Using apps for teaching and learning mathematics: A socio-technological assemblage

Nigel Calder
University of Waikato
<nigel.calder@waikato.ac.nz>

Carol Murphy
University of Tasmania
<carol.murphy@utas.edu.au>

This paper reports on an aspect of a research project that examined the use of apps in primary school mathematics programmes. It reports teacher and student perspectives on how they used a range of digital tools within the apps to solve problems. We consider the interplay between the affordances of the mobile technologies, including multi-representation and haptic, with other social and pedagogical aspects, and how the assemblage of social and technological entities influences the ways that teachers might integrate apps into their mathematics programmes.

Introduction

Mobile technologies (MT) are ubiquitous in our social and occupational landscapes. Their low instrumentation and ease of operation, together with the potential to facilitate interaction, offer potential for enhancing the teaching and learning process. This interaction focuses primarily on touch and visual elements, making them intuitive for learners. Coupled with MT in educative settings is the use of educational apps. These can vary in quality evoking questions regarding the appropriateness of the content and pedagogical approaches of some apps (e.g., Philip & Garcia, 2014), but, with MT relatively prevalent in classrooms, their potential to enhance mathematical learning requires examination. Previous research has suggested that the affordances of digital technologies, including MT, have the potential for offering fresh approaches to engage with mathematical concepts and processes, and for re-envisaging aspects of mathematical education in both primary and secondary settings (e.g., Borba & Villareal, 2005; Calder, 2011). National curricula refer to using digital technologies to: enable new learning environments, facilitate shared learning and enhance opportunities to learn (e.g., Ministry of Education, 2007).

In this paper we explore the potential of using apps in school mathematics programmes by examining teacher and students' views on the use of iPad apps. We also consider how an assemblage of social and technical elements can enhance the mathematics teaching and learning experience. We present data from a larger study on the use of apps, in two primary school settings. The aim of the full project was to undertake a co-inquiry with teachers into the ways MT might enhance student learning in mathematics. Through discussion with the teachers, a question arose in relation to the use of apps, including those used for screen casting to facilitate mathematical thinking. In particular, the features of the apps were examined in conjunction with the dialogue and other social aspects. It was suggested that in order to examine the learning experience provided by the apps and how teachers might enhance the mathematical learning, we needed to consider the inter-relationships between the learner and the digital medium through an assemblage of social and technical entities involved in a learning experience. The question examined in this paper was: How might

2018. In Hunter, J., Perger, P., & Darragh, L. (Eds.). Making waves, opening spaces *(Proceedings of the 41st annual conference of the Mathematics Education Research Group of Australasia)* pp. 194-201. Auckland: MERGA.

teachers utilise the assemblage of social and technical entities to enhance the mathematics learning process, when using apps?

Affordances

Building on the notion of affordance as the inter-relationships between the learner and the environment (Gibson, 1977) we acknowledge how the digital medium exerts influence on the students' approach, whilst the students' existing knowledge guides the use of the technology. Hence, the learning experience is fashioned in distinctive ways. For example, an affordance often associated with digital environments is the aspect of multiple representations, the ability to link and interact with visual, symbolic, and numerical representations simultaneously in a dynamic way (e.g., Calder, 2011; Sharples, Taylor, & Vavoula, 2007). Meanwhile, apps that enable screen casting, the digital recording of the computer screen, along with video and audio recording, introduce a further modal affordance in creating an aural representation of student thinking that can be listened to. This allows students to record individual or group presentations of mathematical processes, strategies and solutions, using a dynamic combination of tools and visual representations.

Other research contends that the affordances of digital technologies, coupled with the associated dialogue and social interaction, may facilitate students learning to pose problems and create explanations of their own (Sandholtz, Ringstaff, & Dwyer, 1997). They allow students to model in a dynamic, reflective way with other learners, mediating the language evoked through interaction with each other, the digital media and the mathematical ideas, and hence influencing the learning experience (e.g., Calder, 2011). Assemblage, as a theoretical perspective, acknowledges this inter-relationship of the multi-representations possible with apps, together with the mathematics and social interaction.

Socio-technological assemblages

Delanda's (2006) assemblage theory explored how inter-relationships are merged to form a social complexity. The social complexity as a whole emerges from heterogeneous parts and the properties of the whole emerges from the interaction between the parts. We relate Delanda's notion of assemblage with other theoretical perspectives suggestive of collectives. For example, Borba and Villarreal's (2005) perspective saw understanding emerging from the reconciliation of re-engagements of the collectives of learners, media, and environmental aspects with the mathematical phenomena. Borba and Villarreal contend that, as each engagement re-organises the mathematical thinking and initiates a fresh perspective, it in turn transforms the nature of each subsequent interaction with the task. The digital media influences the engagement and ensuing dialogue in particular ways, which, with self-reflection or further dialogue with others, transforms the learners' perspective (Borba & Villarreal, 2005). The learners then re-engage with the task from this new perspective.

It has been suggested that MT offer a socio-material bricolage for learning (Meyer 2015). Meyer envisaged interconnected systems where resources interact with knowledge that is socially distributed. A range of people, communities and sites of practice might be influential in assisting student learning. Meyer (2015) used the term socio-material bricolage to describe the "ecological entanglement of material and social aspects of teaching and learning with technology" (p. 28).

The notion of bricolage suggests that there is a mutually influential collective of tools and users affecting the dialogue, learning experience, and mathematical thinking, in particular and personalised ways. For example, when students collaborate on a task, they incorporate input from the wider class, school and “home” communities, while also drawing from the broader underlying discourses, such as political or socio-cultural elements that influence their pre-conceptions about the task and mathematical activity. De Freitas and Sinclair (2014) discussed thought as being distributed across both social and physical environs and influencers. We consider that thought evolves in a complex material and social milieu. When screen casting their strategy and solution(s) the students might incorporate a range of digital, visual, and concrete material resources in mutually interdependent ways. All of this activity has associated social elements, both immediate interaction as well as the drawing forth of the underlying discourses. The resulting process is not just the accumulation of the various ‘bits’, but also a new mesh of the social and material elements.

From these various theoretical perspectives, the whole, or in the case of this paper the learning experience, becomes the articulation of discursive and non-discursive elements of objects and actions (Delanda, 2006). However, a key distinction is Delanda’s proposal that all entities and relationships, whether social or non-social, are ontologically and epistemologically indistinct. As such, knowing or understanding within the learning experience is no longer a means of representing or reflecting on new knowledge but one of interacting with and creating new knowledge. Social assemblages may be codified through language, whereas non-social or technical may not. However, the very use of the technical can be seen as expression and this is illustrated through the multi-representational and multi-modal affordances of the iPad. The learner may select representations as a way of expressing and creating knowledge; the learner may also use hand actions with the touch interface of the iPad screen, again as a way of expressing and creating knowledge.

Despite distinctions, these perspectives of merging learners with digital media within a situated learning experience, point to the notion of an assemblage of digital and social elements which we term a socio-technological assemblage. In this paper we report on teachers’ and students’ perceptions when using mathematics apps and investigate how they perceived the learning opportunities presented by the apps. Some considerations for teachers’ practice are then indicated, in relation to teaching and learning mathematics and to the notion of socio-technological assemblages.

Methodology

The research for the larger two-year project used an interpretive methodology related to the building of knowledge and the development of research capability through collaborative analysis and critical reflection of classroom practice and student learning. The research design was aligned with teacher and researcher co-inquiry whereby the university researchers and practicing teachers work as co-inquirers and co-learners (Hennessy, 2014), In the first year of the project three teachers, all experienced with using MT in their programmes were involved in the study. The schools were situated in a provincial city. One teacher taught a year-4 class (7 and 8-year olds) in a school that used a BYOD approach, while the other two teachers team-taught in a combined year-5 and 6 class (9 to 11-year olds) in a school with one to one provision of iPads (80 students in total). In the second year, 12 teachers across a range of age groups and experience with using apps were involved. Data, obtained through different sources(focus group interviews, classroom observations, interviews with teachers, and blogs), were analysed using NVivo via a mainly inductive or grounded method to identify themes. While the researchers identified the initial themes and

codes, refinement occurred through joint critical reflection between teacher practitioners and academic researchers in research meetings. One theme identified in the research meetings was socio-technological assemblages.

In this paper we present data from teacher interviews, class observations, student focus group interviews and individual blogs in order to investigate their views in relation to student learning. We consider the ways that socio-technological assemblages may help to examine how the use of apps influenced the students' interactions with mathematical ideas. The student blogs were obtained partway through the first year of the project, while the teacher interviews and student focus group interviews were carried out at the beginning and end of both years.

Results and Analysis

Teacher Data

The data were relatively cohesive, in terms of apps being influential in the learning process, regarding the connection between the use of the apps, other technologies such as concrete materials, and the dialogue and social interaction that engagement with them evoked (Meyer 2015). For instance, students were observed using the iPad to investigate a problem in context, then using counters and rods, all the time interacting with each other and the range of tools. They used an empty number line in the app and a white table for story boarding the screencast of their strategy and solution. This was then loaded into a *Google classroom* site that the teacher could access for review and feedback.

One teacher, Brad, saw this tapestry of material and social elements as an ecosystem:

> Brad: There's a really big app eco system – I don't think there's many other devices that you can program on the iPad and then program robots and record your voice and make videos and all that stuff – it's a very rich ecosystem.

There were also instances where concrete materials were used in conjunction with apps. For example, Joy talks mainly of an assemblage of material elements. However, the associated social aspects, including the relationships and interaction between students, teacher, school community and the broader societal discourses are inherent in the activity described:

> You might do something with those Cuisenaire rods… those plastic things… there's also an app that would do it as a lesson and then there's an app that actually has the rods in it, so the kids can go away and practice moving them around the screen after they've done it with you physically… so there's a nice connection.

One teacher commented on the direct interface of the iPad screen, suggesting that the students were interacting more directly with the content of the mathematics:

> Like a physical object that they're interacting with.

The teacher further explained how apps involving screen casting for recording students' strategies were powerful agents in learning as the students were,

> creating something...explaining their own thinking, creating their own content, their own language.

This teacher comment points to the notion of personalisation of the learning. The students are creating their own content and language, hence differentiating the experience and learning to some extent.

Another teacher noted how screen casting enabled less confident students to explain their thinking in a "nonthreatening environment" with

> no teacher staring at them, no other kids waiting for them to hurry up. They're in a safe place where they can just record their thinking without any pressure.

Student Data

In the student blog data, references were made to the features and affordances of the apps and iPads, how these influenced the learning experience and the ways understanding might emerge. Several blog entries referred to the multimodal affordances of screen casting.

> You can record your learning and you can see what stage you are working on and: Instead of writing in our book we can just record our voices and upload it to Google classroom!

The use of the *Multiplier* app also illustrated the haptic affordance as the students used their fingers to draw out the matrix and had both visual (including colour coding), and numeric representations simultaneously linked together. It was a multi-levelled problem-solving environment with a tap used during the experimentation and review stages:

> You tap on which one you think is correct.

The use of programming apps with Sphero robots made strong physical and visual connections too, especially in geometry.

> We used this app (Tickle) to learn about making shapes, angles and vertices.

Students made further comments related to a mixed use of pedagogical media. For example, the students were comfortable moving between their iPad and more traditional media:

> I can still switch back to my book easy and it's still easy to use apps.

The students recognized the same potential for using a mixture of technologies at the appropriate time for their learning:

> Tim: Sometimes I make a plan (on paper) to work out my word problem, then I can put the pictures on and record my answer on the iPad.

Key viewpoints from the student blogs referred to the dynamic multi-modal representations, hand actions and the haptic, and exploration. Students also referred to mediation through programming and the use of different pedagogical media.

These key viewpoints were reiterated in the student interviews. The students talked of videoing themselves doing maths and recording their working. As one said,

> It's just like making a movie for maths.

The use of multiple modes simultaneously supported this student in expressing his thinking. The opportunity to pause, reflect, and edit recordings also appeared to be significant in supporting students in expressing their thinking.

> The cool thing is that you can actually pause it and then think about what you're going to do.

Other students referred to the opportunity to use the different visual and dynamic representations on the iPad and how these introduced them to new strategies.

> I learnt how to use the reversing strategy on the number line.

Students also referred to opportunities for collaboration with their peers and how they worked on a mathematical idea together.

> I like working with my friends and then recording our voices like working out an equation together.

Collaboration also provided the opportunity to explore and experiment with mathematical ideas:

> Luke asks me to work with him because we like to help each other out and solve things – so if we don't get something we try and work it out.

Students also contested ideas and processes when collaborating on a problem using *Minecraft*, on a single iPad. From the observational data:

Aaron	Okay, 5 lots of 5 blocks
Zac	Yep, 5 blocks
Don	Shall we use a line? (He indicated where the 5 blocks might go on the screen)
Zac	No, not 5 blocks up!
Aaron	Yes, you need to use it there.
Don	Yeah, there.
Zac	Is it? No, this one (pointed to the screen)
Aaron	You need the 5 blocks across and going up (indicated on the screen)
Zac	Oh yeah, yeah now I see.

Here, Zac's understanding of the solution and the process changes through the discussion related to the group's direct interaction with the app. It was the visual tension evoked from touching the screen, and the immediate impact from that action, that initiated the dialogue and also enabled, in conjunction with the dialogue, the transition in Zac's understanding. In this way the learning through apps took place within interconnected groupings of digital elements and the social aspects that they evoked. The responses from students suggested further viewpoints in relation to the use of multiple modes in expressing and creating their thinking, visual and dynamic images in learning key concepts, and peer collaboration in sharing ideas and in exploring or working our new knowledge.

Discussion

Teacher and student responses acknowledged the potential of the iPad in manipulating objects dynamically onscreen. They spoke of acting directly with the object and referred to tapping or drawing on the screen. The screen-casting feature was seen to introduce multiple modes and representations as students worked simultaneously with dynamic visual recordings (drawing, manipulating digital tools, and writing symbols and words), along with speech, to create a dynamic aural-visual representation. The coding app *Tickle* was used to connect numeric and symbolic representations in the coding with the physical movements of the *Sphero* and the creation of geometric shapes. Although the movements were mediated by the coding process, the students commented on the connections between the movements and their learning. Furthermore, the teachers and students referred to collaborative working with their peers. They indicated how ideas could be shared and worked on together again. The students also mentioned how non-digital as well as digital technologies were used together. All these elements draw forth from the underlying preconceptions and discourses that each individual's socially situated context evokes.

In sum, teacher and student data were suggestive of inter-relationships between the multi-modal affordances of the iPad, along with other non-digital entities including peer interaction and other pedagogical media. These inter-relationships are interpreted through the notion of an assemblage where social and non-social become merged.

In relation to Delanda's (2006) assemblage theory, the learning experience is viewed as a social complexity constituted of heterogeneous entities. Students' comments were suggestive of social assemblages such as the use of verbal language when communicating with each other or voice recording. However, students also communicated through tapping on the screen or in sharing a document. Students also referred to use of hand actions when using *Multiplier* or *Tickle*. As such, the technical materiality, that is the multi-modal affordances of the iPad, were used by the students to communicate and express ideas. Social and non-social could be seen to merge in line with Delanda's theory, and the learning experience became a means of interacting with and creating new knowledge in ways that were determined by the features of the iPad as well as through other media and communication.

Borba and Villarreal's (2005) perspective focused on engagement within a collective of learners, media and the environment. Engagement re-organises thinking and provides fresh perspectives for re-engagement. The students suggested opportunities to interact in collaborative ways to "work it out" and experiment. The students had opportunities to pause recordings in order to reflect before engaging further with the media. In order to interact with the mathematical ideas, the students drew on existing knowledge and affective dispositions to engage with the mathematical ideas through, not just the iPad, but through a range of social interactions that evoked interpretations or understandings that were negotiated further (Calder, 2011). The teachers noted that the recordings were a way for the students to show their thinking processes when solving a word problem. It appeared that, through pausing and editing, the students took time in preparing and perfecting their recordings. They were able to reflect on what had been said and think about what to say next. Here the students were influenced by the iPad, which they then influenced.

From both theoretical perspectives the multimodal affordances of the iPad can be seen to provide new entities for social and technical to merge as an assemblage or a collective within a learning experience. So, in answer to our initial query about how teachers might utilise the assemblage of social and technical entities to enhance the mathematics learning process, we would suggest that, teachers need to be aware of the potential for the various representations possible through using apps to be connected through engagement. As well, the potential for that engagement to evoke social interaction and collaborative thinking. The content and nature of the screen-casting recordings were seen to merge the multiple modes of verbal expressions with drawings and symbols. Students created their own ways of expressing their knowledge. Furthermore, some students developed these recordings collaboratively and acknowledged opportunities that enabled them to share and negotiate their knowledge in conjunction with the multi-modal affordances. Such recordings compiled individually or collaboratively, would seem to illustrate the notion of a socio-technological assemblage that could influence the mathematical understanding of those that created them and those that viewed them.

Conclusions

Previous research has suggested that MT offer affordances that can reshape the learning experience. In this paper, we aimed to consider how teachers might utilise the assemblage of social and technical entities to enhance the mathematics learning process, when using apps. The idea of an assemblage suggests that the same mathematical phenomena can evoke different ranges of social and technical entities when approached through alternative pedagogical media, and so the resulting learning experiences, constituted by the merging of these different ranges of social and technical influences, will differ. Teachers might consider

the ways that they use apps in their mathematics programmes. Are they including screen-casting apps that allow the students to use an assemblage of technical and social elements to both explore and communicate mathematical thinking? The research suggested that they emphasise the collaborative aspects that using apps evoke, including the potential to stimulate the contestation and validation of ideas and processes. Also, that they give opportunity for students to move seamlessly between material and digital resources. They should consider giving opportunity for coding, which might mediate the mathematical thinking. They might also utilise apps that include haptic and aural affordances as well as the more commonly recognised ones, such as linking multi-representations. As tools, apps have considerable potential for teachers to reshape the learning experience and offer students new ways to engage with mathematics. This is consistent with expectations for teachers' programmes as expressed in national curricula. Most importantly, we found that the quality of the teachers' pedagogy and practice was more influential than the quality of the app.

We acknowledge the support of the Teacher and Learning Research Initiative.

References

Borba, M. C., & Villarreal, M. E. (2005). Humans-with-Media and the Reorganization of Mathematical Thinking: Information and Communication Technologies, Modeling, Experimentation and Visualisation, New York, NY: Springer.

Calder, N. S. (2011). Processing mathematics through digital technologies: The primary years. Rotterdam, The Netherlands: Sense.

de Freitas, E., & Sinclair, N. (2014). Mathematics and the body: Material entanglements in the classroom. Cambridge: Cambridge University Press.

Delanda, M. (2006) A new philosophy of society: Assemblage theory and social complexity. London and New York: Continuum,

Gibson, J. J. (1977). The theory of affordances. In R. Shaw & J. Bransford (Eds,). Perceiving, acting, and knowing: Toward an ecological psychology (pp. 67-82). Hillsdale, NJ: Lawrence Erlbaum.

Hennessy, S. (2014). Bridging between research and practice: Supporting professional development through collaborative studies of classroom teaching with technology. Rotterdam, The Netherlands: Sense.

Meyer, B. (2015). iPads in inclusive classrooms: Ecologies of learning. In P. Isaias, J.M. Spector, & D. Ifenthaler. E-learning systems, environments and approaches theory and implementation. Dordrecht: Springer International Publishing.

Ministry of Education (2007). The New Zealand Curriculum. Wellington : Learning Media.

Philip, T.M. & Garcia, A. (2014). Schooling mobile phones: Assumptions about proximal benefits, the challenges of shifting meanings, and the politics of teaching. Educational Policy 29 (4), 676-707.

Sandholtz, J.H., Ringstaff, C., & Dwyer, D.C. (1997). Teaching with technology: Creating a student centred classroom. New York: Teachers' College Press.

Sharples, M., Taylor, J., & Vavoula, G. A theory of learning for the mobile age. In R. Andrews, & C.A. Haythornthwaite (Eds.) The Sage Handbook of E-Learning Research. (pp. 221–247). Los Angeles: Sage Publications.