and weaknesses and its application in understanding the knowledge and skills needed by teachers to use technology effectively in education (Cavanagh & Koehler, 2013; Deng et al., 2017; Jamieson-Proctor et al., 2013; Koehler et al., 2012; Koh & Chai, 2016; Liang et al., 2013; Stoilescu, 2015; Valtonen et al., 2017).

1.2 Understanding and describing teacher knowledge

Graham (2011) argues that an effective theoretical model has 'prescriptive value' because it describes the phenomenon but also has the ability to describe how the phenomenon develops and what interventions can predictably influence its development. In the case of a theory of knowledge such as TPACK, a description of 'how the phenomenon develops' can take the form of a description of *increasing proficiency*. Useful descriptions of increasing proficiency in a domain of knowledge go beyond generic statements such as 'beginning' and 'advanced' to be "descriptions of the successively more sophisticated ways of thinking about a topic that can follow one another" (National Research Council, 2007, p. 219). These descriptions are useful in a number of ways. Researchers develop and interrogate detailed descriptions of increasing proficiency in investigating constructs, gathering and interpreting evidence and analyzing and monitoring effects and interventions (Archambault & Barnett, 2010; Graham, 2011). Teachers use detailed understanding of increasing proficiency in a domain of knowledge in order to understand where learners are in their learning and the most relevant next steps for teaching and learning (Alonzo, 2018; Black & Wiliam, 1998, 2009; Masters, 2013; Shulman, 1987).

TPACK, like the PCK framework on which it is based, is an attempt to describe one of the things that makes teachers expert: "a form of knowledge that expert teachers bring to play anytime they teach" (Mishra & Koehler, 2006, p. 1030). While significant efforts have been made to describe, investigate, analyze and critique the components of TPACK (Angeli & Valanides, 2009; Archambault & Crippen, 2009; Archambault & Barnett, 2010; Cox, 2008; Koehler et al., 2012; Scherer et al., 2017) there has been less attention given to developing detailed understanding of increasing proficiency in the construct as a whole or in relation to the construct components (Cavanagh & Koehler, 2013; Authors, 2019; Yeh, Lin, Hsu, Wu, &

Hwang, 2015) and so we lack "richly developed portrayals of expertise" (Shulman, 1987, p. 1) in TPACK as a general case and in specific teaching contexts.

1.3 Purpose

The purpose of this study was to contribute to efforts to improve the utility of the TPACK construct for research and teacher education by exploring the question: *what does it mean to have more or less TPACK?* The study addresses the question by describing how a partial credit Rasch analysis of data from a TPACK survey tool can be used to construct a quantitative and qualitative description of increasing TPACK proficiency and how that description can be used to inform further research into effective use of technology in education and teacher education programs.

2. Method

This paper builds on and extends the work described and piloted in Authors (2019). That study used a partial credit Rasch analysis of data collected for a study of the TPACK of 152 practicing Australian teachers to construct measurement scales and person-item maps for two related constructs (TPACK Confidence and TPACK Usefulness) and describes a process for building a qualitative description of increasing proficiency in those constructs in the form of a construct map (Wilson, 2003; Wilson, 2004). The current study uses those person-item maps as the basis for the development of two construct maps describing increasing proficiency in one aspect of TPACK Confidence and TPACK Usefulness.

As background and for convenience, the following summarizes the method reported in Authors (2019). Data was collected using a modified version of the TTF TPACK Survey (Finger et al., 2013; Jamieson-Proctor et al., 2013). The TTF TPACK Survey was originally developed for a large scale study of initial teacher education students in Australian universities (Finger et al., 2013; Jamieson-Proctor et al., 2013). The survey comprises four scales: TPACK Confidence (teacher confidence to use ICT to support student learning), TPACK Usefulness (teacher perceptions of usefulness of ICT to support student learning), TCK/TPK Confidence and TCK/TPK Usefulness. As the research question was focused on collecting evidence of teachers' TPACK, the modified version in the study included only the first two scales (see Appendix).

A partial credit Rasch analysis was performed on the data. The partial credit Rasch model (Masters, 1982; Wright & Masters, 1982), an extension of the dichotomous Rasch model (Rasch, 1980), was chosen as it is appropriate for use when items have polytomous categories, as was the case of the TPACK survey under analysis. Rasch analysis allows for the construction of a scale which satisfies the requirements of objective measurement. It allows for the ability of a person and the difficulty of an item to be measured independently, enabling the estimation of the extent to which a person possesses an ability and the comparison of the ability of a person with the difficulty of an item. A person's ability can therefore be described in relation to the probability of them being able to successfully complete an easier or more difficult item.

Authors (2019) used the Rasch analysis to construct person-item maps for each scale. Person-item maps show the population on the left side of the scale, with each X representing one respondent, arranged along the latent variable scale according to their 'ability', in this case the ease with which they agree with the survey statements. Respondents with higher TPACK Confidence or TPACK Usefulness are shown higher on the scale. Parameters for each item are

arranged on the right side of the scale, showing the difficulty of each item parameter. These item parameters are item category boundaries, the points on the scale at which the probability of being in one category and the next is equal. In the analysis, for each item, the three item category boundary parameters represent the boundaries of the four analyzed categories. For each item, the difficulty of the boundaries are marked as .01, .12 and .23. So for example, q1.01 is the boundary between Less than Moderately Confident and Moderately Confident for question 1. This implies that respondents whose ability is between two item category boundary parameters are most likely to be in that category, so for example, respondents with an ability score between q1.01 and q1.12 are most likely to be moderately confident about item 1.

The current study uses the person-item maps constructed by Authors (2019) as the basis for the development of a qualitative description of increasing proficiency in TPACK Confidence and TPACK Usefulness in the form of construct maps (Cavanagh & Koehler, 2013; Wilson, 2003; Wilson, 2004). As an initial step towards a more comprehensive map of the constructs, a review of the 23 items in the survey identified a group of eight items roughly corresponding to an aspect of TPACK described by Koehler and Mishra (2009) as "pedagogical techniques that use technologies in constructive ways to teach content". The person-item maps for TPACK Confidence and TPACK Usefulness were divided into five bands of equal but arbitrary length. Observations were made of the hierarchical difficulties of the item parameter boundaries of the eight selected items to construct a qualitative description of increasing proficiency for each scale based on the item stems (Nakano & Primi, 2014).

3. Reviewing the person-item maps

The person-item map constructed for TPACK Confidence (Figure 3), first reported in Authors (2019), shows that the abilities of the majority of the respondents are located on the scale between the first and third item category boundaries of most of the items, although relatively few above the third item category boundary. In other words, the majority of respondents were able to agree they were moderately to more than moderately confident for most items but only a relatively small group were able to agree that they were extremely confident for most items. Very few respondents agreed that they were less than moderately confident for the items. Another observation is that while most if not all of the items were fairly easy to agree with at least moderately, there were differences in the location of the item category boundary parameters for the different items and the size of the gaps between the item category boundary parameters, providing an opportunity to analyze and interpret meaning of the scale in a qualitative sense.
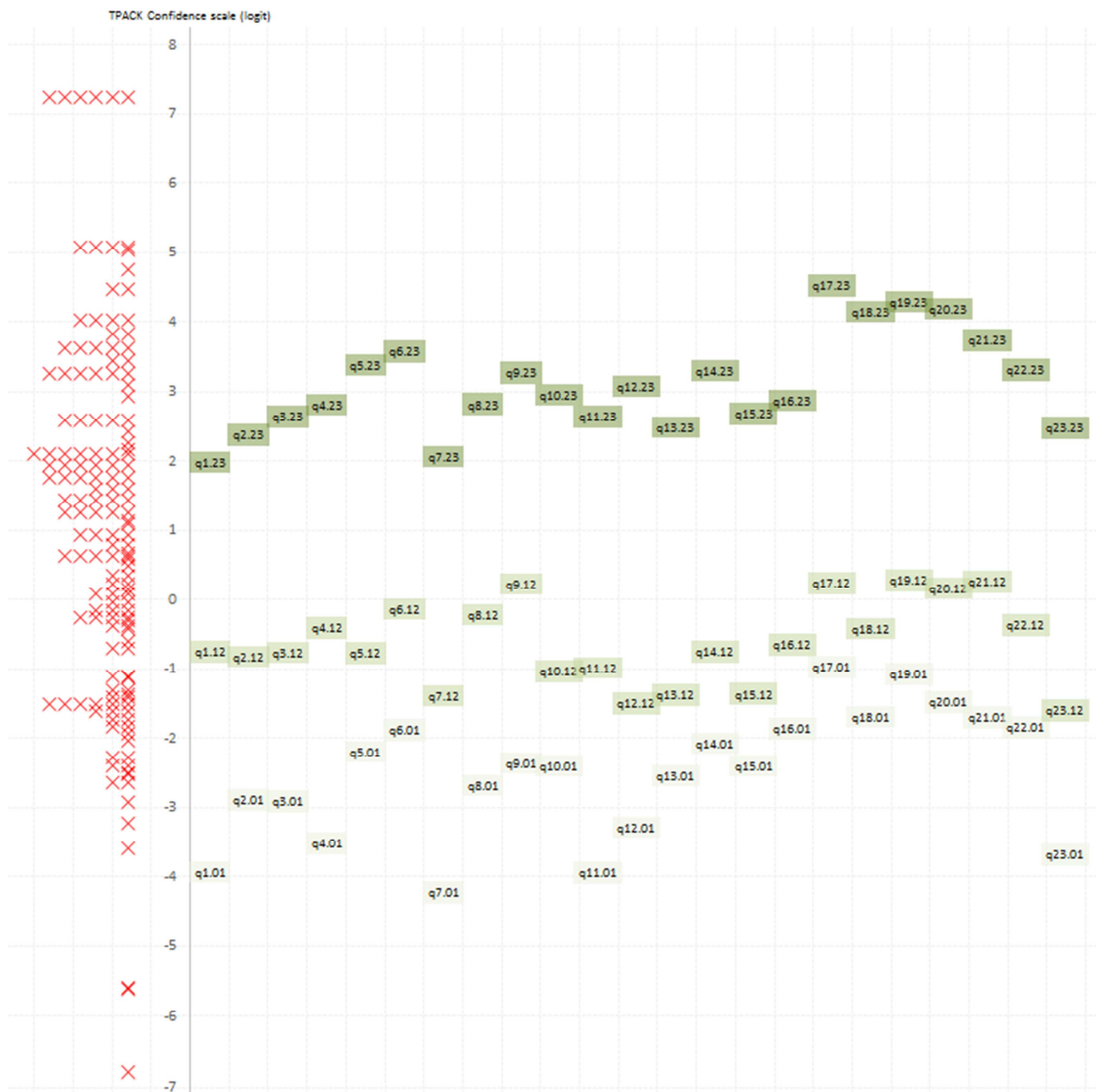
Figure 3: TPACK Confidence Person-Item Map

The person-item map constructed for TPACK Usefulness (Figure 4) shows that the abilities of the majority of respondents are located on the scale between the first and third item category boundaries of most of the items and a sizeable proportion above the third item category boundary for many of the items. In other words, the great majority of respondents believed that most items were moderately to more than moderately useful for their students and many believed that most items were extremely useful for their students. Very few respondents believed that items were less than moderately useful for their students.

As with the TPACK Confidence person-item map, the TPACK Usefulness map showed while most of the items were fairly easy to agree with, there were not only differences in the location of the item category boundary parameters for the different items but also the size of the gaps between the item category boundary parameters, providing an opportunity to analyze and interpret meaning of the scale in a qualitative sense.
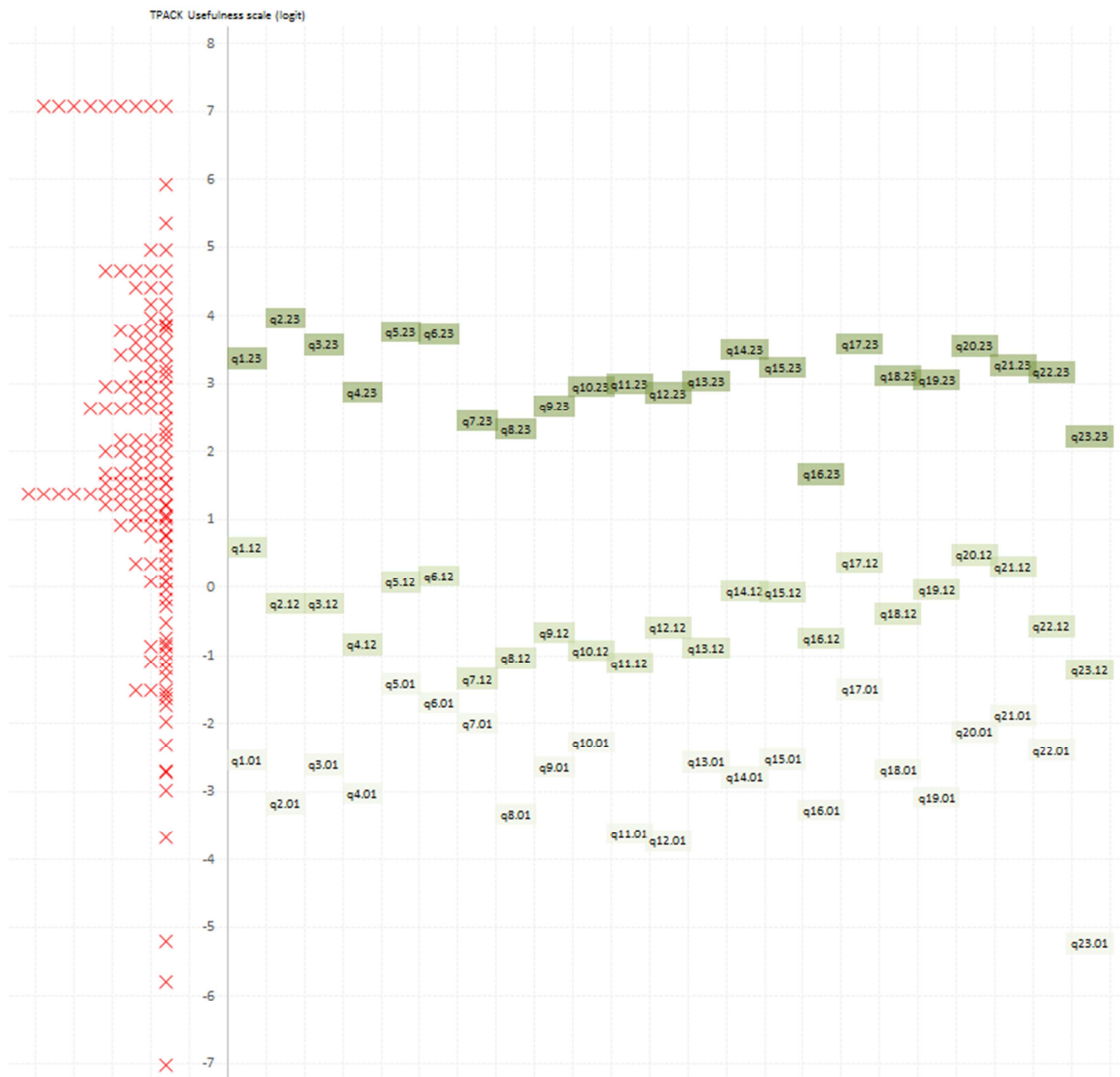
Figure 4: TPACK Usefulness Person-Item Map

4. Developing the construct maps

The development of a construct map uses the locations of the ability estimates of respondents and the difficulty estimates of items along the scale of the constructed person-item maps of the latent variable generated from the partial credit Rasch analysis to develop a qualitative description of what it means to be more or less proficient in a particular construct (Cavanagh & Koehler, 2013; Wilson, 2003; Wilson, 2004). Wilson identifies three types of construct maps: a respondent construct map, which describes qualitatively different groups of respondents; an item construct map, which describes qualitatively different groups of items; and, a item-response construct map, which describes both (Wilson, 2004). In the case of the present study, an analysis of "the hierarchical difficulty of the items - the meaning of low, average or high scores with regards to ability that accumulates" (Nakano & Primi, 2014, p. 2) was used to describe increasing proficiency in TPACK.

As an initial step towards developing a fuller description of the TPACK construct, a subset of the survey items were identified for analysis. Specifically, eight items of the 23 items in the survey were identified as corresponding to an aspect of TPACK described by Koehler and Mishra (2009) as "pedagogical techniques that use technologies in constructive ways to teach content" (henceforth abbreviated to 'teaching content'). They were:

● actively construct knowledge that integrates curriculum areas (item 3)
● actively construct their own knowledge in collaboration with their peers and others (item 4)
● analyze their knowledge (item 5)
● synthesize their knowledge (item 6)
● develop deep understanding about a topic of interest relevant to the curriculum area/s being studied (item 10)
● plan and/or manage curriculum projects (item 13)
● engage in sustained involvement with curriculum activities (item 14)
● facilitate the integration of curriculum areas to construct multidisciplinary knowledge (item 21)

One approach to developing a qualitative description of the scale of a latent variable is to divide the scale into 'bands' of equal length and describe each band in terms of the item parameters that fall within it. For the present study, the TPACK Confidence and TPACK Usefulness scales were each divided into interval bands each of two logits in length starting at -2.0 logits. (A logit is the unit of measurement used in Rasch analysis. A logit is an interval length along the scale.) Figures 5 and 6 show the two scales divided into five bands, the locations of the item category boundary parameters for the eight selected items and the percentage of respondents who fell within that band.
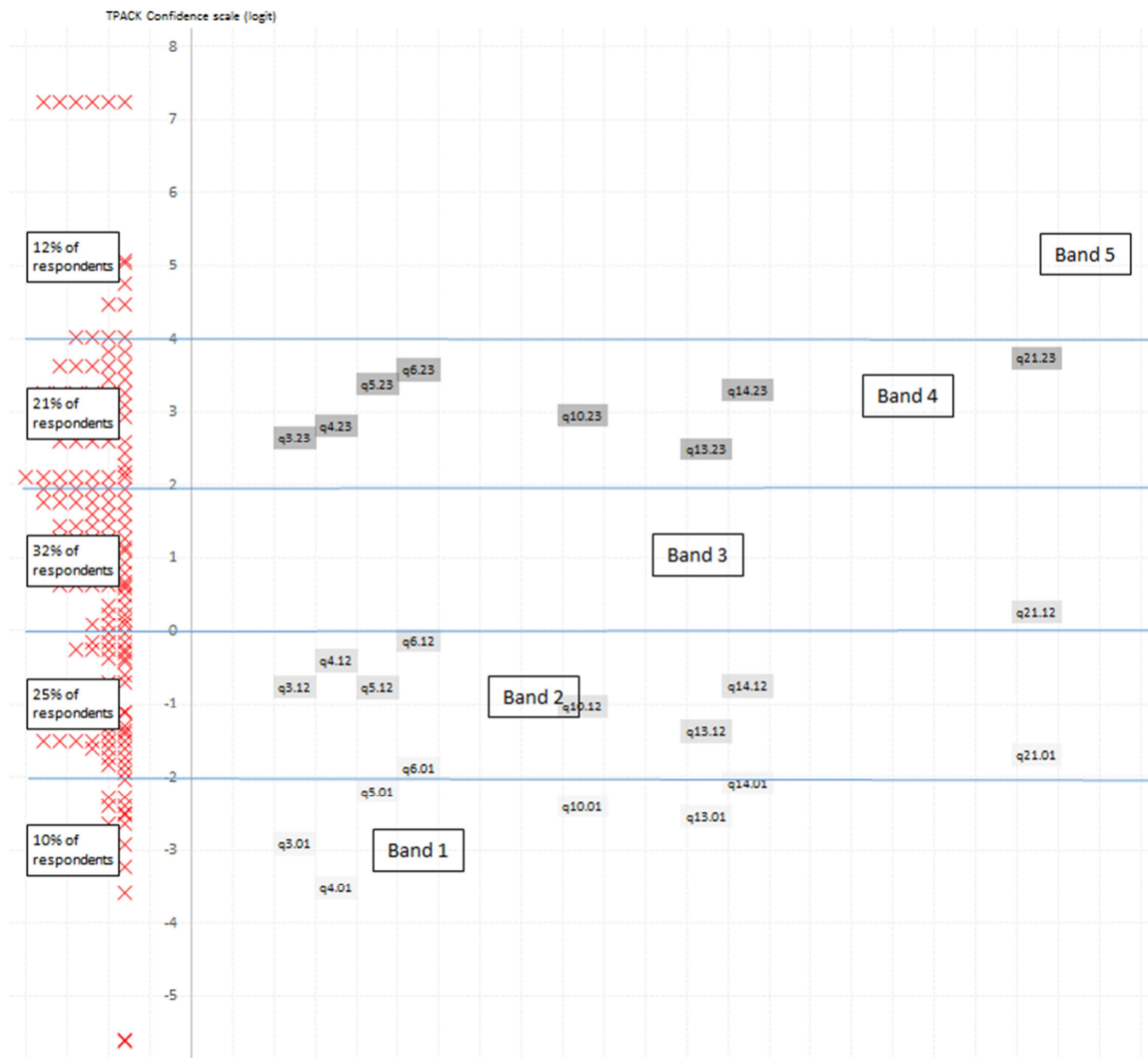
Figure 5: TPACK Confidence scale bands with 'teaching content' items
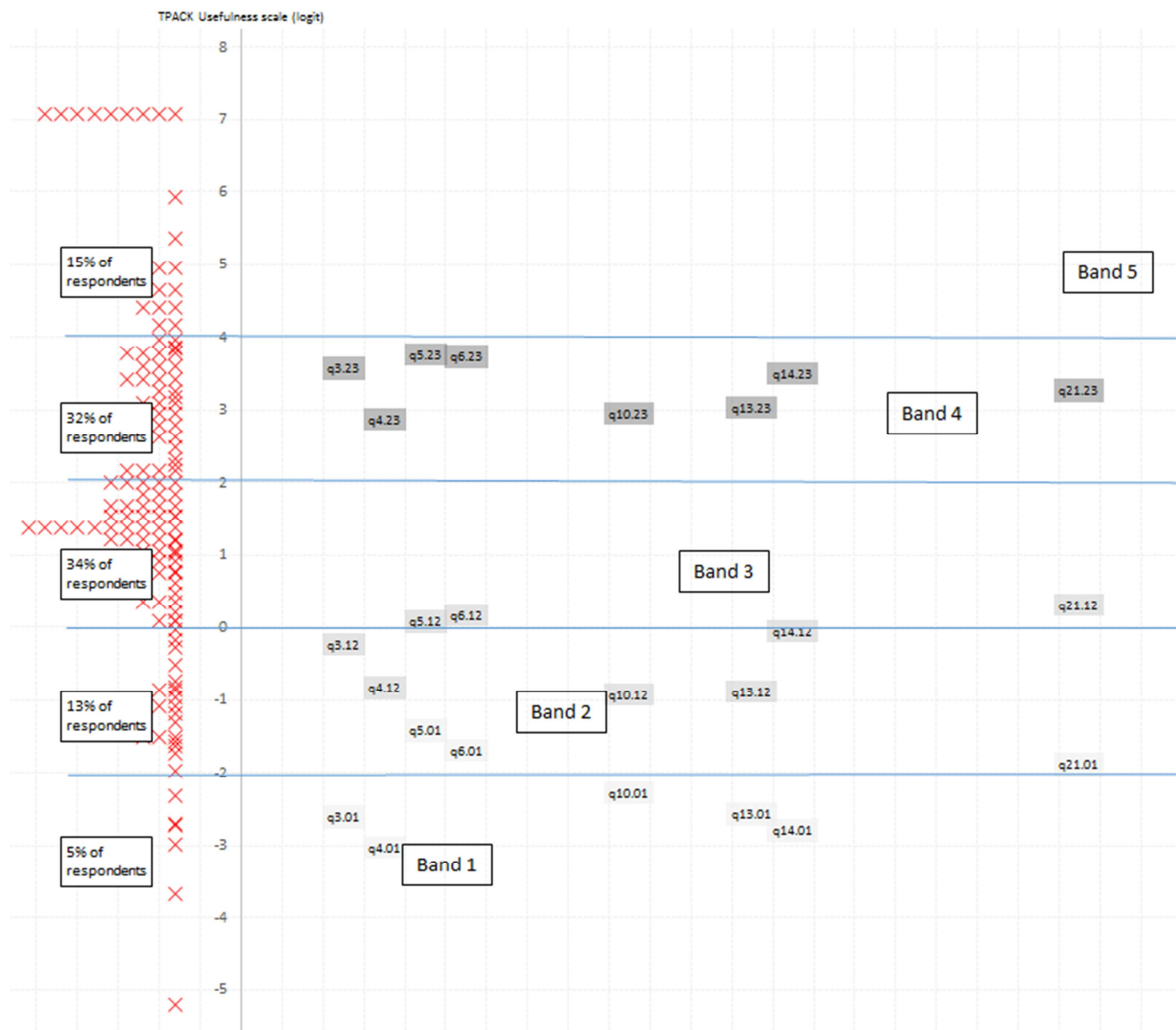
Figure 6: TPACK Usefulness scale bands with 'teaching content' items

A description of each band based on the position of the item category boundary parameters was used to develop a construct map for each scale (figures 7 and 8). For each item, where all or almost all of the respondents in a band fell between two item category boundary parameters, the band was described in terms of the region between those boundaries. Where an item category boundary parameter was located half way through the band (i.e. one logit from the top or bottom of the band), that item was described as changing from one region to another, so, for example, "beginning to be extremely confident". To improve the readability of the qualitative descriptions, the descriptions of the regions between the item category boundary parameters were simplified as follows:

- above item category boundary .23: Extremely confident/useful
- between item category boundaries .12 and .23: Very confident/useful
- between item category boundaries .01 and .12: Moderately confident/useful
- below item category boundary .01: Less confident/useful

| TPACK Confidence	Band	Description
↑	Teachers in **Band 5** are typically… 12% of respondents	… **extremely confident** that they have the knowledge, skills and abilities to support students' use of ICT to actively construct knowledge that integrates curriculum areas, actively construct their own knowledge in collaboration with their peers and others, analyze their knowledge, synthesize their knowledge, develop deep understanding about a topic of interest relevant to the curriculum area/s being studied, plan and/or manage curriculum projects, engage in sustained involvement with curriculum activities and facilitate the integration of curriculum areas to construct multidisciplinary knowledge.
	Teachers in **Band 4** are typically… 21% of respondents	… **beginning to be extremely confident** that they have the knowledge, skills and abilities to support students' use of ICT to actively construct knowledge that integrates curriculum areas, actively construct their own knowledge in collaboration with their peers and others, develop deep understanding about a topic of interest relevant to the curriculum area/s being studied and plan and/or manage curriculum projects and **very confident** that they have the knowledge, skills and abilities to support students' use of ICT to analyze their knowledge, synthesize their knowledge, engage in sustained involvement with curriculum activities and facilitate the integration of curriculum areas to construct multidisciplinary knowledge.
	Teachers in **Band 3** are typically… 32% of respondents	… **very confident** that they have the knowledge, skills and abilities to support students' use of ICT to actively construct knowledge that integrates curriculum areas, actively construct their own knowledge in collaboration with their peers and others, analyze their knowledge, synthesize their knowledge, develop deep understanding about a topic of interest relevant to the curriculum area/s being studied, plan and/or manage curriculum projects, engage in sustained involvement with curriculum activities and facilitate the integration of curriculum areas to construct multidisciplinary knowledge.
	Teachers in **Band 2** are typically… 25% of respondents	… **beginning to be very confident** that they have the knowledge, skills and abilities support students' use of ICT to develop deep understanding about a topic of interest relevant to the curriculum area/s being studied and plan and/or manage curriculum projects and **moderately confident** that they have the knowledge, skills and abilities to support students' use of ICT to actively construct knowledge that integrates curriculum areas, actively construct their own knowledge in collaboration with their peers and others, analyze their knowledge, synthesize their knowledge, engage in sustained involvement with curriculum activities and facilitate the integration of curriculum areas to construct multidisciplinary knowledge.
↑	Teachers in **Band 1** are typically… 10% of respondents	… **moderately confident** that they have the knowledge, skills and abilities to support students' use of ICT to actively construct their own knowledge in collaboration with their peers and others, **beginning to be moderately confident** that they have the knowledge, skills and abilities to support students' use of ICT to actively construct knowledge that integrates curriculum areas and **less confident** they have the knowledge, skills and abilities to support students' use of ICT to analyze their knowledge, synthesize their knowledge, develop deep understanding about a topic of interest relevant to the curriculum area/s being studied, plan and/or manage curriculum projects, engage in sustained involvement with curriculum activities and facilitate the integration of curriculum areas to construct multidisciplinary knowledge.

Figure 7: TPACK Confidence Construct Map: Teaching Content

TPACK	Band	Description

Usefulness		
↑	Teachers in **Band 5** typically … 15% of respondents	… think it is **extremely useful** that they ensure their students use ICT to actively construct knowledge that integrates curriculum areas, actively construct their own knowledge in collaboration with their peers and others, analyze their knowledge, synthesize their knowledge, develop deep understanding about a topic of interest relevant to the curriculum area/s being studied, plan and/or manage curriculum projects, engage in sustained involvement with curriculum activities and facilitate the integration of curriculum areas to construct multidisciplinary knowledge.
	Teachers in **Band 4** typically … 32% of respondents	… are **beginning to think it is extremely useful** that they ensure their students use ICT to actively construct their own knowledge in collaboration with their peers and others, develop deep understanding about a topic of interest relevant to the curriculum area/s being studied, plan and/or manage curriculum projects and facilitate the integration of curriculum areas to construct multidisciplinary knowledge and think it is **very useful** that they ensure their students use ICT to actively construct knowledge that integrates curriculum areas, analyze their knowledge, synthesize their knowledge and engage in sustained involvement with curriculum activities.
	Teachers in **Band 3** typically… 34% of respondents	… think it is **very useful** that they ensure their students use ICT to actively construct knowledge that integrates curriculum areas, actively construct their own knowledge in collaboration with their peers and others, analyze their knowledge, synthesize their knowledge, develop deep understanding about a topic of interest relevant to the curriculum area/s being studied, plan and/or manage curriculum projects, engage in sustained involvement with curriculum activities and facilitate the integration of curriculum areas to construct multidisciplinary knowledge.
	Teachers in **Band 2** typically… 13% of respondents	… are **beginning to think it is very useful** that they ensure their students use ICT to actively construct their own knowledge in collaboration with their peers and others, develop deep understanding about a topic of interest relevant to the curriculum area/s being studied, plan and/or manage curriculum projects and think it is **moderately useful** that they ensure their students use ICT to actively construct knowledge that integrates curriculum areas, analyze their knowledge, synthesize their knowledge, engage in sustained involvement with curriculum activities and facilitate the integration of curriculum areas to construct multidisciplinary knowledge.
	Teachers in **Band 1** typically… 5% of respondents	… think it is **moderately useful** that they ensure their students use ICT to actively construct their own knowledge in collaboration with their peers and others and are **beginning to think it is moderately useful** that they ensure their students use ICT to actively construct knowledge that integrates curriculum areas, plan and/or manage curriculum projects and engage in sustained involvement with curriculum activities and think it is **less useful** that they ensure their students use ICT to analyze their knowledge, synthesize their knowledge, develop deep understanding about a topic of interest relevant to the curriculum area/s being studied and facilitate the integration of curriculum areas to construct multidisciplinary knowledge.

Figure 8: TPACK Usefulness Construct Map: Teaching Content

5. Discussion

The construct maps developed in this study provide qualitative descriptions, based on quantitative analysis of empirical data collected from the survey tool, of what it means to have more or less proficiency in TPACK Confidence and TPACK Usefulness. At a high level, reading the TPACK Confidence: Teaching Content construct map from bottom to top (that is, from lower to higher proficiency) provides a broad sense of how the phenomenon develops (Graham, 2011). Reading the construct map in this way brings to the fore the development of teachers' confidence to use technology to support and facilitate deeper thinking and learning in and across curriculum areas. Teachers at the lowest level of proficiency (Band 1) are somewhat confident that they have the skills to support students to use technology to work collaboratively with other students and research knowledge but they lack confidence in their skills to support and facilitate the use of technology to sustain engagement with the curriculum area and develop deeper understandings. Teachers in the middle range of proficiency (Band 3) are very confident in their skills to support students in a broad range of ways when teaching content but one thing that distinguishes them from the more confident teachers in Band 4 is that those teachers are more confident in their skills to support students to use technology to develop deep understanding of the curriculum area. Similarly, reading the TPACK Usefulness: Teaching Content construct map from bottom to top tells a story of increasing belief in the usefulness of technology to facilitate deep thinking and learning alongside the understanding of technology's instrumental and practical value for teaching content. Teachers in the lowest proficiency band in TPACK Usefulness (Band 1) typically see the value of technology mainly in how it facilitates students working together, planning and managing work and sustaining engagement. Teachers in the middle range of proficiency (Band 3) have a relatively broad and balanced view of the value of technology for student learning, while one aspect of what distinguishes those teachers from the teachers in Band 4 is a stronger belief in the value of technology to facilitate students to develop deep understanding and construct multidisciplinary knowledge.

As well as describing what distinguishes respondents with lower and higher proficiency in TPACK Confidence and TPACK Usefulness, the construct maps describe an inferred typical order of acquisition of aspects of the construct as respondents move from low to high proficiency and so provide a prescriptive view of the construct as it develops, which could inform and suggest future research (Graham 2011; Archambault & Barnett 2010). For example, the maps could be used to help develop and test hypotheses about how teachers' TPACK Confidence or TPACK Usefulness develops or is best developed and reflect on, interpret and develop the theoretical framing of the construct in a fine-grained way. Researchers could also use the maps to refine and improve evidence gathering, ensuring their tools or processes provide appropriate opportunities to identify differences between respondents and to measure changes in respondents' proficiency pre- and post-intervention. For example, one difference between teachers in Band 4 and Band 5 of the TPACK Usefulness map is the extent to which teachers believe that it is useful for students to use ICT to analyze and synthesize their knowledge. Researchers looking to investigate differences in teachers' TPACK Usefulness at the top level of proficiency should consider how to gather evidence of their subjects' beliefs in these aspects of TPACK.

The construct maps can also have an immediate application in teacher education, supporting teacher educators to better understand where teacher education students are in the development of TPACK Confidence and TPACK Usefulness and identifying next steps for action. For example, a teacher educator working with a student teacher whose TPACK Usefulness is in

Band 3 can see that the student teacher will need to develop a stronger understanding of the value to students of using technology to develop deep understandings of the topic and construct interdisciplinary knowledge, amongst other things in order to increase her TPACK Usefulness to Band 4. More generally, the development of the teacher education curriculum is informed by understanding that the majority of teacher education students enter the program at a particular level in relation to TPACK Confidence and TPACK Usefulness (and some at different levels) and that the program has the goal of ensuring students reach a higher level (some agreed standard) on completion.

5.1 Limitations

There are a number of limitations of the study which suggest that care should be taken not to overgeneralize the results without further substantiating evidence. In particular, data used in the analysis was self-report data collected using the TTF TPACK Survey tool, which takes a particular approach to measuring the TPACK construct, focusing on teachers' confidence in their capacity to use digital technology to support learning and perceptions of usefulness of digital technology to students. Further research to collect evidence of teachers' TPACK using other techniques and instruments, including direct observation, would provide opportunities to broaden the construct maps and contribute to their validation. Also, while the TPACK construct is conceived of as highly contextualized (for example, to specific teaching and learning contexts), the data analyzed was aggregated from teachers working in a wide range of contexts. Further research that examined the learning context specific TPACK of teachers could contribute to the development of context specific construct maps.

6. Conclusions

The TPACK framework has proven to be a popular and useful framework for researchers to investigate what expert teachers understand about effective integration of technology in learning and to evaluate and inform initial teacher education and teacher continuous professional learning. However, despite significant efforts to describe, investigate and critique the construct, there has been relatively little research into developing more detailed understandings of increasing proficiency in TPACK or TPACK components. In an attempt to contribute to efforts to improve the clarity and efficacy of the framework, in particular to add to the prescriptive value of the framework, this paper has described how an analysis of data collected in a survey of practicing teachers' TPACK was used to develop empirically based construct maps describing what it means to have more or less TPACK Confidence and TPACK Usefulness. These maps will assist researchers with developing and testing hypotheses about these aspects of teachers' TPACK and support them to develop more targeted and coherent measurement tools, the evidence from which can, in turn, support further efforts to clarify and develop the construct (Graham 2011; Archambault & Barnett 2010). The detailed descriptions can also help teacher educators better understand where student teachers are in their development of TPACK Confidence and TPACK Usefulness and what is needed for them to develop higher levels of confidence and perception of usefulness.

The construct maps developed in this study are a preliminary effort to more fully describe what it means to have more or less TPACK. Further research and analysis of evidence of teachers' TPACK, including in specific settings and using tools which measure different aspects

and components of the TPACK framework and which corroborate the self-report data with direct observation and other measurement techniques, could be used to expand, refine and validate the construct maps and develop new and context specific construct maps of TPACK and each of the seven TPACK components (Cavanagh & Koehler, 2013), providing researchers further opportunities to reflect on and interrogate the construct, including by comparing and contrasting what increasing TPACK proficiency typically looks like in specific teaching and learning contexts.

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Appendix: Survey items

Adapted with permission from TTF TPACK Survey tool (Jamieson-Proctor et al., 2013)

Confidence: How confident are you that you have the knowledge, skills and abilities to support students' use of ICT to…

Usefulness: How useful do you consider it will be for you, as a teacher, to ensure your students use ICT to…

1. provide motivation for curriculum tasks
2. develop functional competencies in a specified curriculum area
3. actively construct knowledge that integrates curriculum areas *
4. actively construct their own knowledge in collaboration with their peers and others *
5. analyze their knowledge *
6. synthesize their knowledge *
7. demonstrate what they have learned
8. acquire the knowledge, skills, abilities and attitudes to deal with on-going technological change
9. integrate different media to create appropriate products
10. develop deep understanding about a topic of interest relevant to the curriculum area/s being studied *
11. support elements of the learning process
12. develop understanding of the world
13. plan and/or manage curriculum projects *
14. engage in sustained involvement with curriculum activities *
15. undertake formative and/or summative assessment
16. engage in independent learning through access to education at a time, place and pace of their own choosing
17. gain intercultural understanding
18. acquire awareness of the global implications of ICT-based technologies on society
19. understand and participate in the changing knowledge economy
20. critically evaluate their own and society's values
21. facilitate the integration of curriculum areas to construct multidisciplinary knowledge *
22. critically interpret and evaluate the worth of ICT-based content for specific subjects
23. gather information and communicate with a known audience

* selected for qualitative analysis as representing that aspect of TPACK described as "pedagogical techniques that use technologies in constructive ways to teach content" (Koehler & Mishra, 2009).

- Examines what it means for teachers to have more or less Technological Pedagogical Content Knowledge (TPACK).
- A partial credit Rasch analysis is conducted on evidence of practicing teachers' TPACK Confidence and TPACK Usefulness.
- Person-item maps are generated showing the relationship between respondent ability and item difficulty.
- Person-item maps are used to develop construct maps which qualitatively describe increasing proficiency in the constructs.

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