Routledge Research in Teacher Education

TECHNOLOGY-ENABLED MATHEMATICS EDUCATION

OPTIMISING STUDENT ENGAGEMENT

Catherine Attard and Kathryn Holmes

ROUTLEDGE

Technology-enabled Mathematics Education

Technology-enabled Mathematics Education explores how teachers of mathematics are using digital technologies to enhance student engagement in classrooms, from the early years through to the senior years of school.

The research underpinning this book is grounded in real classrooms. The chapters offer ten rich case studies of mathematics teachers who have become exemplary users of technology. Each case study includes the voices of leaders, teachers, and their students, providing insights into their practices, beliefs, and perceptions of mathematics and technology-enabled teaching. These insights inform an exciting new theoretical model, the Technology Integration Pyramid, for guiding teachers and researchers as they endeavour to understand the complexities involved in planning for effective teaching with technology.

This book is a unique resource for educational researchers and students studying primary and secondary mathematics teaching, as well as practising mathematics teachers.

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We dedicate this book to all mathematics teachers and their students. The stories within provide an affirmation of the unique contexts within which you work and learn every day.

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1 Why teach mathematics with technology?

When you walk into an average school classroom, you are likely to see students using a range of digital mobile devices such as smartphones, tablets, laptops, or robotics. The students in our classrooms today have never known a life without technology and the Internet, yet technology use in contemporary teaching and learning appears to be inconsistent in quality, quantity, and effectiveness, particularly where mathematics is concerned (Organisation for Economic Cooperation and Development (OECD), 2016). In fact, many teachers in today's classrooms earned their qualifications at a time when available technologies were significantly different to where they are today and where they will be in the future (Koehler & Mishra, 2009; Orlando & Attard, 2016). Although technology is viewed by some as an educational imperative (Bower, 2017), there still remain many questions about how it should be used and whether its use does, in fact, improve student learning.

Many view mathematics as a difficult subject, only accessible to those who are considered "smart" (Boaler, 2009). In addition, many students become progressively disengaged with mathematics as they progress through the school years (Attard, 2014). In part, this disengagement is caused by traditional teaching practices that emphasise memorisation of procedures rather than deep understanding of mathematical concepts (Skemp, 2006). As a result, there is ample evidence (Kennedy, Lyons, & Quinn, 2014; Wang & Degol, 2014) of low participation rates beyond the compulsory years of mathematics leading to potential shortfalls in key skills required in a STEM (Science, Technology, Engineering and Mathematics)-driven workforce. Likewise, mathematics curricula have historically focused on mathematical content rather than mathematical thinking and reasoning. More recent curriculum developments promote a more process-oriented approach to mathematics that includes reasoning, problem solving, and understanding (Australian Curriculum Assessment and Reporting Authority (ACARA), 2010; National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010). The affordances of current and emerging technologies can provide teachers with the mechanism to broaden their pedagogical repertoires and redefine learning and teaching of mathematics for contemporary students, improving engagement and, ultimately, participation in mathematics.

Technology can and should be regarded as a disruptive pedagogy. Hedberg (2011) provides an example of technological disruption caused by the rise of digital photography. The move from chemical processing to instant, high-quality photographs that could be shared immediately and globally was considered a disruptive innovation. Although we expect and hope that the emergence of digital technology would cause significant potential disruption in mathematics education, disruptive innovation does not appear to have kept up with the pace of technology integration into our classrooms. Resistance to innovation, for a range of reasons, is common. Tangney and Bray (2013) suggest that although the affordances of mobile technology align with a social constructivist teaching approach that promotes collaboration, communication, creativity, and problem solving, their use overwhelmingly continues to be restricted to content consumption. Secondary schools, in particular, appear to remain "immune to the transformative potential of mobile learning" (p. 20). Diversity amongst schools, teachers, students, professional development opportunities, resourcing, policy, and funding exists. Tensions relating to the pedagogy of mathematics arise when, for example, standardised testing and school timetabling put pressure on teachers resulting in reduced time for innovation and experimentation with technology.

Although research on the use of contemporary digital technologies in education has begun to build momentum, the report *Students, Computers and Learning Making the Connection* (OECD, 2016), claims that results from the Programme for International Student Assessment (PISA) in 2009 showed that computers were used less frequently during classroom lessons in mathematics than in either language or science classes. Although published in 2015, the significant time lapse between the collection of data in 2009 and its dissemination typifies one of the biggest challenges in educational technology use, that is, the lag between the conduct of research and its dissemination into classrooms. The technological advancements that would have occurred during the six-year gap are significant. Students' social and home lives would have changed as a result. If research cannot keep up with technological advancements, how can we expect teachers to? How can we equip teachers to deal with emerging technologies as they reach classrooms?

The ever-evolving nature of digital technologies coupled with their increasing ubiquity has created a challenge for teachers of mathematics to effectively integrate them into existing practices or use them to create new and innovative practices, and it is a common perception that educators have not yet become good enough at pedagogies that make the most of the available technologies (Attard, 2015; Morsink et al., 2011; OECD, 2016). This sentiment is echoed by Bray and Tangney (2017) who conducted a systematic review of research relating to technology-enhanced mathematics education and found that the usage of technology is mostly confined to an augmentation of existing classroom practices. Furthermore, digital technology challenges teachers of mathematics to conceptualise both the design of new pedagogic approaches and tools, as well as the kinds of knowledge that may be accessed through such tools (Hoyles & Noss, 2009).

If we consider that the OECD report draws on data collected prior to the introduction and popularity of mobile digital devices, it could be argued that the challenges for mathematics teachers continue to become more significant, particularly in light of the increasing popularity of bring your own device (BYOD) programs. Although the structure of BYOD programs varies, many teachers are faced with having to deal with teaching students who are using a range of devices, operating systems, and software applications at any one time. The rate of technological development implies that the technical and pedagogical complexities currently experienced in contemporary mathematics classrooms will continue to increase.

Who are our students?

The term "digital natives" was coined by Prensky (2001) to describe those who have been immersed in technology from childhood. Those born prior to personal computers and the Internet are referred to as "digital immigrants". It would be safe to assume that in most westernised countries we could expect that a large number of students entering formal schooling have had some, if not many interactions with digital technologies. However, as with all other aspects of learning, it would be dangerous to make assumptions about the level of skills and range of experiences each of our students bring to the classroom. Likewise, we cannot assume that those amongst us who are digital immigrants do not have an affinity with technology or that we lack the skills to use them effectively within educational contexts. A common criticism of Prensky's views is that there is little regard for what is termed the "digital divide" that exists between students' profiles and preferences (Bower, 2017). We also cannot assume that the "digital natives" in our classrooms have high levels of technological proficiency or engage in critical analysis of information from online sources. This sentiment is echoed by others, who believe that although adoption rates of a limited number of technologies may be high, other technologies have not been used to their full potential (Kennedy, Judd, Churchward, Gray, & Krause, 2008, as cited in Judd, 2018).

Let's consider the educational landscape at the time of Prensky's work. In 2001, the technology (if any) that appeared in classrooms was limited and immobile (apart from hand-held calculators). Less than ten years later, a new generation of mobile technologies began to appear in classrooms caused by the Internet becoming more accessible than ever. Outside the school, engagement in social media has become the new norm. Access to an unlimited and inexpensive range of software applications (apps) through the use of mobile devices has increased exponentially. The educational landscape has changed dramatically in terms of the range of technological resources that have rapidly become available. Students have also experienced an increase in their access to technology in their personal lives. Similarly, it is arguable that those who were initially termed "digital immigrants" now experience technology as a ubiquitous part of their lives too, and, as Judd (2018) argues, Prensky's terminology may be of little or no value in contemporary educational contexts.

When considering the lives of young people, Gardner and Davis (2013) characterise the current generation as the "app generation", describing them as being immersed in apps, "seeing their lives as a string of ordered apps, or perhaps, in many cases, a single, extended, cradle-to-grave app" (p. 7). They go on to describe how apps allow us to "take care of ordinary stuff and thereby free us to explore new paths" (p. 9). Gardner and Davis also discuss how apps that allow us to engage in new opportunities can be considered "app-enabling". Conversely, when the use and reliance on apps restrict and determine procedures, choices, and goals, users can be considered as "app-dependent". This thinking has implications for the way we utilise technology in mathematics education. Some uses of technology may have limited or no added value to teaching and learning, continuing a dependence on traditional pedagogies. For example, the use of drill and practice apps often simply replicate a textbook or worksheet style of lesson (Attard, 2015). Alternatively, other apps may enable us to reconceptualise the curriculum, our pedagogy, and the way students learn and interact with mathematics.

Prior to Gardner and Davis's research, Hoyles and Noss (2009) had considered the role of digital technologies in mathematics education in a similar manner. They proposed that an important affordance of digital technology is in "outsourcing processing power from being the sole preserve of the human mind, to being capable of being undertaken by a machine" (p. 135). Students often become bogged down in procedures and lose touch with the mathematical problem being tackled, making processing errors and perhaps losing motivation in the task. The "app-enabling" aspect of digital technology can, in this case, have significant potential for the learning of mathematics. However, Hoyles and Noss warn that if the goal is to achieve insight rather than a correct answer, reliance on software for processing may be detrimental, resulting in "app-dependence". Put simply, students need some understanding of how outcomes are produced and to have some ownership of the actual process.

The digital divide: where does it lie?

The digital divide was mentioned in the previous section in regard to the variations in students' technological proficiency. The concept of a digital divide needs to be acknowledged in the introduction to this book as it is often viewed by teachers as a barrier to the effective use of technology in mathematics classrooms. Dolan proposes a simple definition of the digital divide, "the binary view of the haves and have-nots" (p. 16); however, the divide is not as simplistic as it may seem and extends beyond having or not having a computer or mobile device. There are variations and inequities in access to the Internet, bandwidth capabilities, availability of software, the knowledge and skills of students and teachers in their use of technology, factors such as poverty, teacher professional development and training, and internal and external stakeholder expectations (Dolan, 2016; Orlando & Attard, 2016).

Roblyer and Hughes (2019) extend these ideas, referring to technology as a double-edged sword that while potentially providing opportunities to change education and empower students and teachers, also further divides members of our society based on a number of elements that include socioeconomic status, geographical location, and disability. This belief is echoed by others (Henderson, 2011; Selwyn, Potter, & Cranmer, 2009) who further extended the concept of a digital divide to encompass the disparity between the way young people use digital media outside school and the ways in which digital media is used within the classroom.

While writing this book, we specifically selected case studies that drew from a diverse range of schools, teachers, and students; from different socioeconomic areas; geographical locations; and school systems. Our case study students and teachers had access to varying numbers of devices and software applications. This was intentional, as we believe that technology can be used effectively in a range of mathematics classrooms when embedded in high-quality pedagogy and supported from school leadership and the broader school community. We suggest that in the context of mathematics education, there may be an additional divide that is related to students who are engaged and are perceived to be good at mathematics and those who are disengaged and find mathematics challenging. Perhaps the affordances offered by digital technologies in mathematics classrooms can assist in closing this particular divide.

Technology for mathematics education

Emerging technologies require mathematical reasoning in order to function in today's society, yet many adults avoid mathematics, attributing their dislike of the subject to their school experiences (Boaler, 2009; Clarke, 2009). It is believed that an increasingly smaller percentage of students in many countries are pursuing the study of mathematics beyond a lower secondary level, a choice seriously influenced by attitudes towards and performance in mathematics and significantly shaped by mathematics pedagogy. This, coupled with common beliefs that mathematics is a "hard, technical subject where there is an emphasis on learning rules, constant practice and little room for creativity" (McPhan, Moroney, Pegg, Cooksey, & Lynch, 2008, p. 24) and an emphasis on summative assessment has led to serious student disengagement (Bray & Tangney, 2017). We believe that digital technology has the potential to change negative perceptions of mathematics due to the affordances that promote not only the content of mathematics but also the processes of reasoning, communicating, problem solving, fluency, and understanding. The use of digital technologies in mathematics classrooms also offers us an opportunity to rethink how we adapt the teaching and learning tools we currently use and, perhaps, more importantly, how we adapt the mathematics to be learned (Hoyles & Noss, 2009).

The use of and access to technology is regarded as a necessity in today's classrooms, and in some countries, its use is embedded in mandated curricula (e.g., Australian Curriculum Assessment and Reporting Authority (ACARA), 2010). It is widely agreed that digital technology does have significant potential to disrupt traditional teaching approaches. Although much of the literature on contemporary technology use in education does not relate specifically to mathematics, there are many advantages (and, of course, disadvantages) that can be applied within mathematics classrooms. One of the most significant benefits of technology involves opportunities for teachers to personalise learning and provide differentiation (Hilton, 2018; Robinson & Sebba, 2010). While this can be achieved without technology, teachers can take advantage of the affordances of technology to vary instruction and provide learner-controlled learning paths. Contemporary education apps often provide teachers with frequent formative assessment and progression data aligned to curriculum standards and provide instant feedback to students. In some apps, this then leads to tailored learning pathways that can extend learning or provide intervention (Roblyer & Hughes, 2019). The use of technology has the potential to disrupt the way mathematics education is delivered and assessed, and as a result, improve student engagement with the subject.

Contemporary technologies and their affordances

As technology has evolved, devices have become more mobile resulting in a new educational landscape. Although still common in schools today, the traditional computer lab that required timetabled lessons to teach students how to use technology is no longer considered appropriate. Contemporary technologies in mathematics classrooms have progressed from the use of scientific calculators and desktop computers, to interactive white boards and laptops, to an ever-increasing range of mobile devices and software applications that provide both affordances and constraints to influence mathematics teaching and learning (Flegg, 2015).

In general, contemporary technologies offer affordances that provide opportunities to create, innovate, redesign learning spaces, and offer deeper learning approaches. Practices that arise from the use of these technologies have often been referred to as mobile learning, or ‘m’learning. The “mobile” element of ‘m’learning refers to more than just the mobility of the device. It also refers to the mobility of people within a physical space, social mobility in how people connect with one another, and learning the occurs both within formal and informal contexts (Sharples, Arnedillo-Sanchez, Milrad, & Vavoula, 2009, as cited in Bower, 2017, p. 263).

The increase in popularity of mobile technologies has resulted in many schools investing in tablet devices or requiring students to bring their own tablets or laptops. In some schools, the use of robotics has become a popular way to merge mathematics skills through coding activities. These practices, although not always embedded or integrated into mathematics learning, are considered to be accelerating the rate of technology adoption in education more generally, including the emergent view of coding as a literacy and the rise of integrated STEM learning (Freeman, Adams Becker, Cummins, Davis, & Hall Giesinger, 2017).

The relatively low cost coupled with the vast range of affordances offered by mobile technologies has made them appear to be an attractive solution to address