Chapter 7
Digital Technologies in the Australian Curriculum: Mathematics – A Lost Opportunity?

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The initial framing documents that informed development of the Australian Curriculum – Mathematics noted that digital technologies could offer new ways of teaching and learning mathematics that help deepen students' understanding. This chapter examines the extent to which this aim has been achieved. It uses two research-based frameworks to analyse the technology messages in the publicly available versions of the Foundation to Year 10 and senior secondary mathematics curricula. The first framework uses the metaphors of *master*, *servant*, *partner*, and *extension of self* to gauge the extent to which technology transforms teaching and learning roles. The second classifies pedagogical opportunities afforded by technology in terms of changes to *tasks*, *classroom interactions*, and the *subject* of mathematics itself. In all curricula, expected uses of technology were found to be mostly consistent with the *servant* metaphor in that technology was referred to as a more efficient method for calculating or graphing. Pedagogical opportunities afforded by the curriculum were typically restricted to the level of *tasks*, where technology could be used to link representations or work with real data. Thus in this new curriculum for Australian schools, the potential for technology to support new classroom practices and curriculum goals remains unfulfilled.

Digital technologies have been available in school mathematics classrooms since the introduction of simple four function calculators in the 1970s. Since then, computers equipped with increasingly sophisticated software, graphics calculators that have evolved into "all-purpose" hand held devices integrating graphical, symbolic manipulation, statistical and dynamic geometry packages, and web-based applications offering virtual learning environments have promised to change the mathematics teaching and learning landscape. But what should be the role of digital technologies in school mathematics? Is technology meant to help students get "the answer" more quickly and accurately, or to improve the way they learn

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mathematics? It is particularly timely to consider this question when the new *Australian Curriculum: Mathematics* is about to be implemented in schools.

This chapter considers relationships between technology-related research and teaching practice and the development of the *Australian Curriculum: Mathematics*, and implications for supporting effective mathematics teaching and learning in Australian schools. The first part of the chapter considers key messages from research on learning and teaching mathematics with digital technologies. The second part offers some snapshots of practice to illustrate what effective classroom practice can look like when technologies are used in creative ways to enrich students' mathematics learning. The third part analyses the technology messages contained in version 1.2 of the *Australian Curriculum: Mathematics* (ACARA, 2011) and the challenges of aligning curriculum policy with research and practice.

Key Messages from Research on Learning and Teaching Mathematics with Digital Technologies

Fears are sometimes expressed that the use of technology, especially handheld calculators, will have a negative effect on students' mathematics achievement. However, meta-analyses of published research studies have consistently found that calculator use, compared with non-calculator use, has either positive or, at worst, neutral effects on students' operational, computational, conceptual and problem solving abilities (Ellington, 2003; Hembree & Dessart, 1986; Penglase & Arnold, 1996). In addition, it is often found that students who used calculators during class report more positive attitudes towards mathematics than their counterparts who did not use calculators. While rigorously conducted meta-analyses reassure us that calculator use does not erode students' mathematical skills or conceptual understanding, we may question some of the assumptions on which such analyses are based. In particular, meta-analyses typically select studies that compare treatment (calculator) and control (non-calculator) groups of students, with the assumption that the two groups experience otherwise identical learning conditions. They inquire into the *effects* of calculator use on students' mathematical achievement. However, experimental designs such as this do not take into account the possibility that technology fundamentally changes students' mathematical practices and even the nature of the mathematical knowledge they learn at school. A different research question that needs to be addressed is: What *changes* when students and teachers use digital technologies for learning mathematics?

Technology and Mathematical Knowledge

In their contribution to the *17th ICMI Study on Mathematics Education and Technology*, Olive and Makar (2010) analysed the influence of technology on the nature of mathematical knowledge as experienced by school students. They argued as follows:

> If one considers mathematics to be a fixed body of knowledge to be learned, then the role of technology in this process would be primarily that of an efficiency tool, i.e. helping the learner to do the mathematics more efficiently. However, if we consider the technological tools as providing access to new understandings of relations, processes, and purposes, then the role of technology relates to a conceptual construction kit. (p. 138)

Their words encapsulate the contrasting purposes of technology that were foreshadowed in the opening paragraph of this chapter. For learners, mathematical knowledge is not fixed but fluid, constantly being created as they interact with ideas, people, and their environment. When technology is part of this environment, it becomes more than a substitute or supplement for mathematical work done with pencil and paper. Consider, for example, the way in which dynamic geometry software allows students to transform a geometric object by "dragging" any of its constituent parts and thereby to investigate its invariant properties. Through this experimental approach, students make predictions and test conjectures in the process of generating mathematical knowledge that is new for them. Technology can change the nature of mathematical knowledge and the environments in which students learn mathematics. This potential for change should encourage us to reconsider what counts as foundational knowledge to be included in the school mathematics curriculum.

Technology and Mathematical Practices

Learning mathematics is as much about *doing* as it is about *knowing*. How knowing and doing come together is evident in the mathematical practices of the classroom. For example, school mathematical practices that, in the past, were restricted to memorising and reproducing learned procedures can be contrasted with mathematical practices endorsed by most modern curriculum documents, such as conjecturing, justifying, and generalising. Technology can change the nature of school mathematics by engaging students in more active mathematical practices such as experimenting, investigating, and problem solving that bring depth to their learning and encourage them to ask questions rather than only looking for answers (Farrell, 1996; Makar & Confrey, 2006).

Olive and Makar (2010) argue that mathematical knowledge and mathematical practices are inextricably linked, and that this connection can be strengthened by the use of technologies. They developed an adaptation of Steinbring's (2005) "didactic triangle" that in its original form represents the learning ecology as interactions between student, teacher, and mathematical knowledge (Figure 1). Introducing technology into this system transforms the learning ecology so that the triangle becomes a tetrahedron, with the four vertices of student, teacher, task and technology creating "a space within which new mathematical knowledge and practices may emerge" (p. 168). (See also Sträßer, 2009, for a related discussion of the relationship between teacher, student, mathematical knowledge, and artefacts such as digital technologies.)

Within this space, researchers have theorised new relationships between technology and its users. Arguing from a sociocultural perspective, Goos, Galbraith, Renshaw, and Geiger (2000) describe digital technologies as cultural tools that not only amplify, but also re-organise, cognitive processes through their integration into the social and discursive practices of a knowledge community. Learning is amplified in a quantitative sense when technology is used to speed up tedious calculations or to verify results obtained first by hand. A more profound cognitive re-organisation occurs when students' thinking is qualitatively transformed through interaction with technology as a new system for meaning-making. Other researchers take the position that not only does technology shape the knowledge constructed by students, but the tool itself is also transformed in a process described as instrumental genesis. Drawing on the instrumental approach developed by Vérillon and Rabardel (1995), Artigue (2002) explains that through this process a material or symbolic object, or "artefact", becomes an "instrument" through construction of personal schemes of use. Digital technologies are thus artefacts that have no instrumental value until they are used, and eventually transformed, for carrying out specific tasks. They become instruments when the individual constructs schemes of use or appropriates social pre-existing schemes.

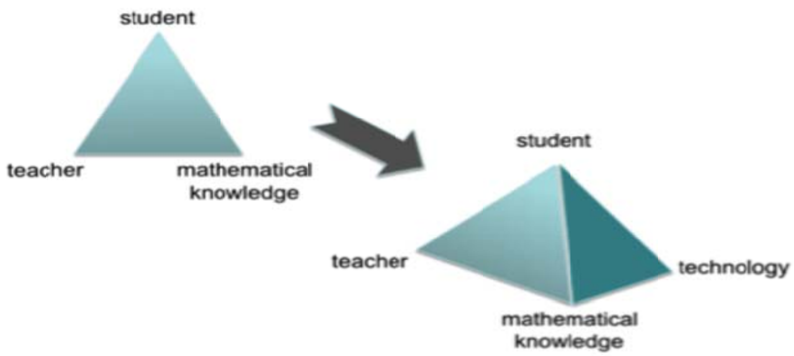

Figure 1. The didactic triangle becomes the didactic tetrahedron

Frameworks for Analysing Mathematical Practices

Within the tetrahedral space imagined by Olive and Makar (2010), students and teachers may imagine their relationship with technologies in different ways. Goos, Galbraith, Renshaw and Geiger (2000) developed four metaphors to describe how technologies can transform teaching and learning roles. Technology can be a *master* if students' and teachers' knowledge and competence are limited to a narrow range of operations. Students may become dependent on the technology if they are unable to evaluate the accuracy of the output it generates. Technology is a *servant* if used by students or teachers only as a fast, reliable replacement for pen and paper calculations without changing the nature of classroom activities. Technology is a *partner* when it provides access to new kinds of tasks or new ways of approaching existing tasks to develop understanding, explore different perspectives, or mediate mathematical discussion. Technology becomes an *extension of self* when seamlessly integrated into the individual and collective practices of the mathematics classroom.

Pierce and Stacey (2010) offer an alternative representation of the ways in which technology can transform teachers' mathematical practices. Their *pedagogical map* classifies ten types of pedagogical opportunities afforded by a wide range of mathematical analysis software. Opportunities arise at three levels that represent the teacher's thinking about:

- the *tasks* they will set their students (using technology to improve speed, accuracy, access to a variety of mathematical representations, or for working with real data or simulated real life situations);

- *classroom interactions* (using technology to change the classroom social dynamics or to change the didactic contract that governs students' and teachers' expectations of each other's roles);
- the *subject* being taught (using technology to provoke mathematical thinking, support new curriculum goals, or change the sequencing and treatment of mathematical topics).

Snapshots of Classroom Mathematical Practice

Three vignettes are presented here to illustrate how technology can be used creatively to support new mathematical practices. Each is analysed with reference to the two frameworks outlined in the previous section.

Vignette #1: Representing Irrational Numbers

Geiger (2009) used the master-servant-partner-extension-of-self framework to analyse a classroom episode in which he asked his Year 11 students to use the dynamic geometry facility on their CAS calculators to draw a line $\sqrt{45}$ units long. His aim was to encourage students to think about the geometric representation of irrational numbers. The anticipated solution involved using the Pythagorean relationship $6^2+3^2=\left(\sqrt{45}\right)^2$ to construct a right angled triangle with sides 6 and 3 units long and hypotenuse $\sqrt{45}$ units long (shown in Figure 2).

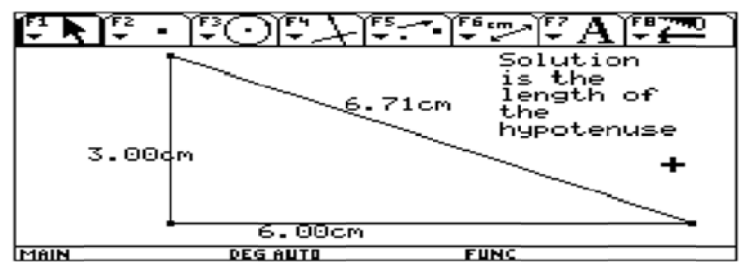

Figure 2. Drawing a line $\sqrt{45}$ units long

Students began by using their calculators in *servant* mode to find the square root of various numbers. They passed the calculators back and forth to share and critique each other's thinking. Because the calculator was used here as a medium to make thinking public, it took the role of a *partner*. The teacher invited one student to present her results to the class – the square root of 45 expressed to ten decimal places, which she assumed was a terminating decimal because the calculator was capable of displaying up to 12 decimal places. Other students pointed out that $\sqrt{45}$ is irrational, however, and cannot terminate. They helped the presenting student change a setting on the calculator that restricted the number of decimal places displayed. For some students, then, technology acted as their *master* because of their lack of familiarity with how to control the display features of the CAS calculator.

The teacher decided to give the class a hint, by making public a comment made by one student relating to triangles.

Teacher: But what would it *look* like?
Sam: Well, you could have a triangle…
Teacher: (to class) I think Sam's given you a hint!
Nicole: Has it got something to do with Pythagoras?
Teacher: Way to go!

Students began to use their calculators in *servant* mode once more, searching for Pythagorean triples without relating this to the geometric representation as instructed by the teacher.

Susie: So we're trying to relate it to 45! The hypotenuse.
Nicole: So the side of "a" could be √5 and the side of "b" could be √40, so √40 squared and √5 squared is 45.
Susie: But the length of the sides will be an irrational number.

Before long, the teacher redirected the class to consider geometry, not just numbers.

Teacher: There seems to be a lot positively related to the work we were doing yesterday, but walking around, there were five of you doing geometry and the rest of you were on your calculators working only with numbers. So, some of us are going to have to take a little risk and get out of our comfort zones. We like working with numbers because it's comfortable, but just because you're busy doesn't mean it's productive. Other people have given you big hints. You need to try to work with that.

Despite this advice, most students continued to search for a numeric solution, that is, by using their calculators merely as a *servant*. Nevertheless, one student, who had previously been working alone, joined the discussion in his group to convince the others that his solution was appropriate. He passed his calculator around the group, in *partner* fashion, to support his investigation of the task.

Diane: We've got two that are the same, so 45 = 9 + 36.
Gena: Yeah, so that equals 9. So write that down!
Karen: Tom wants your attention.
Gena: What are you trying to say Tom?

Tom: No. Because that squared plus that squared … whatever the number what … 6 point something … so ... To get that number, you need a right-angled triangle with a side of 6 and 3 and that -
Frances: I get it now!
Harry: How do you know it's going to be a rational number?
Tom: That! That's the root of 45. If you want to know how to draw it -
Harry: That line is going to be …
Tom: By drawing that and that and the right angle, you get that.
Gena: Yay! Cool!

In this episode, technology was initially used as a *servant* to perform numerical calculations that did not lead to the desired geometric solution. It became a *partner* when students passed their calculators around the group or displayed their work to the whole class to offer ideas for comment and critique. As a *partner* it gave the student who found the solution the confidence he needed to introduce his conjectured solution into a heated small group debate. In terms of Pierce and Stacey's (2010) pedagogical map, this episode illustrates opportunities provided by a *task* that links numerical and geometric representations to support *classroom interactions* where students share and discuss their thinking.

Vignette #2: Creating an Exponential Model

Geiger, Faragher, and Goos (2010) investigated how CAS technologies support students' learning and social interactions when they are engaged in mathematical modelling tasks. In this snapshot, Year 12 students worked on the following question:

When will a population of 50,000 bacteria become extinct if the decay rate is 4% per day?

One pair of students developed an initial exponential model for the population *y* at any time *x*, $y = 50000 \times (0.96)^x$. They then equated the model to zero in order to represent the point at which the bacteria would be extinct, with the intention of using CAS to solve this equation. When they entered the equation into their CAS calculator, however, it unexpectedly responded with a *false* message, shown in Figure 3. The students thought this response was a result of a mistake with the syntax of their command. When they asked their teacher for help, he confirmed their syntax was correct but said they should think harder about their assumptions.

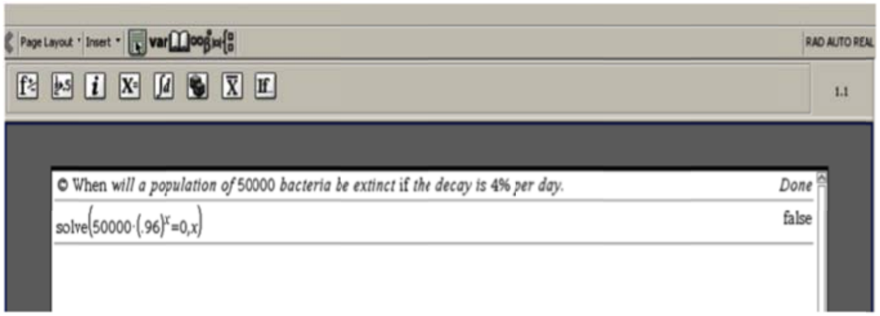

Figure 3. Calculator display for the problem $y = 50000 \times (0.96)^x$

Eventually, the teacher directed the problem to the whole class and one student spotted the problem: "You can't have an exponential equal to zero". This resulted in a whole class discussion of the assumption that extinction meant a population of zero, which they decided was inappropriate. The class then agreed on the position that extinction was "any number less than one". Students used CAS to solve this new equation and obtain a solution.

In this episode the teacher exploited the "confrontation" created by the CAS output to promote productive interaction among the class (technology as *partner*). Using this pedagogical opportunity also allowed the teacher to capitalise on the way the calculator displayed an error message to provoke mathematical thinking, thus fulfilling *subject* level goals of promoting thinking about the mathematical modelling process rather than practising skills.

> Teacher: It was pretty obvious to me why it didn't work but I deliberately made a point of that with a student to see what their reaction would be. And it was a case of pretty much what I expected. That they just grasped this new technology *Nspire* and were so wrapped up in it that they believed it could do everything and they didn't have to think too much. And so suddenly, when it didn't work, it took a fair amount of prompting to get them to actually go back and think about the mathematics that they were trying to do and why it did not give a result.

Interestingly, the teacher noted that even if the students were solving the equation without technology, they would still need to have this discussion about the meaning of "extinction". However, he used the error display to challenge their assumption that the calculator was a "black box" that would always produce the correct answer.

Vignette #3: Analysing Personal Data

This final example is drawn from a study that helped teachers plan and implement numeracy strategies across the middle years curriculum (Geiger, Dole, & Goos,

2011; Goos, Geiger, & Dole, 2011). Teachers were introduced to a model of numeracy whose elements comprise mathematical knowledge, dispositions, tools, contexts, and a critical orientation to the use of mathematics. The incorporation of tools into the model emphasised the ways in which symbolic tools and other artefacts "enable, mediate, and shape mathematical thinking" (Sfard & McClain, 2002, p. 154). In mathematics and non-mathematics classrooms, tools may be representational (symbol systems, graphs, maps, diagrams, drawings, tables), physical (models, measuring instruments), and digital (computers, software, calculators, internet).

As part of the study, one teacher developed an activity within her Year 8 Physical Education program where students investigated their level of physical activity through the use of a pedometer that they wore for one week. In previous years when completing this task, students had recorded their personal data in a table in their notebooks. The teacher would demonstrate the procedure for converting the number of steps to kilometres and instruct students to draw a bar graph to show how many km per day they had walked. However, as a result of her participation in the study, the teacher was now experimenting with a different, less directive approach that would encourage students to take a more active role in their learning.

Every day, students entered their data – the number of paces they had walked or run – into a shared Excel spreadsheet. They analysed their own data by using facilities within Excel, for example, the graphing tool, and then compared their results with those of other students (see Figure 4).

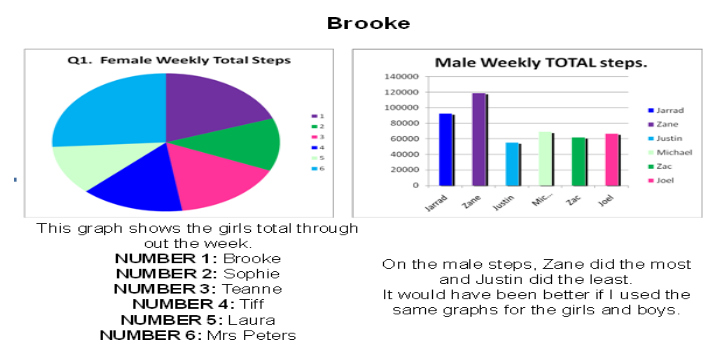

Figure 4. A comparison of males' and females' weekly total steps.

As part of this analysis, students were asked to convert their total daily and total weekly paces into kilometres to gain a sense of how far they typically walked in the course of a day or a week. The task was also designed to help students realize that the distance they walked was not determined by the number of paces alone as an individual's pace length was also a factor. This was the first time that the teacher had introduced digital technologies into her practice, so she relied on students in the class who were familiar with spreadsheets to help their peers, and also to help her. Students entered the daily numbers of steps recorded on their personal pedometers into a class spreadsheet that the teacher displayed via a newly installed interactive whiteboard. They used Excel formulas to calculate the total number of steps per week and the number of kilometres this represented for each student in the class. Students chose charts from the Excel menu to display their data and make comparisons, for example, between steps taken on different days of the week for one student, or between total steps taken by a male and a female student (Figure 4). If students chose inappropriate graphs for these purposes (e.g., line graphs), the teacher questioned them to draw out the reasons and lead them to identify better ways of representing their data.

The teacher and students used the spreadsheet as a *servant* to record, analyse and represent data; but this tool, together with the interactive whiteboard, was also a *partner* that mediated discussion between students in relation to differences they observed as they critically compared their own results to those of others and attempted to explain the differences. From the teachers' point of view, introducing the spreadsheet helped achieve her goal of changing *classroom interactions* by giving students a greater sense of authority and positioning the teacher as a co-investigator.

Aligning Curriculum with Research and Practice? Technology in the *Australian Curriculum: Mathematics*

The brief research summary and classroom snapshots presented above show how digital technologies provide a "conceptual construction kit" (Olive & Makar, 2010, p. 138) that can transform students' mathematical knowledge and practices. This is not a new claim; nor has the transformative potential of digital technologies been ignored in previously published curriculum documents and educational policy recommendations. For example, the National Council of Teachers of Mathematics (2000) lists six guiding principles for the content and character of school mathematics. These principles concern equity, curriculum, teaching, learning, assessment, and technology. The NCTM's Technology Principle states that "Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning" (p. 24). At around the

same time as the NCTM's *Principles and Standards for School Mathematics* were published, the Australian Association of Mathematics Teachers (2000) issued a communiqué on graphics calculators and school mathematics, which said: "There is a compelling case for the advantages offered to students who use graphics calculators when learning mathematics. They are empowering learning tools, and their effective use in Australia's classrooms is to be highly recommended". To what extent does the *Australian Curriculum: Mathematics* support this view of technology?

Early Versions of the Curriculum

The shape paper that provided the initial outline of the mathematics curriculum (National Curriculum Board, 2009) made it clear that technologies should be embedded in the curriculum "so that they are not seen as optional tools" (p. 12). Digital technologies were seen as offering new ways to learn and teach mathematics that helped deepen students' mathematical understanding. It was also acknowledged that students should learn to choose intelligently between technology, mental, and pencil and paper methods.

The draft consultation version 1.0 of the Foundation to Year 10 (F-10) mathematics curriculum expected "that mathematics classrooms will make use of all available ICT in teaching and learning situations". The intention was that use of ICT was to be referred to in content descriptions and achievement standards. Yet this was done superficially throughout the first published version of the curriculum, with technology often being treated as an add-on that replicates by-hand methods. Technology was mentioned in only 27 (14.6%) of the 185 content statements in this version of the curriculum, and 17 of these statements referred to technology in the following terms:

> Plot graphs of linear functions and use these to find solutions of equations *including use of ICT* (Year 8 Number and Algebra strand, emphasis added).
>
> Construct, read, interpret and make connections between tables and simple graphs with many-to-one correspondence between data and symbols, *including using ICT* (Year 4 Statistics and Probability strand, emphasis added).
>
> Visualise, demonstrate and describe the effects of translations, reflections, and rotations of two-dimensional shapes and describe line and simple rotational symmetry, *including use of ICT* (Year 5 Measurement and Geometry strand, emphasis added).

The implication of statements such as this is that ICT methods should do no more than provide an alternative, and perhaps quicker, method of completing the task, rather than transforming the nature of the task itself in developing students' mathematical understanding.

In the corresponding consultation versions of the four senior secondary mathematics courses, the aims for all courses referred to students choosing and using a range of technologies. Nevertheless, each course contained a common technology statement – "Technology can aid in developing skills and allay the tedium of repeated calculations" – that suggested a limited view of its role as nothing more than an "efficiency tool" (Olive & Makar, 2010, p. 138) that supplements pencil and paper calculations. There is no evidence here that the curriculum is informed by research that shows how technology can open the gateway to deeper understanding and exploration of mathematical concepts. Across the courses, variable messages about the use of technology were conveyed in words like "assumed" and "vital" in Essential and General Mathematics, to "should be widely used in this topic", "can be used to illustrate practically every aspect of this topic", or no mention at all for some topics in Mathematical Methods and Specialist Mathematics. An unfortunate implication of this variable treatment was that technology is only considered to be valuable for less able students and only for getting "the answer".

In the early versions of the F-10 and senior secondary mathematics curricula, uses of technology, where made explicit, were mostly consistent with the *servant* metaphor of Goos et al. (2000), despite the more transformative intentions evident in the initial shaping paper. That is, technology was mostly referred to as an alternative, faster, method for calculating with numbers, manipulating shapes, or drawing graphs. Pedagogical opportunities afforded by the curriculum were restricted to the level of *tasks* in Pierce and Stacey's (2010) taxonomy, in that technology was mentioned in relation to making computation and graphing quicker and more accurate and possibly to link representations. The tasks of the mathematics classroom and the sequencing of topics remained unchanged, despite the potential for technology to support new curriculum goals, new classroom practices, and new ways to treat mathematical topics.

Later Versions of the Curriculum

The General Capabilities section of version 1.2 of the F-10 curriculum maintains the emphasis on digital technologies, stating that "Students develop ICT competencies as they learn to use ICT effectively and appropriately when investigating, creating and communicating ideas and information at school at home, at work and in their communities" (ACARA, 2011, p. 9). This version of the curriculum contains 277 content descriptions, 50 of which (18.1%) refer to technology – a slightly higher proportion than in the consultation version. Nearly half of these descriptions (23 out of 50) refer to performing calculations, creating graphs, or manipulating shapes in the following terms:

> Solve a range of problems involving rates and ratios, *with and without digital technologies* (Year 8 Number and Algebra strand, emphasis added).
>
> Construct displays, including column graphs, dot plots and tables, appropriate for data type, *with and without the use of digital technologies* (Year 5 Statistics and Probability strand, emphasis added).
>
> Investigate the effect of one-step slides and flips *with and without digital technologies* (Year 2 Measurement and Geometry strand, emphasis added).

Saying "with and without digital technologies" instead of "including use of ICT", as in the consultation version, does little to elevate technology above its assumed role as an efficiency tool, equivalent in status and purpose to pencil and paper methods. There is now explicit reference to graphing and geometry software in the Number and Algebra and the Measurement and Geometry strands, but, remarkably, no mention of spreadsheets in the Statistics and Probability content descriptions.

The actual treatment of digital technologies in this version of the curriculum was investigated by electronically searching the document for the terms "technology", "technologies", "calculator", "computer", and "software". Content descriptions containing any of these terms were recorded in tables organised by year level (F-10A) and content sub-strand, for each of the three strands of *Number and Algebra*, *Measurement and Geometry*, and *Statistics and Probability*. The summary below draws out the main findings of this analysis in terms of the roles ascribed to digital technologies in each content strand and for the full range of year levels.

Number and Algebra. There is some reference to technologies in every year level from Years 3 to 10A, mostly in the sub-strands of number and place value, fractions and decimals, and real numbers Technology is mentioned in 21.2% of content descriptions, compared with 19.5% in the consultation version. This is usually in the context of using a range of calculation strategies (mental, written, using appropriate digital technologies), or of performing calculations with and without digital technologies. There is no mention of technology use in the patterns and algebra sub-strand; however, digital technologies and graphing software are highlighted in years 8 to 10A of the sub-strand on linear and non-linear relationships. Examples of their role here include plotting graphs, using graphical techniques to solve linear equations, finding distances, mid-points, and gradients, and exploring connections between algebraic and graphical representations.

Measurement and Geometry. Technology is mentioned in 19.5% of content descriptions, compared with 5.9% in the consultation version. Statements about digital technologies appear in content descriptions for all sub-strands – using units of measurement; shape; geometric reasoning; location and transformation; and Pythagoras and trigonometry – but not for all year levels. Surprisingly, technology is not incorporated into any content statements for Years 8, 9, and 10, despite there being plenty of scope for their use. For example, dynamic geometry software can be used to explore conditions for congruence of plane shapes (Year 8), to use the enlargement transformation to explain similarity (Year 9), or to investigate angle and chord properties of circles (Year 10A). Despite this gap, there is some support for using technology to draw and manipulate shapes, investigate transformations and symmetry, and assist in the development of geometric reasoning.

Statistics and Probability. In the chance sub-strand there is only one reference to digital technologies, in Year 6, in relation to conducting chance experiments. In Years 3, 4, and 5, the data representation and interpretation sub-strand refers to constructing data displays with and without the use of digital technologies. There is no explicit mention of technology in the secondary Years 7, 8, 9, or 10, despite the inclusion, for example, of content statements about comparing data displays, interpreting data displays and the relationship between the median and the mean (Year 7), investigating the effect of outliers on the median and mean (Year 8), and constructing and interpreting boxplots and scatter plots (year 10). Technology is mentioned in only 8.6% of content descriptions, compared with 20.0% in the consultation version. While there is scope for using the internet to address content statements that refer to evaluating statistical reports in the media or collecting data from secondary sources, it is surprising that spreadsheets have not been mentioned as an obvious tool for managing and analysing large data sets.

Technology and Mathematical Practices in the F-10 Australian Curriculum

In terms of the framework proposed by Goos et al. (2000) for describing the role of technology in mathematics teaching and learning, version 1.2 of the F-10 curriculum shows scant evidence of imagining a *partner* role for technology in enabling new approaches to existing tasks for developing students' understanding. The only suggestions for using technology in this way are found in the very few content statements that refer to "investigating", such as:

> *Investigate*, with and without digital technologies, angles on a straight line, angles at a point and vertically opposite angles (Year 6, Measurement and Geometry strand, emphasis added).
>
> *Investigate* combinations of translations, reflections and rotations, with and without the use of digital technologies" (Year 6, Measurement and Geometry strand, emphasis added).
>
> *Investigate* and calculate 'best buys', with and without digital technologies (Year 7, Number and Algebra strand, emphasis added).

By far the majority of statements referring to technology limit its use to that of a *servant* that speeds up, but does not really change, the tasks of the mathematics classroom. Perhaps the real problem is in effectively integrating the proficiency

strands with content descriptions so as to demonstrate how technology can help students develop not only fluency (as implied by the *servant* metaphor), but also understanding, problem solving, and reasoning capacities.

The pedagogical opportunities afforded by the curriculum are still restricted to the level of *tasks* in Pierce and Stacey's (2010) taxonomy, in that teachers are encouraged to use technology to improve speed and accuracy, link mathematical representations, or work with real data. To be fair, it is unrealistic to expect a curriculum document to transform *classroom interactions* (the second level of Pierce and Stacey's framework), since this remains in the realm of pedagogy. Nevertheless, a truly future-oriented mathematics curriculum might make a more serious attempt at transforming the *subject* itself, by (1) supporting curriculum goals that increase emphasis on concepts, applications, and mathematical thinking, or (2) changing the way that mathematical topics are approached and sequenced.

Conclusion

Although the technology messages contained in the *Australian Curriculum: Mathematics* do not do justice to what research tells us about effective teaching and learning of mathematics, it is almost inevitable that there are gaps between an intended curriculum and the curriculum enacted by teachers and students in the classroom. The published curriculum offers many opportunities for creative and effective use of existing digital technologies to teach the required content, whether or not technology is explicitly mentioned in the content statements. Teachers using a future-oriented curriculum should also be able to take advantage of emerging technologies associated with the Web 2.0 paradigm to create dynamic and interactive learning experiences. Within this paradigm, technologies such as wikis afford collaborative knowledge building so that students come to develop genuine expertise rather than relying on the teacher as the only authority. Similarly, portals like YouTube have transformed the Web into a performance medium where students can create and share new mathematical experiences. Immersive, media-rich technology environments therefore have the potential to further transform the mathematical practices of the classroom in ways that are still difficult to imagine. Many teachers are already using technology to enhance students' understanding and enjoyment of mathematics. In their hands lies the task of enacting a mathematics curriculum for the 21st century that will prepare students for intelligent, adaptive, creative, and critical citizenship in a technology-rich world.

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