Early Career Teachers, Mathematics and Technology: Device Conflict and Emerging Mathematical Knowledge

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Information and communication technologies (ICT) are positioned in policy/syllabus documents as an essential resource in the teaching of mathematics. Given their youth and lifelong experience with technology, early career teachers (ECTs) are expected to excel in their use of ICT; however, we are not clear on the viability of these expectations and the reality of their teaching practices. This paper draws on data from three separate studies to explore how ECTs use technology in their teaching. Although their use of Interactive Whiteboards did not pose challenges, use of iPads did, and the teachers' mathematical knowledge for teaching appeared to be directly related to how they used their technology.

Now, more than ever, information and communication technologies (ICT) influence the ways we teach and learn. Schools are investing significant funds on ICT and current curriculum documents in Australia explicitly express an expectation that they are integrated into the teaching and learning of mathematics (Australian Curriculum and Reporting Authority, 2012; Board of Studies New South Wales, 2012). In recent years, technologies such as interactive whiteboards (IWBs) and computer tablets have been introduced into classrooms with expectations that teachers embed them into their existing practices, often with little or problematic professional development (Attard, 2013; Orlando, 2014).

ICT is understood to potentially enhance the learning of mathematics by acting as a source of knowledge, a medium for transmitting content and a resource that promotes dialogue and exploration (Levin & Wadmany, 2008). Research that focuses on best practice in the incorporation of technology in primary mathematics teaching and learning has shown the use of ICT can result in improvements to student engagement, motivation, persistence, curiosity and attention (Attard & Curry, 2012; Shin, Sutherland, Norris & Soloway, 2012). However, the literature on ICT pedagogy shows that in many classrooms there are challenges with teachers' incorporation of new ICT into their existing practices (Attard, 2013; Orlando, 2013; Bingimlas, 2009). This is particularly evident in research that compares the teaching approaches and/or capabilities of young, early career teachers (ECTs), (teaching for five years or less) in their uses of ICT to that of their older counterparts (Orlando, 2014). Early career teachers have been found to have significantly greater commitment to technology integration (Pavlou & Vryonides; 2009; Buabeng-Andoh, 2012), more computer proficiency and confidence to integrate technology (Attard, 2013; Bingimlas, 2009), see technology as part of their content responsibilities (Plair, 2008) and embrace opportunities for changing their daily teaching practices or trying new technologies in their classrooms (Inan & Lowther, 2010) when compared to their older, more experienced counterparts. These studies signal that as a group ECTs are more inclined to have an overall greater capability and motivation to integrate technology into their teaching practice; however, they are not able to offer in-depth explanations for what this looks like in practice.

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The purpose of this paper is to explore how a small group of early career primary school teachers use ICT in their teaching of mathematics. A key idea embedded in this paper is that observable teaching is the representation of an inter-related mesh of contextual and individualised variables a teacher constantly encounters, problematises and interprets as part of their practice (Connelly & Clandinin, 1999). Two important variables suggest that ECTs' uses of technology to teach mathematics may not be without complications. The first is that ECTs are often expected to fulfil the same responsibilities in the classroom as more experienced teachers (Brindley & Parker, 2010; Casperson & Raaen, 2014). Many ECTs feel ill-prepared and struggle with student discipline, mastery of instruction, meeting individual student academic needs (Margolis, 2008) and gaining appropriate levels of mathematical knowledge for teaching (Hill, Rowan, & Ball, 2005). Often they deal with these issues in the isolation of their own classrooms, while teaching any content and regardless of any resources they are using to support their teaching.

A second important variable is the association between technology and youth culture. This group of teachers are 'digital natives', a term Prensky (2001) coined when describing what he thought to be an obvious disparity between the technology capabilities of school students and their teachers. Thirteen years on, some of those students are now entering the workforce as teachers. While the term 'digital natives' has been critiqued as an over-generalised construction (Bennett, Maton, & Kervin, 2008), the association between youth and technology competence remains strong (Loveless & Williamson, 2013). ECTs are youthful, assumed to be technologically proficient (Loveless & Williamson, 2013) and therefore there are high expectations of these teachers to teach well with technology.

Younger teachers have grown up with technology and have had many years to develop technology expertise. These teachers will have likely experienced some form of technology as a student, so along with learning technology skills to be used in an education environment it may be expected that their conceptualisation of classrooms and teaching is one that assumes technology use. It would be expected that such skills and conceptualisation would also be strengthened during their experiences as pre-service teachers. These high expectations may hinder ECTs' opportunity and willingness to ask for help in their teaching with technology. It is also not clear how lifelong experience with technology translates to teaching practices as early career teachers.

These key points alone suggest that expecting younger teachers to easily and naturally use technology to teach a complex subject such as mathematics, simply because they may have grown up with technology, is simplistic, unhelpful and negates the opportunity to meaningfully support our new generation of primary mathematics teachers.

Method

We present empirically based findings of the challenges ECTs deal with and how this manifests in their practice to shed light on the experiences of ECTs as they incorporate technology into their mathematics pedagogies. Data analysis involved the application of the participant teachers' data to Windschitl's (2002) framework of dilemmas. For the purpose of this paper, we adapt the framework and apply it to the context of teachers incorporating ICT in their mathematics teaching. The framework describes four categories of dilemmas teachers encounter when expected to incorporate ICT into their practices: (1) *pedagogical dilemmas* for teachers arise from developing a deeper knowledge of the subject matter, managing the integration of technology in the classroom environment and orchestrating meaningful uses of technology to support student learning of mathematics; (2) *cultural* *dilemmas* emerge when teachers become conscious of using technology for different purposes, different contexts and with different bodies of technological and content knowledge; questioning assumptions and discourses about what kinds of activities should be valued; (3) *political dilemmas* are associated with confronting issues of accountability with various stakeholders in the school community regarding the value of ICT; and (4) *conceptual dilemmas* are rooted in teachers' attempts to understand the ways technology can support their understanding of the process of learning and the role technology plays in that process.

In using this analytic framework we were able to identify that novice understandings of pedagogy (contributed to by pedagogical and conceptual dilemmas) contributed to challenges the ECTs encountered in their use of technology to teach mathematics. Identifying their challenges opened scrutiny to the myriad of factors they drew on when making decisions about how and whether to use technology in their mathematics teaching (Wallace & Loughran, 2011).

Galbraith, Goos, Renshaw and Geiger's (2000) four roles for technology in relation to teaching and learning interactions were used to facilitate deeper understanding of why ECTs novice understanding of pedagogy posed challenges for them in using technology to teach mathematics. The four roles include: "technology as master" which occurs when the technology is imposed on the teacher or its use is limited due to the individual teacher's beliefs about teaching. In the role of "technology as servant" the teacher is knowledgeable in terms of using the technology but its use is limited to the teacher's preferred methods. "Technology as partner" describes the use of technology in creative ways that result in improved quality of student learning. "Technology as extension of self" occurs when the technology forms a 'natural' part of the teacher's repertoires and is used in highly creative ways. This framework assisted in identifying and describing the ways in which the ECTs were utilising the technologies.

The findings this paper presents inform how we can importantly support ECTs in the development of meaningful technology practices in the teaching of mathematics. In particular it identifies the need for professional learning to focus on pedagogical and conceptual aspects of technology teaching practices for mathematics.

Methodology

Teaching is a complex practice. Reflecting this we explore the teaching practices of four ECTs as they integrate technology into their mathematics lessons. To do this we draw on three research projects. These projects provided access to interview and observation data relevant to the experiences of ECTs using technology in their mathematics teaching. The first study we draw on, which we will refer to as Study A, is a qualitative study of 30 primary and secondary teachers in low SES schools in regional and city areas of New South Wales, Australia. The teachers were identified by their communities to be exemplary in engaging students in learning (Orlando, 2013); however, exemplary teaching was not defined in terms of mathematics expertise or technology use or expertise. The participants ranged from early career teachers with two years of teaching experience to veteran teachers who had been teaching for over thirty years. As can be expected, technology was more prominent in the practices of some teachers. Two of the teachers (Teacher 1 and Teacher 2) were selected for the purpose for this paper as they were early career teachers with data available relating to teaching mathematics with technology. The predominant technology used by these teachers was the Interactive Whiteboard (IWB).

The second study, which we will refer to as Study B, is a qualitative study exploring one ECT's experiences with using iPads in mathematics lessons during a six-month iPad trial at a government primary school in Sydney (Attard & Curry, 2012). At the time, the teacher (Teacher 3) was in his first year of teaching and was the school's technology coordinator. The teacher had received no professional development to assist in the implementation of the new technology. Data were collected via teacher interviews, observations and student focus group discussions. Observations of the teacher's use of the IWB is also included in this paper.

The third study, which we will refer to as Study C, was a qualitative multiple case study that took place over a six month period in a Western Sydney primary school (see Attard, 2013). The study investigated the experiences of four primary school teachers and their students in relation to the introduction of iPads into their mathematics pedagogies. Two of the participants were classified as early career and for the purpose of this paper the experiences of one of those teachers in her fifth year of teaching (Teacher 4) will be explored. As in Study 2, data were derived from teacher interviews, classroom observations and student focus groups. Observations of Teacher 4's use of the IWB is also included in this paper.

We re-analysed the data from these three studies for the purposes of exploring them against Winschilts' (2002) framework described above.

Findings

Windschitl's (2002) framework of analysis showed that pedagogical and cultural dilemmas dominated the ECTs' uses of technology for teaching mathematics, and alerted them to gaps in their own knowledge of pedagogy and of mathematics content. A *pedagogical* dilemma the ECTs experienced was a lack of understanding of the ways they could use mobile technologies to teach mathematics. Teachers 3 and 4 aspired to use iPads with the intent of introducing innovative ways to teach mathematics; however, there were no established approaches relating to iPads and mathematics that they could use as a foundation for their practices. They were reliant on these resources to be developed for them, they did not consider they were able to develop their own, nor did they consider they could adapt other resources for use in conjunction with the iPads.

This dilemma is evident in the practices of Teacher 3 who introduced a flipped classroom model as an innovative way to teach mathematics. A flipped model he explained to be "…where they learnt about the concept first (online) and the came into the classroom … ready to apply that concept … and then I fill in the gap right there rather than teach … so essentially the classroom is not the place to teach". He used tutorials from the online Khan Academy to replace some of the direct instruction from his mathematics lessons and also used screen-based games to build fluency in mathematics skills through drill and practice. His intention was to allow learners to take responsibility for their learning and he also hoped that online teaching resources would assist with promoting the classroom as a working 'think tank'. He stated, "I'm hoping the Khan Academy will come up with some way that will spin it around, so that the classroom is sort of like a workshop". However, he experienced challenges. Not all his Year 3 learners were successful in this approach and he discovered a broad diversity in the mathematical capabilities of his students so it became difficult to use the technology in the intended way. He did not shift the ways the online resources could be used or differentiated their use with the learners in the class. He also explained that it was difficult to incorporate iPads into mathematics with a lack of access to online open-ended tasks—applications (apps) were mostly limited to drill and practice based activities which he used regularly during mathematics lessons.

Teacher 4 experienced a similar pedagogical dilemma of finding creative ways to incorporate the iPads into mathematics lessons, relying heavily on drill and practice apps (technology as master) during the early stages of their implementation: “I would probably like to learn more about how to incorporate them especially more as a teaching tool ... so I guess it is like trying to think out of the square a little bit more.”

The difficulties Teachers 3 and 4 experienced were particularly pronounced when they used iPads to teach mathematics. They did not experience the same frustration when teaching other subjects using the iPads as there was a greater variety of high quality apps available and it was easier to conceptualise a more creative use of the iPads in other subjects. They were challenged with the need to adapt app usage or create/explore learning experiences in which they integrated the use of iPads. Their challenges might be explained as a lack of knowledge of pedagogy as well as the nature of mathematics content and a lack of knowledge on how to develop learning experiences that integrate technology into the mathematics discipline.

A *cultural* dilemma the ECTs experienced was in the use of mobile technologies, as opposed to fixed technologies such as an IWB. This was most pronounced when we compared the data on when teachers used iPads and when they used IWBs. In the classrooms of Teachers 3 and 4 the mobility of iPads allowed them to extend their students’ learning of mathematics beyond the classroom and the students were not bound to sitting at desks to complete set tasks: “I could take a group outside … and do whatever we were doing” (Teacher 4). This affordance was highly valued by both teachers; however, they were essentially still operating in a traditional manner, with students working independently on tasks, utilising the technology as consumers rather than creators.

However when teachers used fixed technology such as IWBs, the teachers were able to seamlessly weave use of technology into routines as an “extension of self”. For example, Teacher 1 used her IWB for recording student attendance on the IWB to using a combination of technology and more traditional methods to explain mathematical content. Teacher 2’s use of technology capitalised on students’ community context by using the IWB to show video footage of the town centre to teach lessons on position, strengthening connections between school and the students’ lives, and contextualising the mathematics to make it meaningful for her students.

A *conceptual* dilemma the ECTs experienced related to the online content that was available for mathematics and the wide range of content available for mobile devices as opposed to fixed devices. Although the teachers were conscious of the potential to use iPads in new and different ways to traditional technologies, implementing them in such a way to teach mathematics was a challenge. Due to their ‘newness’ within educational settings, Teacher 3’s and 4’s uses of iPads (technology as master) did not appear as seamless as their use of IWBs (extension of self). The added affordances of mobility, ease of use, access to the Internet and to an unlimited number and range of apps posed a challenge in relation to teaching mathematics. It appeared that the devices promoted changes to traditional practice but the teachers found it difficult to reconceptualise mathematics lessons that took advantage of the affordances without any benchmarks or theory to support their planning. There was a tension between these teachers’ positive beliefs about the potential of the devices to change their pedagogies and the enactment of that change.

Teachers 1 and 2 did not expect all uses of technology would result in an observable learning outcome but instead used technology to model learning behaviours and to promote an active learning environment. For example, Teacher 1 tapped into the nature of ICT to model to the students how to learn. She would often spontaneously use a computer to clarify a point being discussed by the class at the time. The sites she used were mostly not planned and the use of technology in this way was also not planned but rather an option of something she could easily do in a lesson to support her teaching. In doing this she was deliberately promoting learning as a natural and dynamic process that changed according to the task at hand. She also used various tools on the IWB to support students' success. For example, a magician would appear on screen at times when students had thought about and responded well to classroom discussion. Teacher 1 had been teaching for five years and was confident in her own technology skills, making this an easy and seamless task she could include in a lesson. Pedagogy was at the forefront and technology in the background of this lesson.

A *political* dilemma the ECTs experienced was the issue of accountability; this is often a dilemma when schools, systems and parents invest significant funds into new technologies (Orlando, 2014). Teachers 1 and 2, whose use of technology was predominantly focused on IWBs, experienced no such issues. However, the situation was quite different for Teachers 3 and 4 who were also using iPads. In Teacher 3's case, his access to the iPads was the result of participation in a system iPad trial. Teacher 3 had the responsibility of reporting back to the Department of Education and Communities (DEC) as well as the school and parent community. There were also high expectations from within the school as he had been appointed as the Technology Coordinator as a first year teacher and was viewed as a technology 'expert'.

Both Teachers 3 and 4 felt some pressure to use their iPads as often as possible and, although they did not require any technical expertise to use the devices and were confident in operating them, their inexperience and levels of pedagogical content knowledge limited the ways they were used to teach and learn mathematics. These two teachers also experienced a political dilemma in relation to the investment of time required to plan and source lessons using the iPads. This was an added burden that was not taken into consideration by other stakeholders who supported the implementation of iPads and was a barrier to developing high quality pedagogies that successfully incorporated the new technologies.

Discussion

In comparing the data and findings from the different studies, two interesting observations have emerged. First was that the teachers experienced device conflict in that different technologies observed appeared to influence the teachers' practices in different ways as a result of their affordances and/or limitations. For example, the mobility of iPads resulted in the potential to alter the physical structure of the classroom and allow a stronger element of student control. In contrast, the Interactive Whiteboards (IWB) reinforced the positioning of the teacher by being located at the front of the classroom, creating a central focus that in many cases replicated the traditional role of the teachers.

The use of IWBs is no longer considered 'cutting edge', indeed it is an expectation that most teachers use these as part of their daily routines. The vast differences in the two types of technologies that were included in this paper appear to have a significant effect on the dilemmas experienced. The IWB is a fixed feature in many classrooms and is conducive to traditional teaching methods, and this is how we observed its use by ECTs. The use of IWBs perpetuates the model where the teacher is in control, as opposed to the use of iPads, which promote higher levels of student control. However, in the case of ECTs, the handing over of control from teacher to student may be impeded by each teacher's level of experience and knowledge of pedagogy.

Teachers 1 and 2 did not appear to experience dilemmas; however, this may have been due to the technology they were using. Another consideration is that these two teachers were selected for participation in their study because they had been identified as exemplary teachers who had displayed a strong understanding of quality pedagogy. Struggles were evident with Teachers 3 and 4, possibly due to the fact that these teachers were dealing with a brand new technology that had a much broader set of affordances than the IWB. For these early career teachers, it appears the greater the affordances associated with a technology, the more complex and challenging it becomes to design quality pedagogies that enhance learning and teaching mathematics.

The ECTs in Study 1 used technology (IWBs) to enhance the students' understanding of mathematics content as well as to promote a classroom environment that was conducive to the learning of mathematics. For these teachers the role of technology appeared to be as 'extension of self' and, at times, as 'partner' (Galbraith et al., 2000). Teachers 3 and 4 experienced different interactions according to the technology used. In the case of the iPads, the technology appeared to take on the role of 'master', in conflict with the same teachers' interactions with IWBs, where the role of technology was 'extension of self'.

The second observation to emerge from the comparison of the three studies is that the teachers' mathematical knowledge for teaching appeared to be directly related to the ways they used their technologies. Although the intention of Teachers 3 and 4 was to use iPads in ways that would enhance teaching and learning, their depth of knowledge of pedagogy made it difficult to localise. Both teachers attempted to implement a new approach; however, their limited teaching experiences highlighted that a stronger focus on learning (technology as partner) rather than on technology (technology as master) may have resulted in more successful results. However, the introduction and integration of new technologies did provide the opportunity for all of the teachers to engage in regular reflection and evaluation of their practices as a result of their enthusiasm to embrace the technologies.

Conclusion

Although this paper may be limited in that its focus was on a small group of teachers and their use of two different technologies, there are lessons that may be useful in broader contexts. It seems to be an unspoken expectation that Early Career Teachers are confident in their use of technology and therefore able to incorporate technologies into their practices in effective and innovative ways. This puts a significant amount of pressure on these teachers who are still learning the craft of teaching and developing their pedagogical content knowledge in mathematics and other subject areas. To add to their dilemmas, there is little empirically based research on teaching with new technologies due to the fast pace of development and the length of time it takes for research to filter down to teachers and schools. Further research into effective teaching practices specifically related to mathematics and new technologies and timely dissemination is critical if early career teachers are to successfully implement new and potentially transformative technologies into the teaching and learning of primary mathematics.

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