Editorial: Volume 33 Issue 3

TPCK/TPACK research and development: Past, present, and future directions

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Scholarship addressing technological pedagogical content knowledge (TPCK or TPACK) has examined how to develop, apply, and assess it in diverse educational settings and content areas. During the last 12 years, multiple ways to understand this knowledge and support its development have emerged, generating approximately 1,200 publications that utilise the construct, impacting the practice of postsecondary faculty, administrators, and others invested in meaningful educational uses of technology. Perhaps inevitably, TPACK's enthusiastic reception and rapid dissemination have generated multiple points of divergence, which in turn need further study; especially the construct's accurate measurement and validation; how to assist preservice and in-service teachers' TPACK development; contextual influences upon teachers' TPACK; and the relationship of TPACK-based knowledge to teachers' decision-making and action. Given the widespread diffusion of TPACK, research focusing on these and related issues will help to determine the direction of future post-secondary learning and teaching with technologies. Therefore, this special issue of AJET addresses future directions in TPCK/TPACK research and development.

Introduction

Building upon Shulman's (1986b; 1987a) ground-breaking conceptualisations of *pedagogical content knowledge*, or the knowledge needed to teach effectively (and differently) within different curriculum areas, educational technology researchers have embraced technological pedagogical content knowledge (Angeli & Valanides, 2005; Mishra & Koehler, 2006; Niess, 2005) during the last 12 years. *Technological pedagogical content knowledge*, abbreviated as TPCK or TPACK (Thompson & Mishra, 2007-2008), is the interdependent, situated knowledge that is needed to integrate the use of digital tools and resources effectively in curriculum-based teaching.

TPACK scholarship examines how teachers develop, apply, and assess this knowledge in diverse settings (e.g., K-12, post-secondary, and informal learning environments) and across multiple content areas. Recent explorations document a proliferation of ways to understand and support teachers' development of TPACK, resulting in approximately 1,200 publications that utilise the construct as a foundation (http://activitytypes.wm.edu/TPACKNewsletters/index.html). To date, TPACK research and development has impacted the practice of teachers, professional development providers, administrators, and other stakeholders invested in meaningful educational uses of technology.

This special issue of AJET addresses future directions in TPACK research and development, and is, we believe, the first TPACK-themed journal issue to do so. Its contributors represent the methodological, substantive, and geographical diversity of the TPACK community. Their papers focus on recent models, interpretations, and implementations of the construct; emerging and varied ways to measure TPACK;

innovative professional development approaches that help experienced teachers to build TPACK; new ways to depict and develop TPACK within preservice and in-service teacher education, and nascent work that connects teachers' pedagogical reasoning with their TPACK and its enactment.

We trust that the issue's contents will be of considerable interest to researchers and teacher educators who are exploring TPCK/TPACK for use in current and future educational technology research and development. But before we explore possible future trajectories for this work, we offer a brief summary of the construct's past.

PCK and TPCK/TPACK: A brief history

Teachers' knowledge has been studied by educators for decades, producing many different ways of understanding, developing, and enacting what teachers know and do. Research about knowledge for effective teaching in the 1980's and 1990's described it from differing epistemological viewpoints, reflecting important shifts in our understanding of the specialised nature of teachers' knowledge and knowing. Readers of work from this period can find perspectives such as Tom and Valli's (1990) philosophically grounded review of professional knowledge; Grimmit and MacKinnon's (1992) analysis of craft-based conceptions of teaching; and Clandinin and Connelly's (1987) explorations of links between teachers' personal and professional knowledge. Shulman's extensive work (1984; 1986a; 1986b; 1987a; 1987b; 1989; 1992) sought to "show what forms and types of knowledge are required to teach competently" (Fenstermacher, 1994, p. 6). It is Shulman's notion of pedagogical content knowledge (PCK), however, that is most often cited in subsequent research.

Describing the origins of PCK, Nelson (1992) writes, "In his 1985 [American Educational Research Association] presidential address, Lee Shulman tossed off the phrase 'pedagogical content knowledge' and sparked a small cottage industry devoted to the scholarly elaboration of the construct" (p. 32). Fenstermarcher (1994) suggested that Nelson's "notion of 'tossed off' seemed a bit ungenerous, given the amount of scholarly development that went into the concept, [however] there is no doubt that the concept has spawned an extensive set of research studies" (p. 14), highlighting the impact of the PCK construct on understanding the nature of teachers' knowledge. A comparatively recent development in this scholarly lineage has interwoven teachers' technological knowledge with their pedagogical and content knowledge.

Given the increasing use of educational (specifically, digital) technologies in K-12 and higher education contexts in the early 2000's, researchers began to explore the technological aspects of pedagogical content knowledge that teachers need and use. Pierson (2001) was among the first, suggesting that the effectiveness of technology integration practices may be a function of pedagogical expertise. Building on the previous 17 years of PCK research, Pierson's investigation of experienced teachers who demonstrated exemplary pedagogical use of computers prompted her suggestion to add:

> [A]nother component to the [PCK] model, that of technological knowledge. This knowledge would include not only basic technology competency but also an understanding of the unique characteristics of particular types of technologies that would lend themselves to particular aspects of the teaching and learning processes. A teacher who effectively integrates technology would be able to draw on extensive content knowledge and pedagogical knowledge, in combination with technological knowledge. … The intersection of the three knowledge areas, or technological-pedagogical-content knowledge, would define effective technology integration. (p. 427)

The addition of technological knowledge to Shulman's knowledge base for teaching was also recommended by a number of other researchers in the early 2000s. For example, Niess (2005) and Angeli and Valanides (2005), while examining preservice teachers' knowledge for technology integration, suggested using the terms "technology PCK" (p. 510) and "ICT-related PCK" (p. 294), respectively, to describe somewhat similarly conceptualised constructs, although the methods recommended to develop this knowledge were quite different. All of these notions included descriptions of teachers' technological knowledge (TK), pedagogical knowledge (PK), content knowledge (CK), and the intersection of technological, pedagogical, and content knowledge (TPCK) that is necessary for effective technology integration. Angeli and Valanides' (2005) definition added contextual knowledge to TK, PK, CK, and TPCK, and Niess (2005) contributed the sub-constructs of technological pedagogical knowledge (TPK) and technological content knowledge

(TCK) to the nascent TPCK framework—which were introduced as P-T, or "pedagogical-technology knowledge" and C-T, or "content-technology knowledge" (p. 3) by Koehler, Mishra, and Yahya (2004) a year earlier. Of particular note, all TPCK conceptualisations mentioned here also included teachers' knowledge of students' content-based understanding, thinking, and learning patterns (albeit in different ways), which reflect other components from Shulman's knowledge base for teachers (e.g., 1986b), and also later work that built upon his notions of PCK (e.g., Cochran, DeRuiter, & King, 1993).

TPCK/TPACK measurement and validation

As described here, the development of the TPACK construct built upon Shulman's notions of PCK, enriching our understanding of the dynamic interplay among the different forms of knowledge that underpin teachers' praxis. The extensive corpus of research that grew along with, and from, the evolution of the TPCK/TPACK construct has also provided deeper understanding of how teacher knowledge is related to pedagogical integration of digital technologies in educational contexts, and this work in particular, is ongoing. TPCK/TPACK scholarship has introduced multiple knowledge development methods (Harris, 2016), numerous measurement tools (Cavanaugh & Koehler, 2013; Chai, Koh, & Tsai, 2016) and many empirical approaches (Archambault, 2016; Koehler, Shin, & Mishra, 2012) for examining and understanding teacher technology integration knowledge. In this issue, four articles explore emerging ways to measure, validate, typify, and interpret TPACK-based data generated by preservice teachers.

Deng, Chai, So, Qian, and Chen highlight that, despite the development of a sizable number of quantitative measures that attempt to assess teachers' TPACK, "few studies to date have comprehensively validated the structure of TPACK through various criteria of validity, especially for content-specific areas." In this article, the authors measure alignment amongst 280 preservice teachers' self-reported TPACK, lesson plans, and epistemological beliefs about chemistry. Their study's results establish convergent, discriminant, factorial, and predictive validity for the TPACK construct and its subcomponents, plus their relationships with the teachers' beliefs, and their TPACK as it was represented in lesson planning. These findings are unique and important in their verification of interrelationships among preservice teachers' TPACK-based knowledge, beliefs, and practices.

Valonten, Sointu, Kukkonen, Kontkanen, Lambert, and Makitalo-Siegl also examine the challenges presented by the psychometric properties of existing TPACK survey instruments, then share a new, validated questionnaire that focuses upon preservice teachers' self-reported TPACK and twenty-first century skills. In doing so, these authors, like Deng et al., model appropriate instrument testing for reliability and validity, while also raising important questions about the TPACK construct and its subcomponents as they are reflected in self-reported data. Valonten et al. suggest that such work can "outline the effects that the TPACK components have on one another, as well as identify the weak and strong areas that require special consideration in teacher education."

Poitras, Doleck, Huang, Li, and Lajoie illustrate one approach to how these areas can be explored in future research by showing how preservice teachers develop mental models of the pedagogical affordances of technologies. Using emerging data mining techniques, this article illustrates how trace log data collected by an intelligent web browser used by teachers can provide prolific opportunities to amass larger, performance-based data sets to facilitate complex longitudinal research. This work also demonstrates the potential power of sophisticated data analysis algorithms that can help researchers to generate deeper and more nuanced insights into teachers' TPACK-related thinking.

Tondeur, Scherer, Siddiq, and Baran illustrate another way to explore and describe teachers' TPCK/TPACK. Using correlational and latent profile analyses, these authors developed and examined profiles based upon data from 688 preservice teachers, comprising their TPACK; attitudes about ICT and its educational use, ease of use, and self-efficacy; and their perceptions of the quality of technology integration support provided by their teacher education programs. These profiles are suggested as a way to depict the teachers' "readiness to integrate technology in education." Initial findings suggest that "TPACK and other individual ICT-related characteristics are positively correlated;" that is, teachers "with strong TPACK, attitudes, and self-efficacy scores also report high scores on the support they perceive at their teacher training institutions." The strong correlations (whether high or low) among the different ICT and program-related attitudes, along with the teachers' TPACK, suggest a number of intriguing possibilities for future attitudinal research related to technology integration.

Pushing TPCK/TPACK's boundaries

For educational technology researchers, TPACK is perhaps a quintessential example of what Seymour Papert (1980) long ago termed a *powerful idea*. Papert suggested that some particularly useful "concepts … become tools to think with. They are powerful ideas that organise thinking and problem solving" (p. 132). Yet given its generativity, TPACK and the processes through which it is developed lack a coherent and universal understanding (Koehler, Mishra, Kereluik, Shin, & Graham, 2014). It is this lack of coherence, along with TPACK's proliferance, that has led researchers to tinker with each and all of the components underpinning the TPACK construct, its representations, and its use.

Some writers have proposed varieties of TPCK/TPACK that are differentiated according to particular types of digital tools, curriculum content, or pedagogical approaches used. For example, Lee and Tsai (2010) suggested *technological pedagogical content knowledge-web* (TPCK-W) in response to their concerns regarding over-generalisation to the many different types of technologies addressed in the TPACK framework. These authors recommended specifying web knowledge, which includes teachers' knowledge about general uses of the world wide web, specific web tools, and other, more advanced uses of the web, in a separate conceptualisation of TPCK.

Olofson, Swallow, and Neumann (2016) suggest a more pedagogical interpretation of the construct. Drawing on ideas from radical constructivism, they suggest *TPACKing* as a dynamic process of knowledge construction that comprises individual contextual considerations and pedagogical assumptions as key factors in the active and ongoing development of teachers' knowledge in the educational workplace. Their work forefronts the importance of constructivist pedagogy in particular as a core component in the ongoing development of teachers' TPACK.

A third example of TPACK's expansion is illustrated in the work of Mishra, Koehler, and Henrickson (2010), who saw the asserted neutrality of the TPACK framework as a concern with regard to the broader goals of twenty-first century education. These authors argued against the separation of curriculum-based content by traditional disciplines. They suggested that TPACK can play a role in the development of twenty-first century trans-disciplinary skills if educators consciously seek and explore unique and generative connections amongst and between previously separated bodies of knowledge.

The development of the TPACK construct "has significantly influenced theory, research, and practice in teacher education and teacher professional development" (Koehler et al., 2014, p. 101) during the past 12 years. Throughout this time, perceived inconsistencies within, and corresponding revisions to, the framework have been suggested and debated by the community of scholars who are interested in the knowledge underpinning teachers' technology integration practices. This questioning and discussion, we would argue, is essential to the continued development of a robust and useful theoretical construct.

For example, in this issue, Mouza, Yang, Pan, Ozden, and Pollock suggest a new way to conceptualise preservice teachers' TPCK/TPACK. Drawing on data from 21 adult students who participated in a 15-week course designed to examine effective technology integration in K-8 classrooms, the authors examined the nature of the teachers' developing computational thinking and dispositions, along with their technological, content and pedagogical knowledge. The findings from this descriptive study suggest that future TPACK conceptualisation and development may do well to include work with computational thinking, as this can help teachers and their students to "move from [being] consumers to creators of computing innovations" in the twenty-first century.

TPCK/TPACK and pedagogical reasoning

Another trend in current TPCK/TPACK research is more subtly stated. Several authors have begun to consider the ways in which teachers' technology integration knowledge connects to specific educational practices through explorations of pedagogical reasoning and action. This work returns to aspects of PCK research that have, to date, been somewhat under-theorised in TPACK scholarship, and, we would suggest, in PCK research, also.

During the past decade-plus, contributions to the knowledge base about teaching have focused increasingly on the interplay and interdependence among technological, pedagogical, and content knowledge in a variety

of teaching and learning contexts. Suggested additions to, and variations upon, this knowledge reflect Shulman's (1987a) assertion that "a knowledge base for teaching is not fixed and final" (p. 12). In addition to his notion of PCK and its role in the aetiology of the TPACK construct, we suggest drawing attention to another aspect of Shulman's framework. Together with PCK, Shulman (1987b) highlighted the importance of better understanding and valuing what he termed a *wisdom of practice*. Loughran, Keast, and Cooper (2016) suggest that this notion "offers a way of conceptualizing more fully that which Polanyi (1966) described as teachers' tacit knowledge" (p. 388) or, as Shulman (1987a) stated, teachers "know a great deal that they have never tried to articulate" (p. 12). In an attempt to unpack these unseen aspects of teachers' knowledge, Shulman (1987a) proposed a model of pedagogical reasoning, comprising a cycle of activities that include:

- comprehension: of purposes, subject matter structure, ideas within and outside the discipline;
- transformation: [which involves] preparation, representation, selection, and adaptation to students' characteristics;
- instruction: the activities associated with teaching;
- evaluation: checking student understanding, assessing learning, and evaluating, then adjusting one's own [teaching] performance; and
- reflection: reviewing, reconstructing and analysing in light of evidence of one's own and students' performance; leading to
- new comprehension: of purposes, subject matter, students, teaching and self; [plus] consolidation of new understandings and learning from [teaching] experience. (p. 15)

Although Shulman's (1987a) model can appear to be a linear sequence of interactive elements that lead from one phase to another, he emphasised that this model was not to be interpreted as such, saying:

> [A]lthough the processes in this model are presented in sequence, they are not meant to represent a set of fixed stages, phases or steps. Many of the processes can occur in a different order. Some may not occur at all in some acts of teaching. Some may be truncated, others elaborated. (p. 19)

Central to the model was that "teacher education should provide students with the understandings and performance abilities they will need to reason their ways through and to enact a complete act of pedagogy" (p. 19). Hence, the power and promise of pedagogical reasoning and action is the opportunity to unpack the complex and sophisticated nature of praxis.

Shulman's (1987a) model of pedagogical reasoning has also been used in investigations of teachers and their use of digital technologies. Webb (2002) for example, offered a comprehensive explanation of pedagogical reasoning in teaching with ICT in secondary schools, whilst more recently, Starkey (2010), Finger and Finger (2013), and Smart (2016) adapted Shulman's pedagogical reasoning and action framework to incorporate teachers' decision-making and enacting of their technological pedagogical knowledge.

In this special issue, two articles use TPACK and pedagogical reasoning to further explore teachers' knowledge and its enactment in technology-rich contexts. Niess and Gillow-Wiles examine the influence of a systems pedagogical approach to professional learning on teachers' developing technological pedagogical reasoning. In doing so, the authors suggest that mental models, or schema, provide richer conceptualisations of teachers' knowledge than what has characterised TPACK to date. They assert that through careful examination of the development of technological pedagogical reasoning, we are better able to understand and describe how teachers use their TPACK to make pedagogical decisions.

In a second article that references pedagogical reasoning, Heitink, Voogt, Fisser, Verplanken, and van Braak argue that "underlying teachers' practice is a professional reasoning process" and "teachers need to be aware of this reasoning to be able to tailor practical examples from other teachers to their own contexts." To facilitate this professional reasoning process, the authors demonstrate the value of using classroom-based video clips that focus upon teachers' authentic pedagogical use of digital technologies. The findings from this study point to the power of using bona fide examples of classroom-based technology integration, especially in helping preservice teachers to develop their TPK.

Perhaps more importantly, the inclusion of these two studies in this special issue suggest that future TPACK work may begin to focus more upon cycles of teachers' knowing and doing. We will explain our reasons for this prognostication in the next section.

The future of TPACK scholarship: Knowing and doing

The foci of the articles in this special issue suggest several directions in which TPCK/TPACK research and development efforts are already beginning to travel. Our reading of current TPACK scholarship suggests that work addressing TPACK measurement, validation, (e.g., in this issue: Deng et al.; Poitras, et al.; Valonten, et al.) and reification (e.g., Tondeur, et al.), will continue, while becoming increasingly diverse in focus and method, along with ongoing efforts to help preservice (e.g., in this issue: Mouza, et al.; Poitras, et al.) and inservice teachers (e.g., Heitink, et al.; Niess & Gillow-Wiles; Tondeur, et al.) to deepen, widen, and apply their developing TPACK in practice.

In addition, future TPACK work may begin to focus more upon cycles of teachers' knowing and doing, focusing TPACK scholarship increasingly upon representations of teachers' knowledge in action, and the reasoning processes that lead to specific technological pedagogical, and curriculum-based decisions and teaching acts within particular teaching and learning contexts. As Loughran, Keast, and Cooper (2016) assert, any model of teacher knowledge or knowing "serves as a framework for thinking about practice as comprising much more than just the act of 'doing teaching'" (p. 393). The TPCK/TPACK framework—certainly a powerful idea (Papert, 1980) for teacher educators and researchers—has helped us to understand some of what teachers know relative to educational uses of digital tools and resources, and several ways to help teachers to build that knowing. Now, we are beginning to use TPACK to help us to better understand the nature of those knowing, reasoning, decision-making, and teaching processes. We hope that the contributions in this special issue of AJET will assist in this present and future endeavour.

Acknowledgements

We are indebted to the 17 TPACK researchers who agreed to review manuscripts for this special issue, offering detailed, constructive feedback to the manuscripts' authors. We also thank AJET's Lead Editors Michael Henderson and Eva Heinrich, and copyeditor Kayleen Wood, for their suggestions and expertise.

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Please cite as: Harris, J., Phillips, M., Koehler, M. & Rosenberg, J. (2017). TPCK/TPACK research and development: Past, present, and future directions. *Australasian Journal of Educational Technology, 33*(3), i-viii. https://doi.org/10.14742/ajet.3907