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Mobile Technologies: How Might Using Mobile Technologies Reshape the Learning and Teaching of Mathematics?

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As our attention moves to the opportunities and constraints that mobile technologies (MT) might afford, app developers, teachers and researchers have become more adept at identifying and enacting opportunities for enhancing mathematical thinking. These opportunities emerge through the various environments, both hardware (i.e., tablets) and software (i.e., applications), and the mathematical activity that these facilitate. The features of MT, for instance the ability to use in-built video and audio tools, allows users to capture authentic data in their everyday world and use the data for modelling, or statistical inference. Processing this data in situ changes the nature of the learning experience. Likewise, the potential for visual, interactive engagement with some learning experiences, coupled with the haptic and oral/aural affordances of the technology, change the nature of the mathematical activity. By inference, this changes the nature of the mathematical thinking. Engaging with number sequences by creating sets of objects that represent numbers as you touch the screen, using an oral count, using concrete materials, or learning a sequence by rote, are all different representations of number that might evoke a variety of understandings and ways of thinking mathematically. Being able to elegantly connect these various representations, and move between them, appears to offer opportunities for deeper conceptual understanding of mathematics concepts.

With MT being a relatively recent addition to the scope of digital technologies that might facilitate learning in mathematics, there is a need for research on the use

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of MT, and for this research to be presented in a coherent, multi-faceted manner. Such research is of particular importance as schools are investing heavily in mobile devices, often without a concomitant investment in developing practices regarding how such devices may be used to develop conceptual rather than procedural or declarative knowledge (e.g., Calder, 2011), nor of how such devices connect with other resources in the classroom. The effectiveness of their engagement in shifting conceptual understanding is also contingent on associated professional learning for teachers (O'Malley et al., 2013). Theoretical frameworks for teaching and learning with MT might also be influential in our understanding of the ways that using MT in the learning of mathematics might be examined.

Some researchers have noted a lack of theoretical rigour regarding the use of MT (e.g., Larkin, 2015), identifying issues in relation to the lack of mathematical quality of many mathematics apps. He also reported the lack of time and expertise for teachers to accurately evaluate them or their use. Nevertheless, MT offer vast potential to enhance mathematical learning. This book builds on international research (e.g., Attard, 2015; Calder & Campbell, 2016; Moyer-Packenham et al., 2015; Sinclair & Heyd-Metzuyanim, 2014) into the use of MT in mathematics education. It includes an examination of the ways MT might influence student engagement, cognition, collaboration and attitudes, through reshaping the learning experiences across a diverse range of year levels and contexts.

Central to learning mathematics through using MT is the nature of the tools and the apps utilised, the learning intentions of the teacher, and the type of activity that the students are engaged with. While there is frequently a focus in schools, and in the media, on *consumable* apps that is, those where students follow a set task at a specified level; more recently there has been a focus on apps that: enable students to create screencasts of their mathematical thinking; can be used for coding, including the programming of small robotic devices; enable students to create visual, dynamic representations of mathematical situations.

In this relatively new field of engaging with mathematics learning through using MT, this book reflects the growing understanding of how the learning experience might be reshaped to harness the opportunities that MT afford. It also incorporates an examination of using MT for developing mathematical thinking, enhancing teacher pedagogy, and understanding the embodied cognition inherent when using mobile, touch-screen devices. In addition, the broader assemblages incorporating underlying discourses and political elements are hugely influential in using MT effectively. The book proposes emerging frameworks, or new uses for existing frameworks that encourage educators to better interrogate student engagement and learning aspects as well as to evaluate the vast range of apps that continuously appear. As the field is always in flux, with researchers and teachers often scrambling to keep up with recent innovative developments, we are reminded to look beyond the specific to the general (Mason, 2005). Thus we look to find common themes and trends that enable us to gain insights into and evaluate MT, and the associated learning/teaching practices, from vantage points not dependent on understanding specific examples or apps. Not withstanding the need for a global approach, the examination of individual apps and experiences are crucial as they mark new initiatives and point toward potential innovation. And what of the methodologies that we use to theorise the terrain? There is an advantage in looking through a range of lenses, as what one lens doesn't highlight, another may. However, with the continual developments in technology, we need to also consider how MT might open up innovative approaches to methodology and research design. As a community, we need to continue to explore the edges, while incorporating the generic ways these innovations inform practice, reshape the learning experience and might enhance students' mathematical thinking.

This book draws from a diverse range of international studies, where MT have influenced the ways that learning might occur across a range of educational contexts. The book is divided into four sections: *Looking across the terrain; Traversing the learning and teaching landscape; Navigating content: focussing on particular concepts*; and *Exploring new forms of communication to make mathematical learning visible*. While the purpose of these groupings is to draw the reader's attention to particular themes within the chapters, there is nevertheless considerable overlap between the sections, and most chapters could have easily been situated in more than one section.

The first section, *Looking across the terrain* considers some generic aspects that straddle the diversity in the field. Larkin and Milford use cluster analysis to group apps based on particular processes, features and concepts. Undertaking this process enables the apps to be grouped independently from developers' marketing and highlights particular aspects that mathematics educators consider as important. Through this educators are supported in their selection of apps for the user's intended purpose, and hence enhance app use in mathematics classrooms. Calder and Murphy analyse aspects of a 2-year study involving primary children learning mathematics through the use of mobile devices and apps. With the teachers as co-researchers, they examined teacher practice and the inter-connectivity between teacher pedagogy and the affordances of the apps. The teachers used a diverse range of apps, including ones for screencasting and coding, with the various learning experiences and opportunities for influencing the learning outlined and considered. An interesting theme to emerge across the use of various MT was socio-material assemblages. The final chapter in this section also investigates the interplay between a range of contexts and the types of apps used in these contexts. Attard considers the notion of student engagement when using apps for mathematical learning. Her framework for interrogating aspects of engagement incorporates cognitive elements. She draws together common threads about engagement, while synthesising insights into a collection of different studies related to engagement in various contexts.

The second section, *Traversing the teaching and learning landscape,* includes chapters that link teaching and learning related to various learning processes that utilise particular processes or affordances of MT. Kyriakides and Meletiou-Mavrotheris discuss a multifaceted programme designed to provide a group of in-service teachers with the knowledge, skills, confidence, and practical experience required to effectively use tablet devices for enhancing mathematics teaching and learning. The teachers integrated the app *A.L.E.X* into their lesson plans and thus reshaped the students' learning experience. Sollervall, de la Iglesia, and Zbick explore how mathematics classroom teachers can implement an innovative mobile learning activity. They report on an ongoing, 5-year study into using a GPS app for geometry, with the focus of the activity involving GPS and spatial orientation tasks that are executed in outdoor settings. Sedaghatjou and Rodney's chapter considers how a particular multitouch app called *TouchCounts*, along with children's collaborative engagements, can enhance mathematical learning of number. They utilise *StudioCode* software to better understand children's collaborative, gestural practices within the *TouchCounts* environment. In the final chapter of this section, Bokhove, Clark-Wilson, and Pittalis consider two cases of how MT provided opportunities for "mathematics outside the classroom". The examples describe how using mobile phones with augmented reality allowed students to bridge between formal and informal mathematics learning. Their examples, a dynamic Ferris wheel and a static cathedral are used to demonstrate how educators can use *geo-location* and *augmented reality* to enhance the learning of mathematics through MT.

In the third section of the book, *Navigating content: focussing on particular concepts*, the authors primarily attend to specific mathematical concepts or processes. Pelton, Milford, and Francis Pelton use an app to develop children's understanding of time. Their chapter details the integration of a researcher-designed iPad app into a series of collaboratively created lessons to facilitate the learning of clock-reading and time concepts. The authors used a lesson study approach to design and refine the intervention that included teacher-led activities and structured use of the iPad app. Lommatsch, Tucker, Moyer-Packenham, and Symanzik examine what patterns were revealed when heatmaps were used with hierarchical clustering to examine pre-schoolers' performance with two touchscreen mathematics apps in two different learning sequences: counting and seriation. Their analysis highlighted changes in children's performance, speed, and developmental progressions after using the two apps. The use of hierarchical clustering analysis facilitated the analysis of individual and whole group data leading to the identification of young children's developmental progressions. Rosen, Palatnik, and Abrahamson explore an embodied-design for engaging particular mathematical concepts with an action level where the virtual objects were either generic (e.g., a circle), or situated, (e.g., a hot-air balloon). They evaluate an instructional methodology whereby students first learn to physically move objects on the screen before eventually generalising these movements as formal mathematical rules. Chorney and Sinclair describe a research project with first-grade children using a multi-touch, dynamic geometry app called *WebSketchpad* to study how the concept of symmetry arises. They analyse the data through the lens of inclusive materialism, considering the intra-actions involved in the child-device-geometry assemblages, and how new mathematical ideas might emerge from these assemblages. Their particular focus is how the multi-touch environment can provide the basis for emerging geometrical ideas. Ferrara and Savioli discuss a classroom-based

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intervention with a group of first-grade children using the multi-touch app *TouchCounts* to develop children's number sense. They investigate how understanding might emerge out of the relational entanglement of numbers, iPads, and learners, engendering new kinds of mathematical experiences with number and providing the basis for emerging relational meanings of number. In the final chapter of this section, Soldano and Arzarello examine an approach to geometry in a secondary-school context. Their chapter illustrates a way of using MT to support the transition from an empirical to a theoretical approach to geometry. Drawing on Zbiek's et al., (2007) notions of pedagogical, mathematical and cognitive fidelities, they implement group game-activities whereby students investigate the geometric property upon which the game is designed.

In the final section of the book, *Exploring new forms of communication to make mathematical learning visible,* the notion of screencasting is the focus. The use of screencasting opens up opportunities for mathematical thinking of learners to become more transparent as students and teachers might create individual explanations of their thinking using a blend of both digital tools and their associated social elements. Galligan and Hobohm examine a case study of the use of mobile devices and screencasting in university mathematics education teaching. They incorporate this with an evaluative tool for teachers and students to evaluate their own and others' screencasts, with the intention of developing pre-service teachers' understanding of mathematics and ways to teach it. The chapter concludes with recommendations for using screencasting to assist with developing mathematical understanding and pedagogical content knowledge. Prescott and Maher explore the ways primary-school students worked collaboratively to solve a problem, explaining their mathematical thinking. The students used screencasting apps such as *Explain Everything* and *Educreations* to produce create-alouds, which helped them to collaboratively understand and explain mathematical concepts. The apps also assisted teachers in providing formative assessment and feedback to the students. In the final chapter of this section, Ingram, Pratt, and Williamson-Leadley discuss how a Show and Tell app can make the students' thinking more observable in problem solving. They consider how using Show and Tell apps for problem solving can lead to improvements in the level and quality of student engagement. Students were encouraged to socially negotiate their understandings, making student thinking more visible during this process. The apps can also scaffold students in reflecting upon the processes they used for problem solving.

The learning opportunities provided, and the evolution of the ways of promoting engaging mathematics learning and thinking through MT, exist in a fast moving, dynamic space; one where the comparative costs for mobile devices and connectivity are dropping markedly. There are also emergent MT that might quickly come to dominate the field: virtual reality is already developing rapidly, as is artificial intelligence and robotics. Some trusts and educational systems are distributing, to all schools in their community, 3-D printers that can print using materials as diverse as wood and titanium. Due to the reduction in the costs of MT, many of the previous equity and accessibility issues are alleviated. The potential to envisage space, location, shape, number, movement and rates of change has already been transformed. Likewise, ways of analysing data to model real-life situations in situ have changed. Yet, despite the rapid change we have witnessed in recent times, we do not really know where the technology, or its potential as a digital pedagogical medium, is headed. What might the landscape look like in 5 years, let alone in 20 years?

Underpinning each of the chapters in this book is the understanding that mathematical thinking must be given primacy—in the end it is our guiding premise and intention. We need to ask ourselves whether what we do with MT enhances mathematical thinking and understanding and to reflect on how the MT might be changing what counts as mathematical activity. The chapters in the book contribute to mathematics teaching and learning by providing readers with opportunities to reflect on their practice. It is not possible, nor wise, to ignore the role of MT in enhancing teaching and learning in mathematics. Therefore, all educators need to be alert to the potential that MT provide to enhance student learning.

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