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Title: A holistic approach to TPACK for Indigenous students in mathematics and science classrooms

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Abstract
The Australian Government has funded the Teaching Teachers for the Future (TTF) project to increase pre-service teachers' capacity to embed ICT in their teaching practice (Education Services Australia, 2011). The planning model promoted by the TTF project details three overlapping knowledge domains: technological knowledge, pedagogical knowledge and content knowledge. The intersection of these domains is referred to as technological pedagogical content knowledge (TPACK). TPACK is promoted as a model for teachers to use when they plan to integrate technology into mathematics and science curriculum for all students. This paper argues that when planning with the TPACK model, the teacher also needs to explicitly acknowledge the attributes and resources of Indigenous students. This feature of teaching design and implementation needs to be further developed in pre-service education and teacher professional development. It is imperative for educators to acknowledge and value the attributes and cultural dimensions Indigenous students bring to the classroom: their lived languages, experiences and knowledge for the purpose of their learning. Here, the term 'culture' is used to refer to an individual's habit of mind; the development of a whole society; or the whole way of life of a group of people (Rojek, 2007). The paper positions Indigenous students as agentic in both negotiating their mathematical and scientific learning dispositions, and using technological models and simulations. A key purpose of the paper is to highlight the socially negotiated and embedded nature of meaning-making, how one's culture influences how an individual or a group can make primary sense of their world. It thus proposes a more holistic approach to TPACK for Indigenous students in mathematics and science classrooms.

TPACK; Indigenous students; cultural dimensions; mathematics and science

Introduction
The Australian Government, through the Information Communication Technology (ICT) Innovation Fund, is targeting projects to increase the ICT capability and innovation of Australian teachers (Australian Government Department of Education, Employment and Workplace Relations (DEEWR), 2011). One of the projects, Teaching Teachers for the Future (TTF), focuses on the transformation of pre-service teacher education (Education Services Australia (ESA), 2011). The TTF project involves all Australian teacher education institutions and includes development of exemplars in the form of TTF TPACK professional learning packages (ESA, 2011). These exemplars are accessible from The Learning Federation website (econtent.thelearningfederation.edu.au) and align with the Australian Curriculum learning areas Science, Mathematics, English and History.

The authors' interest and involvement with the TTF project stems from our responsibilities at a regional university to coordinate science and mathematics education subjects for pre-service teachers. We are collectively responsible for strategies to integrate the TTF materials and associated technology integrations messages into these subjects. A variety of approaches are being trialled to embed both the materials and messages, for example, demonstrations of how to access and use the TTF exemplars; explanations of the technological pedagogical content knowledge (TPACK) framework and its components; opportunities for students to use ICT during peer teaching sessions; and discussions on purpose of ICT integration connected to the inclusion of learning objects, simulations and Web 2.0 technologies in teaching, learning and assessment.

The pre-service teachers' approach to technology integration in the science and mathematics assessment tasks shows considerable variation. The assessment stimulus materials highlight several distinct learner identities within a hypothetical school class. The learner identities include students with special needs and Indigenous students. This hypothetical situation reflects the experience of most of our pre-service teachers who will teach in schools with a significant proportion of Indigenous students. While the majority of pre-service teachers chose pedagogical and assessment practices supportive of their varied learners, very few extended those connections to their technology integration choices. This apparent disconnect between technology integration and learner identity has highlighted for us the importance of an approach to teaching technology integration that makes more explicit connections between the differentiation and Indigenous perspectives aspects of the subjects and the TPACK framework.

The TPACK framework

Mishra and Koehler (2006) designed TPACK to provide guidance to teachers about how to integrate technology into their pedagogy. The TPACK framework starts with three of Shulman's (1997) teacher knowledge categories: content, pedagogy and pedagogical content. Shulman (1996) first proposed the term 'pedagogical content knowledge' (PCK) to describe "the most powerful analogies, illustrations, examples, and demonstrations – in a word, the ways of representing and formulating the subject that makes it comprehensible to others." (p.9). Shulman does not specifically address technology in these articles, though it is not excluded. Current pressures to explicitly embed technology in a teaching framework are linked to the increased importance currently placed on student engagement with ICTs rather than specific dissatisfaction with earlier constructs such as PCK.

The TPACK model adds technology to these three teacher knowledge categories and creates a series of intersections (Mishra & Koehler, 2006). Using a Venn diagram, Mishra and Koehlar represent the knowledge domains with three overlapping circles. The TPACK framework thus presents seven interconnected knowledge domains: pedagogy, content, technology, pedagogical content, technological pedagogy, technological content, and technological pedagogical content. Archambault and Barnett (2010) argue that although it is difficult to separate out each of the knowledge domains, hence calling into question their existence in practice, the TPACK framework as a whole is helpful from an organisational standpoint. We adopt descriptions of the TPACK framework from Mishra and Koehler (2006) on the seven knowledge domains as they apply to pre-service teachers' capacity and readiness to teach mathematics and science to Indigenous students.

The pedagogy, content and technology teacher knowledge domains include areas separate from the other domains. Pedagogy knowledge (PK) is deep knowledge about the processes and practices or methods of teaching and learning and how it encompasses, among other things, overall educational purposes, values, and aims. This includes general knowledge that relates to student learning, classroom management, lesson planning and implementation. Content knowledge (CK) is teacher knowledge about the mathematics and/or science key learning areas. This includes knowledge of central facts, concepts, theories, and procedures central to mathematics and science subjects; and explanatory frameworks that organize and connect ideas central to mathematics and science. Technology knowledge (TK) includes knowledge of operating systems and computer hardware, and the ability to use standard sets of software tools such as word processors, spreadsheets, browsers, and e-mail. TK includes knowledge of how to install and remove peripheral devices, install and remove software programs, and create and archive documents.

At the intersections of pedagogy, content and technology teacher knowledge domains are three knowledge domains: pedagogical content, technological pedagogy and technological content. Pedagogical content knowledge (PCK) goes beyond a simple consideration of content and pedagogy in isolation from one another. PCK represents the blending of content and pedagogy into

an understanding of how particular aspects of mathematics and science subject matter are organized, adapted, and represented for instruction. Technological pedagogy knowledge (TPK) is knowledge of the existence, components, and capabilities of various technologies as they are used in teaching and learning settings, and conversely, knowing how teaching might change as the result of using particular technologies. Technological content knowledge (TCK) is knowledge about the manner in which technology and content in mathematics and science subjects are reciprocally related. Mishra and Koehler (2006) suggest that although technology constrains the kinds of representation possible, newer technologies often afford newer and more varied representation and greater flexibility in navigating across these representations.

At the centre of the TPACK framework is technological pedagogical content knowledge (TPACK). All of the previously mentioned six teacher knowledge domains overlap at TPACK. Mishra and Koehler (2006) write that TPACK is considered the basis of good teaching with technology. It requires an understanding of the representation of concepts central to mathematics and science subjects using technologies; pedagogical techniques that use technologies in constructive ways to teach mathematics and science; knowledge of what makes concepts in mathematics and science difficult or easy to learn and how technology can help redress some of the problems that students face. It also requires knowledge of theories of epistemology and how technologies can be used to develop new epistemologies or strengthen old ones.

A notable absence from the TPACK framework is precise information about where, when and how to consider teacher knowledge about the individual learners in the class. Although Shulman's (1997) original list of seven important categories of teacher knowledge includes teacher knowledge of learners and their characteristics, this category is not among the three highlighted in the TPACK framework. Additionally, the original knowledge category definitions are imprecise, not used consistently and very little theoretical development is available to assist researchers and teachers to make distinctions between the knowledge domains (Graham, 2011). Thus it is not clear if teacher knowledge of specific learners is actually represented in the TPACK framework. Pre-service teachers who only use TPACK to plan for technology integration risk making choices from their perspective only and without significant consideration of their learners.

Acknowledging the attributes of Indigenous students

Teaching and learning demands a new way of thinking about other cultures and intercultural exchange. It requires pre-service education and teacher professional development to enhance intellectual skills to examine ways to create knowledge about and with others, and use it to engage with them. In this way, pre-service education and teacher professional development highlights the cognitive dimensions of intercultural learning. This suggests a dialectical mode of thinking, which conceives cultural differences as neither absolute nor necessarily antagonistic, but deeply interconnected and relationally defined (Rizvi, 2008). It underscores the importance of pre-service teachers to value their students' lived languages, experiences and knowledge both in their terms as well as theirs, as a way of comprehending how both representations are socially constituted.

We argue that developing TPACK frameworks for pre-service teachers can be more sensitive to the attributes and cultural resources Indigenous students bring to the classroom: their lived languages, experiences and knowledge for the purpose of their learning. Rigney (2011) suggests that 21st century learning requires new spaces that are culturally safe, coherent and consistent, which do not override Indigenous cultures, but draw upon them as sources of learning foundation on which to build new digital learning structures. The term 'culture' is used to refer to an individual's habit of mind; the development of a whole society; or the whole way of life of a group of people (Rojek, 2007).

We argue that education programs that attempt to develop the TPACK frameworks for pre-service teachers separately from the socio-cultural environment they might encounter undersell the value to be gained from using an integrated and holistic approach. Angeli and Valanides (2009) call for consideration of factors beyond content, pedagogy and technology, such as teachers' epistemic beliefs and values about teaching and learning, and not a simplistic perception about the nature of integrating technology in teaching and learning. We argue that the TPACK framework should also take into consideration the learners' epistemic beliefs and values about teaching and learning. Developing TPACK frameworks for pre-service teachers cannot be treated as free from the socio-cultural context they might encounter in their future classrooms, and that good teaching requires an understanding of how the TPACK relates to those socio-cultural contexts.

From a socio-cultural approach to learning, it is imperative for teachers to acknowledge and value the cultural resources Indigenous students bring to the classroom. A socio-cultural approach to learning and knowing recognises the cultural variations in the nature of learning and the way that individual learners draw on their cultural legacies (Rogoff, 2003). Thus, socio-cultural approaches to learning emphasise the socially negotiated and embedded nature of meaning-making and how learners can use the cognitive tools of their cultural community (Murphy & Hall, 2008). To enable learners to develop agency, those who support learning have to recognise the funds of knowledge drawn on by learners, and create hybrid pedagogical spaces, where points of intersection between these and institutional practices and values are enabled (Hicks, 2001). It becomes imperative for the teacher to know as much as possible about the learners and the cognitive tools of their cultural community.

Learners use their own representational, cultural and cognitive resources to engage with subject specific representational practices of mathematics and science (Hubber et al, 2010). Negotiating representation and meaning in familiar languages can be empowering for Indigenous students. According to Zevenbergen and colleagues (2008) Indigenous students are shown to engage more actively in developing conceptual understanding when they are able to 'code switch' between their home language or representations and instructional language or representations. For Indigenous students who have limited facility in Standard English, the cognitive load created through working in a second language or culture can limit the potential to develop new representations and meanings.

Indigenous cultures, languages and literacy's must be explicit and sustained in a TPACK framework for teacher education programs. Gee (2005) acknowledges that students' lived experiences are foundations for academic learning, and they must be recognised, respected and valued. Indigenous students' culture strongly influences their ways of talking, thinking and engagement with learning new experiences (Murphy & Hall, 2008). This means that one's culture influences how an individual or a group can make primary sense of their world. Thus we can infer that learners of different cultures use different styles of communicating and representing knowledge as they make sense of their worlds.

A holistic approach to TPACK

According to van Rossum and Hamer's (2010) six-stage progressive model for students' learning, deeper understanding occurs when the students are active agents in their learning. When students increase their influence and agency on/in the teaching-learning process, their understanding increases. The classroom environment is thus shaped by the agency of students as they interact with each other, the teacher, and the curriculum and material resources in ways that afford their agency. Sewell (1992) defines agency as acts that occur when an individual brings resources learned in one context to bear upon another, and thus positions humans as active agents of change. Humans engage in acts of agency when they transpose resources learned in one context to another. This implies that contexts in which one's cultural dimensions are valued, recognized and legitimized as resources for

learning are empowering, and contexts in which these cultural resources are not valued are dis-empowering.

We argue that TPACK frameworks that take into account Indigenous students' lived languages, experiences and knowledge increase their agency in their learning and can use technological models and simulations to represent the concepts in the subject. This means that pre-service teachers should develop skills to facilitate these students to engage their cultural resources to represent concepts central to mathematics and science subjects using technologies. Nathan (2000) suggests that the historical, Indigenous alienation from the written word – perceived as a one-way communication system, quite discontinuous from Indigenous forms of communication – is not sustained in the interactive network environment. The online, interactive, network environment has reconstituted the balance between visual, oral and textual modes of presenting information, in ways that can support Indigenous students' cultural perspectives. The online environment helps "destroy the myth that meaning is really contained in text, by highlighting the inter-dependence of documents and showing that meaning arises from the relationship between texts and from our interactions with them" (Nathan, 2000, p. 41). Pre-service teachers can be better prepared to use technology in ways that enhances the culturally different styles of communicating and representing knowledge of the Indigenous students in mathematics and science classrooms. Representing knowledge of Indigenous peoples includes storytelling, ceremony, songs, ritual and sharing a diversity of languages and dialects – what Martin (2008) describes as 'multiliteracies'.

Rigney (2011) argues that we have limited knowledge of how to integrate technology into non-English speaking Indigenous communities, and remain unaware of its cultural, ethical, moral and socio-political consequences. We argue pre-service teachers can be better prepared to use technology in ways that can enhance Indigenous students' cultural, ethical, moral beliefs and values. TPACK frameworks for pre-service teachers should use technologies in constructivist ways to teach mathematics and science by building on existing knowledge of Indigenous students. This implies that pre-service teachers should have knowledge of what makes concepts in mathematics and science subjects difficult or easy to learn for Indigenous students and how technology can best help to redress some of the problems that the Indigenous students face. Pre-service teachers also need to realise that different languages, experiences, knowledge systems and cultures comprise distinct systems of representation which are not necessarily equivalent. The representation offered by the resources of each language, knowledge system or culture is not just reflections of particular ways of looking at the world; they also reinforce those perceptions for their users.

Morris and Matthews (2011) observes that there is very little research about what constitutes a highly effective teacher of mathematics in the context of Indigenous learners and call for culturally responsive mathematics pedagogy. We propose that pre-service teachers not only need to develop high levels of mathematical and scientific technological pedagogical content knowledge, but beyond this, they should be able to teach the concepts in the subjects in ways that are 'relevant and responsive to social realities and cultural identities' (Martin, 2007) of their students.

Conclusion

We have argued that to increase pre-service teachers' capacity and readiness, TPACK frameworks for pre-service teacher education programs should use technologies in constructivist ways to teach mathematics and science. This can be achieved by building on and explicitly acknowledging the attributes and cultural resources of Indigenous students. This approach positions Indigenous students as agentic in both negotiating their mathematical and scientific learning dispositions and using technological models and simulations to represent the concepts in the subject. Teaching and learning demands a new way of thinking about other cultures and intercultural exchange. It requires pre-service teacher education programs to acknowledge the students' different resources: languages,

experiences, knowledge systems and cultures, and that these different cultural resources can comprise distinct systems of representations which are not necessarily equivalent.

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