Engaging Pre-Service Non-Specialist Teachers in Teaching Mathematics Using Embodied Technology Tools

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We report on an initial analysis of survey data that was generated through a collaboration between the schools of Education and Information Technology in exploring pathways through which future teachers could envision mathematics as engaging and creative subject, while also enhancing their awareness of, and skills in, using digital technologies in teaching mathematics. We specifically share insights generated into students' attitudes towards, current understandings of, and expectations for uses of technology in teaching and learning mathematics in schools. We bring attention to a mismatch between pre-service teachers views of technology and those of technology educators.

The study reported in this paper was initiated under an umbrella of a large Australian multi-university project *Inspiring Mathematics and Science in Teacher Education (IMSITE).* The project aimed at enriching pre-service teacher education in science and mathematics by fostering genuine, lasting collaboration of relevant discipline and education scholars, and by institutionalising new ways of integrating the content and pedagogical expertise of education and discipline professionals. We analyse data collected as part of a collaboration between the schools of Education and Information Technology, in exploring pathways through which future teachers could envision mathematics as engaging and creative subject, while also enhancing their awareness of, and skills in, using digital technologies in teaching mathematics. We specifically share insights generated into students' attitudes towards and current understandings of and expectations for uses of technology in teaching and learning mathematics in schools.

Australian secondary pre-service teachers are becoming increasingly aware of a shortage of qualified mathematics teachers, with recent reports estimating that 21% of those who teach mathematics in middle years (teaching 12-15 year old students) in Australia teach the subject out-of-field (Weldon, 2016). This means that even for pre-service teachers whose specialisation area is not mathematics, it is rather likely that they will be, at some point in their teaching career, asked to teach middle years mathematics subjects. As a means of addressing this situation, universities are offering mathematics education courses for pre-service secondary teachers of other subject areas. At the University of Queensland, an elective course focuses on introducing the notion of teaching mathematics for conceptual understanding (Boaler, 2016; Carpenter & Lehrer, 1999), and engages pre-service teachers as learners in types of mathematical activities where they explore mathematical patterns and relationships and where memorising formulas and producing calculations is not positioned as central to mathematical activity.

Over the years, many pre-service teachers recognised the need to take the mathematics elective course and expressed the belief that this choice can positively impact their

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employability. In spite of such awareness, enrolling into a mathematics course—or imagining themselves as teachers of mathematics—is not unproblematic for many of these students. Anxiety towards mathematics broadly and mathematics teaching specifically remains a persistent issue (Haciomeroglu, 2014; Ho et al., 2000). For some of the pre-service teachers, their prior experiences from mathematics classrooms, beliefs about mathematics and how it should be taught, and identities as mathematics learners that they developed in the process of schooling (Boaler, 2002; Cobb, Gresalfi, & Hodge, 2009; Gresalfi & Cobb, 2006) present difficulties when attempting to productively re-engage with mathematics in teacher education courses. At the one hand, technologies are often conceptualised and trialled as a tool for engaging students' in curriculum (e.g., Norton, 2006). At the other hand, technology itself can be a source of additional anxiety for teachers and pre-service teachers (Duhaney, 2001; Wachira & Keengwe, 2011), and this in turn can instigate lack of interest and motivation to integrating technology when teaching mathematics. Bennison and Goos (2010) remind us of the importance of supporting and educating teachers in the use of technology, so that they experience opportunities to build up their confidence and develop positive beliefs about technology.

Background: Digital Technology in Mathematics Education

Even today, most of the research on technology for mathematics classrooms focuses on use of computers and calculators (Wachira & Keengwe, 2011). As a number of more hands-on alternatives become available, a number of distinctions about their uses in classrooms or by learners become relevant. We would like to focus in particular on the distinction between *passive*, *passive interactive*, and *interactive tangible technology*.

The category of passive technology includes those technologies where a user is viewed primarily as a consumer or recipient. Examples include online videos and PowerPoint slide shows, when intended uses do not extend beyond viewing the ready-made content. Passive interactive technology includes so called *amplifiers*, such as Excel spreadsheets and calculators, which allow users to perform the same actions that they performed with non-digital tools and technologies earlier, but provide significant improvements of the speed and organisation of these actions (Lee & Hollebrands, 2008). *Coding platforms* that allow students to create their own tools (e.g., to perform calculations and create graphs) are another example in this category. Finally, the term interactive tangible technology refers to those technologies that not only aim to develop students' computational thinking ability and deepen their learning of mathematics, but also allow for creation of physical representations of the mathematical concepts.

Within the latter category, visual programming tools, including robotics with Lego Mindstorm and Scratch programming language, have been documented to serve as adequate platforms for students' development of problem solving skills (Spector, Lockee, Smaldino, & Herring, 2013). These tools have generated unparalleled student interest, encouraged independent thinking, while at the same time increased the immediacy of relevant feedback. Examples of ways in which instructional activities with these tools facilitated learning include learners noticing a mistake or a faulty assumption quickly, and taking (often) independent steps to correct it. For instance, if the robot doesn't behave in the way the learner intended, inputs can be re-assessed, conjectures about their functioning readjusted, and new iteration or trial enacted.

Within such classroom activities, the focus is taken away from whether an incremental 'result' has been 'correct' and the premium is instead placed on figuring out, progressively, how to create the desired solution. Errors and mistakes have their legitimate place in the students' activity as they become a means of increasing the insight into the problem situation and contributing to the resolution. While this set of values is highly compatible with mathematics teaching practices that aim for students' conceptual understanding, focus on correctness and speed remains ingrained as a focus in too many mathematics classrooms (cf. Boaler, 2016).

In the types of activities afforded by visual programing tools, students' construction of understandings from their lived experiences is almost palpable (Mikropoulos & Bellou, 2013). Robotics allow knowledge to be presented in a variety of different forms as an aid to substantive knowledge (Merrill, 2002). This creates possibilities for logical, objective truths and abstract problems to take on new meaning by becoming adaptive tangible experiences that provide tools for sense making (Núñez, Edwards, & Matos, 1999).

The Study Background

All 87 students undertaking a Graduate Diploma in education who enrolled in mathematics elective course during their one-year program were invited to participate in various aspects of data collection related to IMSITE study. Within the elective course, they were offered to participate in two optional, free, four-hour workshops that focused on (a) developing skills in technology for mathematics classroom use and (b) how technology can be used as an exciting pathway to mathematical learning. The workshops were conducted on campus on Saturdays and aimed at introducing new, practical, and engaging ways of exploring and using specific mathematical ideas in a classroom setting. The workshops were largely self-standing: The first one introduced Ev3 Mindstorm robots, while the second one focused on Scratch visual programing language and Makey-Makey technology.

We will limit our description to *Ev3 Mindstorms Robotics* (see Figure 1), which is a collaborative educational technology that uses simple visual blocks to program (Figure 1a), and technic Lego bricks with a variety of sensors that allow for construction of relatively sophisticated robots (Figure 1b) that execute programed code (Eguchi, 2010). It is currently used in many primary and secondary schools in Australia due to its modification flexibility, ability to interact with the world using sensors, and relatively easy-to-learn visual programing with blocks. It also allows teachers to later introduce more challenging programming through using a more traditional written code.

Figure 1. Ev3 Mindstorm Robotics (a) block code program, and (b) robot in action

Technologies that were the focus in the workshops are advantageous for their adaptability, as they can readily be reconfigured to expose a variety of mathematical principles in a physical and dynamic way. Specifically, activities during the workshops included programing the robot to trace a square on the floor, estimate distances and angles, flexibly switch between metric units and units needed in programing the robot (e.g., number of rotations of wheels). Additional activities designed for classroom use included programing robots to move with uniform speed for differing numbers of seconds, as a means to explore graphs of linear functions.

After the course, students were expected to develop a lesson plan, and then implement that plan with support in a classroom during their pre-service placement in a state school.

Participants were recruited by an open invitation on an online student portal; emails and reminders in-class were given throughout the course. Although initially there was considerable interest from the 79 students in the course, in the end only five students could participate in the workshops with only two participating on both days. These numbers were much lower than anticipated, however we decided to still offer the program. Not only did we want to see how the pre-service students went about implementing robotics in their classrooms, but we decided that it would be imperative to understand what motivated the students to participate and what were the main barriers to participation to those who initially expressed interest in the activities.

At the end of the semester, after lectures had finished and in-service work was completed, a survey was sent out to the students. It was intended to generate insights into students' views of technology in the mathematics classroom and an understanding of the low participation numbers in the optional workshops. The survey had four main themes: attitudes towards mathematics, attitudes towards inclusion of technology in mathematics subject areas, technology and teaching in the future, and participation in workshops.

From a class of 79 students, eight completed and returned the survey. From the responses, we derived emerging themes (Harding & Whitehead, 2013) of attitudes towards technology and how these pre-service teachers currently perceive its role in mathematics, which we discuss in the remainder of this paper.

Results

Attitudes towards Mathematics

Our initial questions regarded students' enjoyment of mathematics. Our aim was to ascertain their level of anxiety towards mathematics, that might hinder further development in this area. All participants agreed or strongly agreed that they enjoy mathematics, and all but one participant felt confident in teaching mathematics in high school up to Year 9. We took this to indicate that the majority of participants who chose to fill out the survey, although their major was not in mathematics, believed they had reasonable mathematical background and were generally positive towards teaching mathematics in middle years classrooms.

Although respondents themselves were positively disposed to mathematics, they believed not many students would be so disposed. Respondents were asked to finish either or both statements "Overall, students dislike mathematics because…" or/and "Overall, students like mathematics because…" Interestingly, there wasn't a consensus between the respondents as to why students have a dislike of mathematics. Eight different types of factors were given as to students' unfavourable dispositions:

Relevance, mathematics is not grounded in subject areas that concern or interest students and "may seem irrelevant to what they think is important". If mathematics is not grounded in what students perceive they will be doing in the future, then mathematics becomes an obsolete subject - something they have to get through.

Difficulty level, the unachievable measure which students believe they have to attain to succeed and do well in mathematics was discussed four times in the responses given. Respondents used phrases such as “they tell themselves they are too stupid to do it”, “difficult to understand”, and “they don’t get the concepts”.

Teaching styles, the way in which content and approach to problems is given by teachers isn’t consistent, among each year level.

Teaching levels, teachers don’t always explain concepts at the child’s level, “students who do not ‘get’ maths from a young age are forever playing catch up”, “from my prac experience, some students didn’t listen to the teacher at all because their maths was not good in the beginning to learn new content” and “it’s hard to find someone who explains things well i.e. at your level”. The three responses indicate how teaching mathematics was perceived as difficult especially in classrooms with diverse students, where teachers had to ensure that everyone has access to mathematics required in classroom activities.

Maths assessment, respondents noted two different ways assessment may hinder students’ enjoyment of mathematics. The first was success at exams, “they don’t do well in maths exams so they start to dislike the maths.” The second was related to the style of assessment “Maths is also frequently tested for procedural competency and not frequently placed in applied contexts that students are familiar with and as such produces high levels of anxiety about failing the subject”

Hindrance to independent thought, students may believe that mathematics does not allow for different views of the world “Because there is no room for individualism and interpretation” that other subjects allow. Students’ belief that there is either a right or a wrong solution or way of doing something would shape their enjoyment of mathematics.

Required Practice, exercises are required to be performed outside the classroom, if you want to become better mathematician you need to practice.

Only for the gifted, “Viewed as the specialised or privileged knowledge of those with a ‘maths gift or talent’”

The richness and complexity of reasons that the pre-service teachers could generate for why students might dislike mathematics indicates that, in their views, supporting students’ mathematical learning would be a complex issue, often outside of teacher’s control.

When commenting on “overall students like mathematics because…”, not all respondents provided answers, and only 3 types of responses were given:

Successful, it is satisfying when one can solve a problem, obtain the solution, and move on to bigger challenges.

Interesting, teachers can make maths a “fun and interesting” subject to learn.

A right answer, a “perceived clear equity in results (eg. I got 20/25 right)”

The positive responses given to how students perceive mathematics were limited compared to the negative responses. The pre-service teachers did not suggest that mathematics in and of itself might elicit enjoyment. Instead they seem to believe that it is always up to the teacher to provide the fun during the lesson, and problems that would allow students to experience success. While this is a potentially useful perspective, the responsibility can be at times overwhelming for pre-service teachers.

Attitudes towards Inclusion of Technology in Mathematics Subject Areas

Pre-service teachers were asked if they planned to use technology in their classrooms and what type of technologies they would use. Figure 2 shows the distribution of the types of technologies discussed. Screen based, non-interactive technology and PowerPoint (also a non-interactive technology) were most frequently selected to be used. In contrast, data generating or collaborative work spaces, which can be seen as more tangible type of technologies, were at the low end of included technologies. Embodied tangible technologies such as Robotics and Makey-Makey were not discussed.

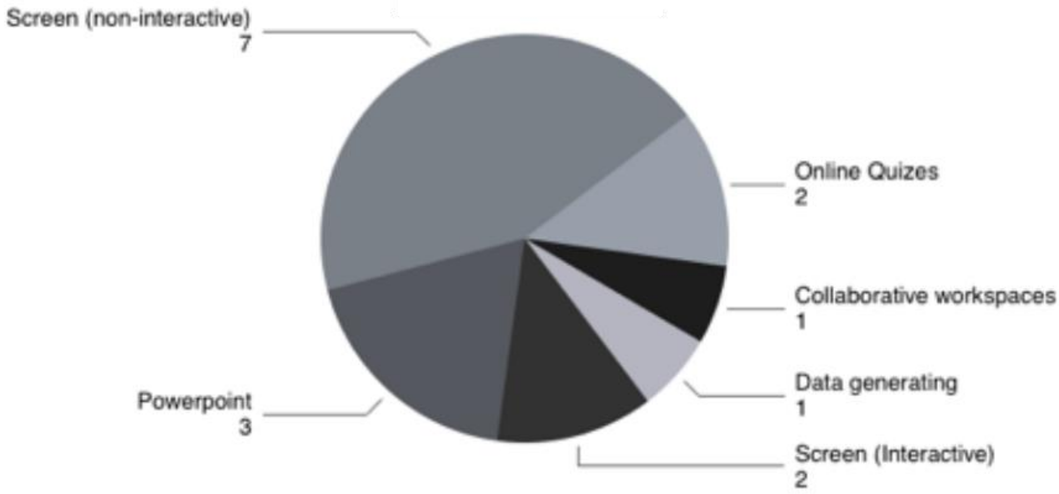

Figure 2. Technologies planned to be used in the classroom

Pre-service teachers were asked to evaluate their level of confidence and how interested they would be to learn more about technology in the classroom. Seven respondents stated that they are confident user of technology and seven said they would like to learn more about use of technology in the classroom.

When viewing these two results together, respondents viewing themselves as having a high level of confidence and utilising non-interactive screen-based technologies indicates that they view ‘confidence in technology’ in the sense of users rather than creators. This points to the need for design of activities that would support pre-service teachers in coming to view themselves as creators of technology. This would be a necessary step if we hope that pre-service teachers would create ‘technology creation’ goals for the learning of their future students.

Technology and Teaching in the Future

Respondents were asked to give their views of where they see the role of technology in the next 2-5 years, in relation to education and classroom teaching. The most responses were varied with most consensus that technology will be a larger part of day-to-day classroom. The majority of responses was made up of uses such as replacing paper. For example, one respondent saw technology to become “integral but not a dominant component - it does not cater for all learning styles”. In their responses, pre-service teachers indicated that they view technology as a means for passive use, not as something they can proactively control, shape, and integrate as an interactive tool.

Limitations

When viewing the outcomes of the data, it is important to note that the participants in the survey are not necessarily indicative of the population of pre-service non-specialist teachers studying mathematics in Australia. However, the insights generated are indicative of some currently existing views. Further explorations would be essential to elaborate the range and prevalence of different perspectives that could inform design of effective teacher education interventions and programs.

Discussion

One of the reasons why we find this to be an especially interesting case, is because the students' responses portray how the pre-service teachers conceptualised technology primarily, and at times exclusively, as a tool for passive content delivery. This is in a stark contrast to the valuation of technology that is widespread amongst technology educators, where students are to be supported in developing computational thinking skills and building their own tools. If the views of these two communities continue to misalign, the potential for technologies to enhance core curriculum areas will remain under realised. Although classrooms are full of technologies, these technologies are being used to either marginally enhance content delivery (e.g., by viewing videos over internet streaming) or as amplifiers to allow students to perform task quicker and easier than they would be able to do with a pen and paper. While these kinds of interactions with technology might build users confidence, and the level of comfort they perceive around the use of technology, they rarely significantly alter the range and depth of mathematical (and other disciplinary) ideas that are accessible to students in the classroom.

Interestingly, through optional course additions, we have not been able to equip the pre-service teachers with understanding that interactive technology can help students create their own tools and help them understand abstract mathematical principles. It is also interesting to note that research previously discussed revealed in multitude of ways how different technologies help in mathematical understanding by making it fun, interesting, adaptive tangible experiences. Finding ways to support pre-service teachers in both engaging in similar experiences and in designing such experiences for their students is of utmost importance.

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