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Research paper

Teachers' perspectives of changes in their practice during a technology in mathematics education research project

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HIGHLIGHTS

- Explores teacher change using digital technology for teaching mathematics over three years.
- Ongoing support necessary, but not sufficient for sustained teacher change.
- Knowledge, beliefs, and practices impact on potential for teacher change.
- Digital technology use in teaching mathematics remains a challenge.
- Transformative power of digital technologies for learning mathematics often unrecognized.

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ABSTRACT

Teachers' perception of changes to their teaching practice, with respect to digital technology use in secondary school mathematics, during their participation in a research project are reported. Two case studies are presented of teacher perspectives illustrative of the range of perceived changes teachers made to their practice and positions along the 'path of change' during their participation in the project. Participating in a project supportive of teacher change and resulting in perception of substantial change was necessary, but not sufficient, to meet the goal of transformative use of digital technologies to increase the level of cognitive demand experienced by students.

1. Introduction and background

Many teachers around the world participate in research projects most often as the ones being researched or vicariously through teaching those who are being researched. In some projects, however, in particular design experiments (Collins, Joseph, & Bielaczyc, 2004), teachers are seen as co-researchers with others who are from outside the schooling environment. As Bielaczyc notes, "design research methodology is meant to provide a means of constructing robust theories of why certain practices are effective and how learning occurs in context." (2013, pp. 258–259). This paper focuses on secondary mathematics teachers' perceptions of changes in their own practice in digital technology use during the time of their participation in a three-year project where the research methodology used was a series of design experiments.

The overarching aim of the project was to enhance mathematics achievement and engagement by using technology to support real world problem solving and lessons of high cognitive demand in secondary mathematics classrooms (Years 9–11). The research presented in this paper is part of a larger study by the author, within this project, focusing on teachers' and students' perception and enactment of the affordances of *technology-rich teaching and learning environments (TRTLE's)* with the major mathematical focus being student understanding of function (See for example, Brown, 2013, 2015). In the educational jurisdiction of the study, in Year 9 (14 year olds) the main focus is typically linear functions with quadratic and simple exponential functions introduced in Year 10. In Year 11, in Mathematical Methods (the main pre-tertiary mathematics subject) the focus expands to include polynomial, reciprocal, logarithmic, and exponential functions.

According to Evans (1991, pp. 125–126):

One way of characterising teaching tasks is through the kind of cognitive demand they impose on the learner: whether these

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consist in the requirement of specific procedures elicited by particular cues, recall of specific knowledge, development and application of structured conceptual knowledge, or higher order procedures involving interpretation, transfer of rules to unfamiliar materials, or the combination and modification of procedures.

Discovering how best to use technology in classrooms remains a priority research theme and "continuing challenge" in mathematics education (English & Kirshner, 2016) as well as other areas (Kim, Kim, Lee, Spector, & DeMeester, 2013). Kim et al. found that even participating in a four-year project, with teachers receiving the same resources, technology and professional learning opportunities, "the levels of technology integration were not the same" (p. 84). Technology use was a major focus of the research project described here with Texas Instruments Australia being an Industry Partner in the project, providing mathematical software and hardware to teachers and students in the project. This included graphing calculators (including, but not exclusively, CAS-enabled graphing calculators), and software including TI-Interactive (a CAS), spreadsheets, various geometry packages, and GridPic (an application developed specifically for the project, available http://extranet.edfac.unimelb.edu.au/DSME/RITEMATHS/general_access/curriculum_resources/).

1.1. Role of technology

Tikhomirov (1981), and many others since, described two possible roles for digital technologies, supplementation and transformation or reorganisation. The first of these, which he rejects, sees digital technologies as operating either as a substitute for humans or supplementation of human activity by a tool. He argues we should be working toward the second role. To explain these roles more clearly, a task commonly used in teaching functions is presented. The task involves beginning with a rectangular sheet of paper or metal, removing four identical squares from each corner, and folding to create an 'open box'. The aim is to optimise or maximise the volume of the container thus created. The task can be used prior to the introduction of calculus and either, or both, the numerical and graphical representation of the function used to identify dimensions when the capacity of the container is a maximum. A version of the task is then commonly revisited in the early study of calculus. The first version to be presented here, used by one of the teachers in the study (discussed further in Section 4) would be classified by Tikhomirov as using technology as a substitute or supplement. This is followed by a version of the task, design by the author to illustrate how the task can be altered such that the use of the technology provides opportunities for new or additional learning.

Fig. 1 presents an example of a task where the role of technology is predominantly one of supplementation. In this task, technology supplements human thought by the processing of information. In particular, the increased speed of this processing reduces the time taken, and, depending on the person, the results may also be more accurate. In this version of the task, designed and implemented by one teacher in the project, each student was given a specific measurement, individually constructed an open box, and determined its volume. The class then worked together to plot the results and interrogate the data to identify which box had the maximum volume. Technology, in this case a spreadsheet, was then used to recreate the data and show the same maximum value was identified.

Tikhomirov (1981) argued that, with regard to intellectual activity, we should be aspiring to the situation where "a transformation of human activity occurs, and new forms of activity emerge" (p. 271) through the use of digital technologies. In other words, human activity is mediated by technology use (p. 277). The revised version of the task presented in Fig. 2 illustrates how the task *can be* reorganised in such a way that the role of the technology becomes one of transforming learning. Tikhomirov (1981) argues that solving a problem is more than the processing of information. The changed task places demands on the solver to formulate the problem. Students having access to technology has allowed the task to be transformed and thus allows students to engage in a task of higher cognitive demand than was inherent in the original version of the task.

Needless to say, a teacher can alter a task during implementation and the potential for transformation is not necessarily enacted. As reported elsewhere, Stillman, Edwards, and Brown (2004) describe three mediators of cognitive demand: task scaffolding, task complexity, and complexity of technology use. Each of these can be varied by the teacher, thus altering the level of cognitive demand. The third mediator, in particular, is closely associated with the opportunity for transforming teaching and learning. Mathematical modelling, or real-world problem solving, has as its focus the complex real world, and hence by their very nature are of high cognitive demand. One focus of the project was to ascertain how technology could be used to support real world problem solving. It is important to note that technology can be used at all stages in the modelling cycle, and is not restricted to carrying out computations.

The graphing calculator screen shots (illustrated here using a TI-84Plus graphing calculator), shown in Fig. 3, are illustrative of likely solution paths students may follow in solving the revised version of the task, although students may not necessarily undertake all steps. Differing digital technologies, specifically function graphers (rather than data plotters), allow similar approaches. The steps include:

- Using dynamic LIST formula to generate data for the initial card dimensions (See Fig. 3a),
- Plotting the data, and identifying coordinates showing dimensions of the open box with the maximum volume of the discrete set plotted (See Fig. 3a),
- Generalising the symbolic LIST formula to an algebraic formula and entering this as a function (See Fig. 3b),
- Graphing this function (See Fig. 3b),
- Recognizing that the function graph passing through the plot means the function is a correct representation of the data (See Fig. 3b),
- Identifying the function maximum within the domain using the TABLE feature and/or the inbuilt MAXIMUM feature (See Fig. 3c),
- Generalising the dimensions of the card used and entering a function with parameters that can be allocated different values so different size cards can be investigated (See Fig. 3d),
- Comparing the coordinates of the maximum turning point of different functions and interpreting this in terms of the actual maximum volume and the height of the box for a given size card that results in this maximum (See Fig. 3d).

1.2. Teacher knowledge frameworks in education

Whilst the roles for technology proposed by Tikhomirov (1981) are key constructs in this paper, it is important to acknowledge other important frameworks in education. Shulman's (1986) constructs of subject matter knowledge and pedagogical content knowledge, and their importance for successful teaching, are considered seminal work in the mathematics education research community (and beyond). He drew the attention of teachers and researchers around the world to the "difference between what it means to know and understand something yourself and what it takes to help someone else to come to know and understand" (Shulman, 2000, p. 130). Mathematical content knowledge (MCK)