Changing Landscapes in New Zealand Secondary Mathematics Classrooms?

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Introduction

Since the last ICME meeting in 2003 there have been three critical areas of development within lower secondary mathematics classrooms in New Zealand. Developments in these areas, broadly identified as assessment, numeracy practices, and the introduction of Computer Algebraic Systems (CAS), have been fuelled by changes in curriculum and practice both in the primary and upper secondary school sectors. Firstly, an upward thrust of national numeracy initiatives within the primary school sector has seen the introduction of the Secondary Numeracy Project (SNP) within selected secondary schools. Secondly, the relatively recent introduction of a National Certificate of Education Achievement (NCEA)—a standards-based assessment system focused on the final 3 years of secondary schooling—has created a trickle down effect into junior secondary mathematics classrooms. And thirdly, the gradual introduction of technology in the secondary schools and associated teacher concerns about students using technology in national assessment formats has generated interest in the integration of CAS at junior secondary school level. While implemented as discrete projects, collectively these ongoing projects have undoubtedly influenced our newly revised national curriculum framework document (Ministry of Education, 2007), and the mathematics curriculum in particular.

This paper first provides a brief overview of the Secondary Numeracy and CAS projects, and the introduction of standards-based assessment (SBA) practices within secondary mathematics classes. To look more closely at the influences on pedagogical practice the paper considers to what extent the SNP project and assessment reforms have the potential to 'change the landscape'. Drawing on data from a case study of one teacher's practice when teaching fractions to a year 9 class, I consider whether we are simply 'replacing' old trees with younger stock, or are we 'introducing' new species of trees that will contribute towards issues of sustainability and social justice within this new "age of consequence" (Al Gore, cited in McAlesse, 2007).

Overview of Programmes

Computer Algebraic Systems (CAS): This project focused at the junior secondary school level is a direct response to the increased use of technology within the senior secondary school and associated changes in assessment practices. The newly implemented NCEA mathematics assessment includes items which specify the use of technology. Prior research (e.g., Thomas & Hong, 2005) confirmed that despite the availability of graphic calculators there was little evidence that teachers had made significant and appropriate changes in their teaching of mathematics with technology. In 2005/6, a pilot project was implemented across 28 secondary schools at the junior level. The focus on the junior schools was for two reasons: the junior school level was seen to be an appropriate level to introduce this technology, and with the early stages of NCEA implementation in force, it was deemed practical to minimise disruptions to wholesale changes in NCEA classrooms. To date, project outcomes have been largely positive concerning changes in classroom teaching and learning (Neill & Maguire, 2006). However, of note, was the initial resistance to integrating CAS technology by some participating teachers and the ongoing concern regarding resistance from students and parents.

Standards-based assessment: In 2002, New Zealand replaced traditional end-of-year national examinations at the senior secondary level with a National Certificate of Education Achievement (NCEA). Comprised of sets of achievement standards for each subject and year level, students are awarded with 'achieved', 'achieved with merit' or 'achieved with excellence' grades. A major change within this standards-based assessment system was the introduction of significant internal assessment components that are managed by teachers. Current research concerning the impact of NCEA assessment on student achievement and pedagogical practices at the senior secondary school level (e.g., Hipkins, Wylie, Hodgen, 2007; Steward, Gray, &, Pilcher, 2007) suggests that teachers are embracing new assessment strategies, albeit slowly. Within the mathematics classroom, however, Rawlins' (2007) study found that some mathematics teachers are experiencing difficulties in adjusting from the summative 'end-of 'unit' test approach. While still in the early stages of NCEA implementation, the mathematics teachers in this study were yet to realise the formative potential of standards-based assessment within their classroom. Despite these concerns and considerable teacher protestations about atomisation of the mathematics curriculum and workload and moderation issues, the last few years has seen an *importing* of the senior assessment format into the junior secondary levels. Examples of assessment items provided for junior secondary schools as a result of adaptations of national standard-based assessment can be accessed on the New Zealand Association of Mathematics website (see reference). A critique of these exemplars suggest that while the new form of assessment provides specific information to students about *which areas* of their learning they have been successful in, the criteria associated with 'achieved', 'merit', and 'excellence', in many cases, represents a record of learning that is concerned with 'more correct' rather than on depth of conceptual understanding.

Secondary Numeracy Project: Since 2000 there has been a systematic implementation of a national Numeracy Development Programme (see Ministry of Education reference) within the primary school sector, to the extent that by 2009 all primary school teachers will have participated in mathematics professional development. The expectation that primary school students are experiencing reform type numeracy programmes that focus on the development of a flexible range of number strategy solutions rather than reliance on formal algorithms, combined with national testing evidence of 'gaps' in year 9 and 10 students' multiplicative and proportional reasoning, has stimulated the introduction of the Secondary Numeracy Project (SNP) within selected secondary schools.

SNP is a professional development initiative aimed at enhancing the teaching of year 9 and year 10 (first two years of secondary schooling) mathematics. In 2007, 132 schools were involved in professional development focused on the teaching of number and algebra. Unlike the primary level based professional development that involved external facilitation support, professional development in the SNP schools is coordinated by an in-school-facilitator—typically a senior member of the mathematics department—who has accessed national-based training.

The content of the school-based professional development shares feature with the established Numeracy Development Projects implemented within primary schools. The focus is on a Number Framework detailing progressions of number knowledge and calculation strategies, together with diagnostic interviewing. The aim of the professional development is to support teachers in developing students' numerical competency and understanding and generalisation of number strategies as a basis for algebraic thinking. The advocated pedagogical approach—one based on Skemp's (1986) theory of relational understanding and its derivative practice of students' strategy sharing—is structured around a formalised model of developmental stages of number. Learning experiences transition through physical representations, imaging, towards abstract mathematical concepts and algebraic thinking (Hannah, 2006). The overarching aim is that students will more readily develop the skills and dispositions towards mathematically accepted ways of thinking and reasoning.

Recent national evaluations of SNP project (Harvey & Higgins, 2007) focused on assessing the impact of teacher participation on teachers' professional knowledge and teaching. Analysis of self-reported questionnaire data from participating teachers and facilitators noted that whilst participation in the SNP had limited impact on teachers' mathematics content knowledge, approximately 50% of the teachers claimed that their knowledge of teaching mathematics had been challenged and or extended. Responses included references to an increased range of teaching strategies—including greater awareness and use of discussion and scaffolding techniques, greater use of a variety of representations, and increased responsiveness to the diversity of student needs within their class:

> Have had to learn, model and teach strategies. Have had to force myself to think in new ways rather than use algorithms. (p. 12)

> Learnt logical ways of introducing and developing concepts of proportions (fractions, decimals, percentages, etc.). (p. 12)

Many teachers reported that their increased responsive to students was influenced by new understandings of how students might view number problems and concepts, combined with greater awareness of students' thinking facilitated by classroom discussion, group work, and the use of diagnostic interviews. These changes in teaching practices and teacher knowledge were for many teachers directly related to reports of "positive attitude and progress of all students" (p. 16).

However, some of the responses implicated teachers with misunderstanding the programme intent, especially with regard to the focus on multiple strategies. For example, a teacher who suggested that the value of the SNP was "not necessarily all positive," cited doubts about the "pedagogical worth of *teaching* numerous strategies to solve one type of problem" (p. 13). Some teachers expressed concerned that their students continued to work with existing algorithms rather than the 'new' strategies that they were teaching and with the introduction of more materials and models one teacher remarked that "some students seem to remember the activity but not the theory behind it" (p. 16).

The advocated reforms in the SNP demand a major shift in teachers' thinking about and operationalising of practice. Working with secondary mathematics specialist teachers required that project designers be more accountable for the project directions than was the case for the parallel numeracy projects within the primary school sector. Focusing on the engagement of diverse learners in particular, many teachers questioned the use of ability-based grouping with such critique as:

> I find physical grouping of pupils disruptive and detrimental. Instead, I offer different methods of solving and the choice of which methods to tackle to the whole class. (p. 18)

For some teachers, adoption was at a surface level only. For example, such teachers interpreted getting on board as implementing the 'set' lessons; an exercise that proved "tricky…and caused differentiation issues" (p. 15). Several teachers expressed concern that the SNP was good for only some students, namely the "low ability" students. In contrast, one teacher attributed the SNP with making mathematics more enjoyable for the "weaker student" but simultaneously attributed the project with providing the "more able students a very clear expression of what they are doing" (p. 17).

An upside of the SNP project, with its origins in the primary school sector, is the greater understanding between the secondary and primary school sectors. Secondary teachers have had to engage with the teaching strategies promoted within the contributing schools, and have had to take increased cognisance of year 9 students' knowledge and understandings—building on rather than starting from fresh. As one teacher remarked:

> Primary school was a closed book to me previously. This knowledge has given me the skills and confidence to prepare lessons and deliver, which I didn't have before. I was a confident teacher with my existing knowledge but having the whole picture is of immense value to me. (p. 14)

Case study summary

Mathematics pedagogy is a complex and multilayered practice (Anthony & Walshaw, 2007) and is formidably difficult to change (Cobb, McClain, de Silva Lamberg, & Dean, 2003; Little, 2003; Spillane, 2000). Using data drawn from a case study (Lawrence, Anthony, & Ding, in preparation) of an experienced teacher who participated in significant professional development opportunities within the SNP during 2006 we examined how such efforts to support teacher learning and change played out in her teaching of fractions in the following year. The case study, part of a larger study examining the teaching and learning nexus, involved a year 9 class of high achievement grouped students within a large urban school. The data were generated from observations and video records of a sequence of ten lessons on fractions. In addition, stimulated recall interview data was collected from both teacher and a small group of students across the study.

In choosing fractions the teacher acknowledged that after the SNP professional development (including access to research literature) she was keen to make changes to the way she taught fractions. Her teaching of fractions in 2007, she claimed, was "totally different" and the post-fraction assessment indicated "huge improvement…especially in addition and subtraction of fractions" for the students in her class.

For her, changes in pedagogy were particularly associated with increased pedagogical content knowledge—specifically greater awareness of fraction representations and potential areas of students' difficulties. The introduction of the SNP diagnostic assessment material provided her with evidence of students' current levels of understanding—understanding that the teacher noted had previously been taken for granted:

> I knew fractions were difficult for students but I hadn't realised quite what was so difficult…when you look at it more, you realise just how complex fractions are.

However, while the diagnostic testing supported the teacher to become more aware of the diversity in students' understanding and the need to respond to individual needs, her explicit in-class references to the need to "fill the gaps" and sort out "difficulties" created tensions between teaching that emphasised building on students' existing proficiencies and teaching that focused on remediating apparent student weaknesses.

The teacher claimed that a change in orientation toward student learning outcomes was a key driver to changes in her pedagogical approach:

> I used to focus on what to do rather than the understanding…ordering, equivalent fractions, different representation plus the algorithm…but understanding of concepts are important.

Whilst she explicitly expressed this intent to the whole class—frequently telling students that she wanted them to understand or that she wanted them to demonstrate understanding—at times, her intent preceded her actions. That is, the teacher's attempts to occasion students' understanding involved, in some instances, the teacher *imploring* students to understand, the teacher *demonstrating* understanding, or the teacher *acknowledging* or *rewarding* student explanations that demonstrated understanding:

> That's where this method falls apart with the subtraction. That's what I wanted you to find out.
>
> I want to show you the understanding or the reason of what you are doing rather than just the rule.
>
> What I wanted you to do was to see visually what you were doing

The teacher's aim to promote greater student understanding was reflected in her move from textbook planning to the use of a wider range of instructional activities—including manipulatives and folding and cutting activities—that would not have been used previously with the higher streamed/set students. Her 'starter' questions/activities were more carefully chosen to link to students' current mathematical competencies. For example in exploring equivalence concepts, students constructed fraction fringes that enabled the physical identification of a range of equivalent fractions using area models, and in introducing multiplication, students used fraction grids to solve 1/2 of 1/3 as represented by the intersecting area. Reflecting on her changed stance the teacher noted:

> It's not that I didn't use diagrams before…I would use them to illustrate an example in notes, say…but now I use them to develop the understanding, see in different ways, so they can get the picture then move onto the abstract.

Diagrams were frequently promoted as a useful tool—they offered 'thinking spaces' that helped organise students' mathematical thinking:

> You might want to draw diagrams, so visually you can actually see.
>
> Did it help drawing a diagram? I find it helps to see.

Focused on developing students' understanding, the teacher exhibited an awareness of the need to place students' reasoning at the centre of instructional decision making. She reported that starter activities were chosen to elicit student solution strategies—strategies that she hoped would form the basis of new learning across the class. For example when teaching division of fractions, in contrast to her previous provision of the invert and multiply algorithm, her approach this time was more focused on students developing an understanding of the algorithm through using material and diagrams. In one lesson she pressed the students to take responsibility for learning as follows:

> Look at it through a diagram and I want to see if you can come up with the rule…did you notice the pattern in all of the questions that you did? Rather than me coming in and going here's the rule, ladies, I want you to see what you were doing in terms of area.

However, inviting the students to 'come up with a rule' was not always a successful instructional practice. For example, within the lesson sequence fraction division was introduced via a set of word problems involving scenarios such as: *The Murphy family had a party and had 3 and 3/4 pizzas left over. The kids decided they could invite friends over the next day for pizza. They figured each friend would eat 3/8 of a pizza. How many people could be fed?* We observed the majority of students solving this problem by re-presenting the pizza problem as $30/8 \div 3/8$. This then was solved as equal to $10/1 = 10$ people or (less frequently) by using repeated subtraction. In asking the students to share their strategies the teacher appeared not to recognise that the proffered informal methods were at odds with the 'formal' method involving reciprocals that she was about to present as 'notes'. Without this connection it was not surprising to find that the two students who were interviewed post lesson expressed uncertainly as to why division problems 'turned into a multiplication' problems. Alas, Sally demonstrated to us immediately following the lesson that $2/3 \div 3/4 = 3/2 \times 4/3 = 12/6 = 2$. It appeared that in this instance the change in pedagogical practice was mediated by the teacher's pedagogical content knowledge. Unable to anticipate the range of strategies that might arise from the division activities meant that the teacher's intent to utilise the students' solution strategies as building blocks to develop a more formal strategy for division of fractions was unable to be enacted effectively.

However, throughout the lesson sequence it was evident that the discussion of and access to multiple solution strategies, rather than a teacher provided way, was a key routine that the teacher was keen to promote. The teacher frequently asked students to share their solution strategies, prompting others to offer alternatives, and highlighting that problems could often be solved in a variety of ways: (e.g., "You can use your fraction fringes, but don't have to"; "There are many different ways to get the answer.") However, the benefits or connections between alternatives were sometime unexplored. For example, when discussing the multiplication of fractions the teacher provided notes detailing two ways of proceeding—multiplying across numerator and denominators and then simplifying to an equivalent fraction, or cancelling first and then multiplying across numerators and denominators. However, there was no mathematical discussion of the merits or links between these two 'methods'—they were presented as an 'either or' based on personal preference.

While clearly focused on the establishment of norms of participatory discourse, changes in her listening and interaction behaviours were still in the process of development. Ainley and Luntley (2007) describe the importance of teachers developing *attention-dependent knowledge*—knowledge that enables teachers to respond effectively to what happens during the lesson. For the case study teacher, the press for students to voice their emergent thinking meant that she was sometimes faced with the challenge of unexpected student observations or questions. For example, one student completing practice exercises on multiplication questioned the teacher as to why the answer "is smaller when it is times". The teacher's on-the-spot response—"I'm impressed with you coming up with that because whenever you multiply you think it's going to be bigger…we saw that in decimals as well didn't we?"—while commending the student's observation and attempting to make connections with decimals was unlikely to significantly extend the student's mathematical thinking. In the post-lesson observation the teacher reflected "how much more the students were thinking about things themselves", but she was aware that in this instance the student's comment was "left hanging" as she resisted further engagement in dialogue that may have digressed from the lesson script.

These few exemplars attempt to capture the emergent and non-linear nature of teacher change. Whilst the teacher noted in post-lesson interviews that she had made significant changes in the expectations concerning students' participation rights and obligations, orchestrating the discussion in ways that were simultaneously responsive to individual responses and collective understanding proved challenging. In addition to emergent pedagogical practices of anticipating, monitoring, selecting, sequencing, and making connections between students' mathematical solutions (Stein, Engle, Hughes, & Smith, submitted), the teacher needed to more readily make connections between the students' and *her own* solution strategies.

While the teacher's efforts to provide richer learning activities and contexts frequently occasioned learning opportunities for *both* the teacher and students, the use of classroom video in the post-teaching interviews revealed that the teacher was in some instances unaware of tensions (as discussed above) in intent and enactment of some practices or was prompted to reflect on these only when reviewing the lesson. It appears that the professional development for this teacher—an experienced and highly regarded teacher—went only part-way to creating stimulus for change. In terms of the metaphor introduced in beginning of the paper, 'new seedlings' have indeed been planted. However, for these seedlings to grow into 'new species' involving pedagogical practices that simultaneously increase students' sense of control and support the development and use of effective mathematical inquiry practices, change needs to be generative. Drawing on Leinhardt and Greeno's (1986) accounts of the cognitive skills involved in teaching, Ainley and Luntley (2007) suggest that expert teachers, as was the teacher in this study, should have a greater capacity to obtain information about students' progress and thinking. Having successfully established a learning environment which values respectful interactions that contribute to the enhancement of students' aspiration and attitudes, the likelihood is that the increased opportunities for shared participation will result in the teacher understanding her students better. However, we tentatively hypothesise that the teacher attention-dependent knowledge of this teacher will only strengthen in relation to reform practices if her attention moves from a more traditional focus on what Ainley and Luntley label *cognitive problems,* where students show differing understanding of mathematical ideas promoted by the teacher, to include a greater focus on *cognitive opportunities,* opportunities that involve trying to extend students' thinking.

Conclusion

While implemented as discrete projects, collectively the projects highlight changes in teachers' formative assessment practices within the mathematics classroom, their provision of increased opportunities for inquiry learning and sense making, and their use a range of tools to assist students thinking about, and engaging with, mathematics. Notwithstanding the challenges of reform (Leinhardt & Steele, 2005; Walshaw & Anthony, 2007), teachers in these projects are increasingly mindful of the need to address major issues facing mathematics today. For New Zealand, curricula and policy directions reflect a realisation that specific groups of students continually register low proficiency levels in mathematics and increased recognition of the challenge of student diversity inherent in classrooms today (Anthony & Walshaw, 2007).

For generative growth to occur post professional development there is clearly a need to constantly water and nourish the 'seedlings'. Understanding more about how to support both experienced and novice teacher learning both during and following professional development is the object of much research internationally. Within New Zealand, recent studies (involving primary teachers) have signalled some possible ways. Specifically, the use of a communication participation framework that can scaffold the development of inquiry classrooms (Hunter, 2008) and the use of video study (Davis & Walker, 2005, 2007) provide examples of ways to support teacher learning within communities of practice.

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