An Evaluation of the CAS Pilot Project

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Six schools were involved in a pilot scheme to evaluate the use of CAS calculators (Computer Algebraic Systems). Twelve teachers underwent professional development on effective ways to use CAS calculators in algebra and geometry. They then integrated the CAS hand-held calculators into these strands in their mathematics teaching. The project aimed to improve the teaching and learning of mathematics through the use of new generation graphics calculators that include CAS technology. Indicators of effectiveness that were monitored included changes in teacher practice, changes in student attitudes towards mathematics, and changes in student learning. Other areas that were evaluated included the professional development provided, the impact of CAS technology on assessment, attitudes towards technology, and issues of sustainability for the CAS initiative. The project shares many common values with the Numeracy Development Projects, and synergies between the two should be explored.

Background

During the first three years of the implementation of the National Certificate of Educational Achievement (NCEA) in mathematics, it became apparent that there was a need for support for teachers in the use of technology to improve teaching and learning in the classroom. Although a considerable number of teachers were using graphics calculators, there was little evidence that they had made changes in their teaching practice. *Mathematics in the New Zealand Curriculum (MiNZC)* (Ministry of Education, 1992) endorses the use of technology in mathematics and "assumes that both calculators and computers will be available and used in the teaching and learning of mathematics at all levels" (p. 14).

Reports from teachers and from research suggest that the use of this technology can improve students' conceptual understanding of mathematics. It was decided to initiate a pilot project in 2005 that would look at ways to improve the teaching and learning of mathematics in New Zealand schools using calculators that included CAS technology. CAS (Computer Algebraic Systems) refers to mathematical software that has the capability of manipulating algebraic expressions, solving equations, and differentiating and integrating complex functions.

This pilot project focused on the junior secondary school level (two year 9 classes in six schools around New Zealand were involved in the 2005 pilot) so that any effects of NCEA examinations in New Zealand schools on classroom practice would be kept to a minimum. Other countries are using CAS technology in the teaching of mathematics, but that teaching is at senior secondary level.

Methodology

Six schools took part in the pilot project, four in the North Island and two in the South Island. While there was a range of decile ratings among the schools selected, they were predominantly in the high range. The schools were all state schools located in urban areas, with four being in major population centres and two in smaller provincial centres. All but one were co-educational. The schools ranged in size from 770 to 2250 students.

An important aim of this research was to capture the stories of students, teachers, and professional development (PD) providers in the CAS Pilot Project, so that elements of effective practice could be identified and replicated. The information is based upon case studies in each of the pilot schools and includes some quantitative data. Asking common questions has allowed triangulation between the teachers, students, and PD providers.

Two mathematics teachers and two classes from each school took part in the study. In each school, we undertook:

- a face-to-face interview with each teacher involved in the project;
- a self-reflective questionnaire to each pilot teacher, asking them to contrast their teaching practices prior to and near the end of the 2005 CAS Pilot;
- lesson observations in each of the classrooms;
- a focus group of students who reflected on their experience of the project.

As well as this, both of the PD providers and the PD co-ordinator were interviewed. While most of this data was of a qualitative nature, quantitative data was also available, particularly from the teacher questionnaire. Quantitative data of students' attitudes and experiences of the project was also gathered in the student focus group. The findings are a meld between these qualitative and quantitative measures.

Results

Pedagogy: A New Paradigm For Teaching

Teachers, PD providers, and the literature are all in agreement; it is how the CAS is used in teaching that makes the difference. The PD co-ordinator went so far as to say "The technology [CAS] is an excuse to impact pedagogy where teachers have not taken on the philosophy of the curriculum."

MiNZC (1992) gives approaches to teaching and learning that emphasise good problem-solving skills in real-life situations, often on open-ended questions that are amenable to a range of different mathematical techniques. Students are encouraged to:

> search the information for clues, and to make connections to the various pieces of mathematical and other knowledge and skills which they have learned (p. 11).

This more exploratory approach is an essential ingredient of the teaching styles encouraged by the CAS Pilot Project. *MiNZC* also endorses the use of technology in mathematics. The technology, however, is intended to be the servant of the pedagogy. The two providers who facilitated the PD training days were promoting a new way of teaching and learning mathematics based on these principles. One of them stated:

> It's not to do with CAS at all. The stuff I've prepared is only 5% CAS. If you think [about it] there is a different pedagogy. I've used all these techniques for years without technology; then I used spreadsheets and graphics calculators, and now CAS. It is easier with CAS to move between the different representations.

Several of the teachers in the pilot made similar reflections. One said, "The pilot is all about pedagogy, and what learning we want to occur." Another attributed the changes to the pedagogy more than to the CAS. A third teacher stated, "The whole project is redesigning the way we do mathematics." Further evidence of the recognition of the importance of the new style of teaching was that about half of the teachers commented that they were already using some of the pedagogical approaches in their other classes. In addition to this, a number said that other teachers at their school were being influenced by the teaching ideas in the pilot project.

The literature also emphasises that it is not the technology that will bring about change, but the teaching and learning methodology in which it is embedded. Many authors discuss appropriate pedagogies for CAS use in the classroom. Often these papers referred to the "white box–black box" metaphor introduced by Buchberger (1990, cited in Cedillo & Kieran, 2003, p. 221). This distinguishes between using the technology blindly to perform routine mathematical tasks (black box), and using it to help students construct meaning for mathematical concepts and procedures (white box). Kutzler (2003) explores pedagogical approaches to CAS usage. He postulates, "The reason that so many students are at odds with mathematics may be related to their lack of experimentation" (p. 61). Kutzler cites Freudenthal (1979), who said, "We should not teach students something they cannot discover for themselves" (p. 61). Kutzler also recounts a telling personal communication from Heugl (the director of Austrian projects on CAS usage), who said, "If it is not pedagogically justified to use CAS, it is pedagogically justified not to use CAS" (p. 54). Hence, all indications are that CAS should only be used within a pedagogically sound framework.

So Has Teaching Changed?

Nine of the 12 teachers reported making changes to their teaching with their CAS pilot classes. The remaining three reported that their teaching remained largely the same. This is consistent with the self-reflective questionnaire results, which showed there had been a shift in teacher practices. Students had also noticed changes in many of the same areas that teachers had identified. Teaching had become:

- *more student led.* Around half the teachers commented on a shift away from teacher-led classrooms ("talk and chalk" as one described it) towards a far more student-focused approach. One said, "I let the students play with ideas and come up with their own ideas." Some students had also picked up on this. Students in the focus groups made remarks such as:

  I have time to work it out for myself.

  We work out how to get the answer.

- *more interactive.* A teacher from one school changed his teaching to "let the students see me solving the problem 'live' without [me doing] any preparation".

  This allowed the students to observe and respond to the teacher's problem-solving strategies. One student shared that "The teacher does it with us now. With the book, he acted like he's right, [but] he learns CAS like us." High levels of teacher–student interaction were seen in all of the lessons, with these being initiated by both teachers and students. These episodes addressed mathematical issues as well as details of how to use the CAS technology. All the teachers were roving the class for substantial parts of the lesson. A student noted, "There is more walking around [by the teacher]."

- *more explorative.* Both teachers and students reflected that the approach involved far more activity, exploration, and self-discovery, with far less emphasis on a rules-based approach to algebra or geometry. A teacher described letting the students tussle with a problem by themselves for longer before offering help. A student in a focus group remarked that they had to find the mathematical rules for themselves rather than being shown or told them. Another student said, "[We] explore to find out the formula." All the observed classes had a strong activity-based approach, with a focus on the explorations that were provided in the PD. These employed multiple methods of problem solving and multiple representations of mathematical concepts.

- *more discussion and questioning.* Several teachers commented on this:

  We are getting more mathematical discussions now.

  We are asking more open-ended questions and giving students more time to contemplate and debate issues.

Students observed that they had to do more explaining of ideas or answer questions such as "How does it work?" Teachers commented:

> Discussion on all units has been great. [It has] helped students generate ideas for themselves.
>
> Students were taking greater responsibility for learning.
>
> My class got into discussions of metacognition, discussions of how we learn.

The implication is that in a more student-led, discussion-based approach, students become more aware of their learning.

- *more collaboration.* A strong focus on either group work or working together in pairs aided this exploratory style. Most teachers reported that they were already using group work, but some reported an increase in this or in the frequency of peers helping each other to learn. One teacher stated, "There is a completely different feeling in the class. There is much more peer learning and helping each other." A student said, "When you teach others, you learn it more." Several students also commented that they shared ideas more now. One said that there was more sharing of answers as well. In all the observed lessons, many students were helping and explaining things to each other.

Students were asked for their responses to the statement "Lessons using the CAS calculator are just like any other mathematics lesson." They were asked to place their response on a continuum from strongly disagree to strongly agree. These are shown in Figure 1. Students saw clear differences between the lessons in the pilot and other mathematics lessons.

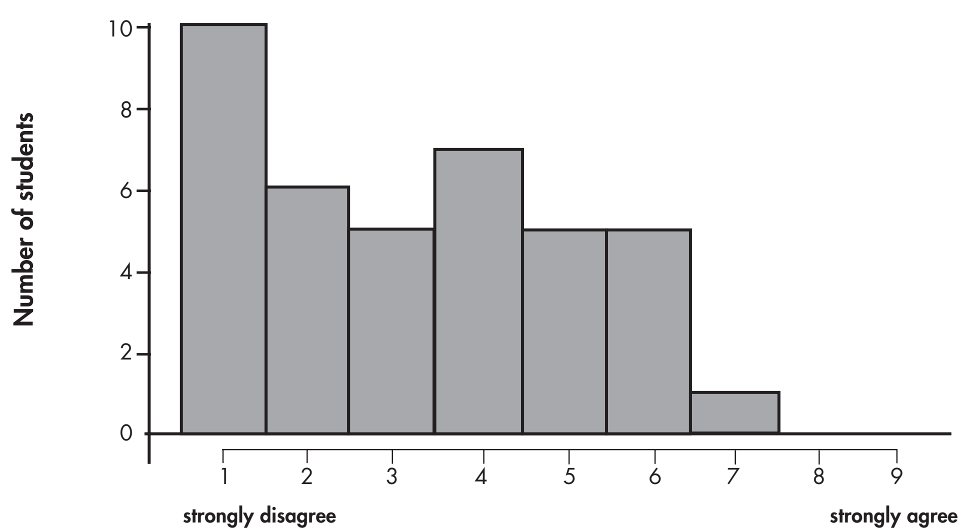

Figure 1. Student response to "CAS lessons are just like other maths lessons."

Perceptions of Teaching Style

In an Australian study of CAS teaching, the practices of three teachers were followed over a period of time (Kendal et al., 2005). Their practices were summarised as:

A: I ensure students have mastery of the rules and procedures of algebra.

B: I focus on the learner's personal construction of algebraic ideas.

C: I emphasise understanding of algebraic concepts.

Figure 2 shows the teachers' perceptions of their own teaching style pre- and post-CAS (teachers were allowed to select a combination of styles if they wished, so there are more than 12 responses both pre- and post-CAS). The graph shows a definite movement away from a rules and procedural style of teaching towards an exploratory and constructivist approach, or an understanding-based style. Teachers primarily saw their style as leaning most heavily towards teaching for understanding. Students, on the other hand, saw their teachers as employing a constructivist approach (style B).

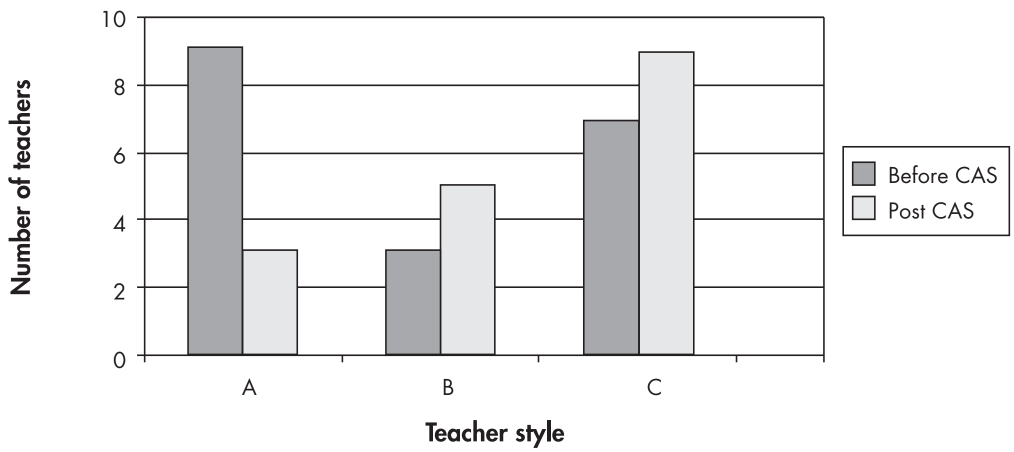

Figure 2. Teachers' perception of their teaching style pre- and post-CAS

Stories of Teaching

Altogether, nine classes were observed in the six pilot schools. The different styles of teaching in the observed lessons have been categorised into several distinct teaching methods. In some of the classes, the teaching was a mix of more than one method, while other classes primarily followed one pattern. These patterns are displayed in Figure 3. The stories that follow describe four quite different teaching approaches. These are arranged from most heavily student-led to those with a more teacher-led approach.

- *Story 1.* The major emphasis in this approach was using expert groups that each performed an exploration that helped them to discover a specific geometric property. The expert groups then returned to their "home" groups and explained to them what they had discovered. This teaching strategy has been referred to as the expert jigsaw method (see Kagan, 1994).
- *Story 2.* This was typified by students performing explorations at their own pace and in their own way. Students could choose to work individually, in pairs, or as a group. At times, we observed mathematical interactions between groups in quite different parts of

the classroom. During the independent explorations, the teachers roved and interacted with the students, asking and answering questions. The amount of off-task behaviours in each of these classes was the highest observed.

- *Story 3.* The emphasis of this teaching approach was a dialogue between the teacher and the whole class. While this method was teacher-centred, students were constantly responding to challenges from the teacher to perform mathematical activities and explain them. There was dialogue between teacher and students in a whole-class setting. The teachers in these classes used the strategy mentioned by Kutzler (2003) of "sequentially using and not using technology to achieve certain learning goals" (p. 53). Discussion was lively, and students were willing to defend their ideas even when they were in the minority.
- *Story 4.* This approach most closely resembles the traditional method of teacher instruction followed by students performing tasks. Generally, the period of whole-class teaching was short, as was the time when students performed the tasks. This pattern was then repeated several times during the lesson.

"a" to "i" are codes for each individual lesson observed.

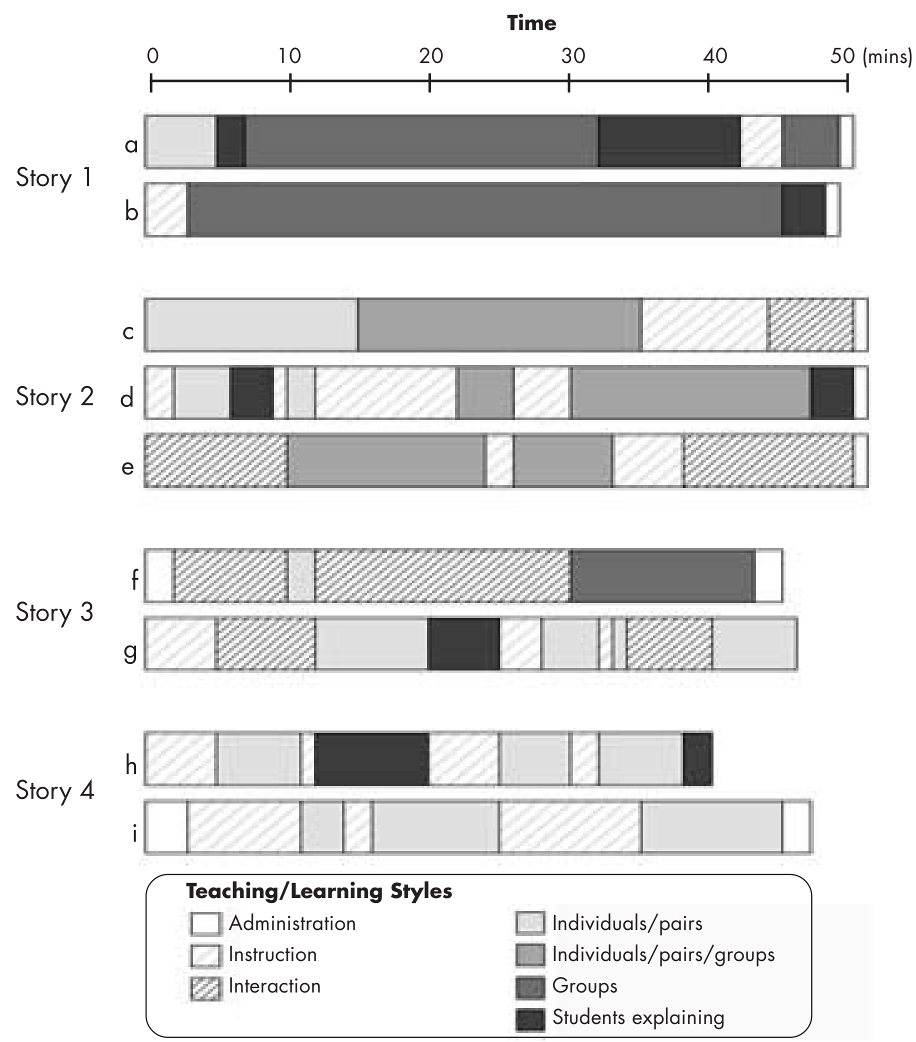

Figure 3. Observed style of teaching in lesson observations

Learning Issues: It Is Not Like Other Maths

Student learning could not be directly measured because no baseline data existed on the students in the pilot. The literature suggests that student learning can be enhanced by appropriate use of CAS. Heid (2003) noted that, after using CAS, "students' mathematical development seemed to proceed more rapidly" (p. 40). Heid and Edwards (2001) found that weaker students were able to "examine algebraic expressions from a more conceptual point of view ..." (p. 131). Noguera (2001) also commented that "[students'] cognitive development in algebra improved" (p. 263).

To evaluate this, teachers were asked whether they thought students were learning at a deeper level or at a faster pace and to give anecdotal evidence of any such improvements. Students were also asked what effects the pilot was having on their learning.

Student understanding

Over half the teachers believed that the CAS pilot had led to students having a deeper understanding of mathematical concepts. One teacher suggested that the learning might be broader as well as deeper, while another commented that the students were going further in their mathematics. Another said, "They are actually thinking now."

The remaining teachers were still unsure, apart from one who thought that the learning would be of the same depth. None of the teachers saw the CAS pilot experience leading to understanding that was not as deep. While teachers found it hard to quantify the improved depth of learning, the fact that the students were asking more sophisticated questions convinced one teacher that students' understanding had improved.

Students in the focus groups were asked whether using the CAS calculators had helped them understand mathematics better. The distribution of student responses is shown in Figure 4. This is clearly bimodal, with a significant group stating their understanding was worse since the CAS pilot and a similarly sized group viewing it positively.

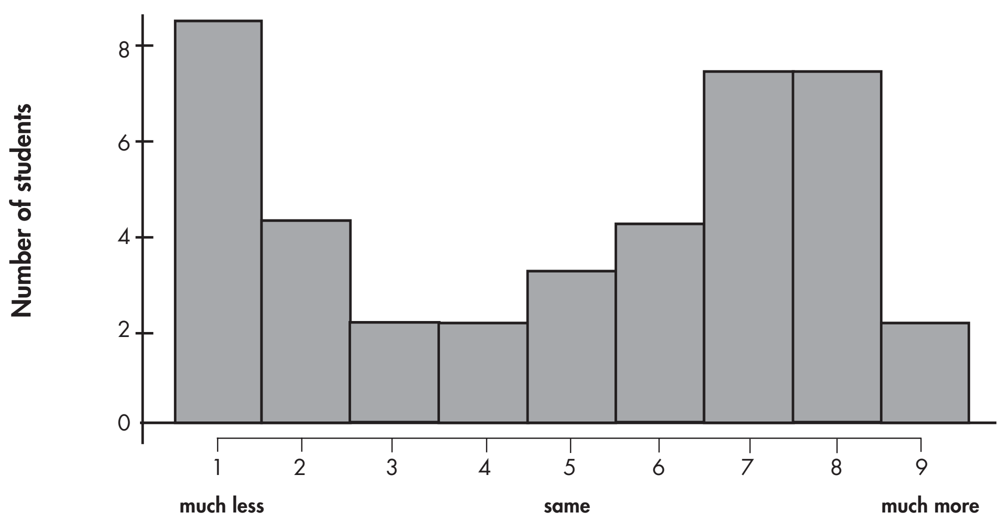

Figure 4. Students' views on their mathematical understanding in the CAS pilot

A number of issues seem to be affecting students' perception of whether their understanding was better, worse, or about the same. The main contributor to the negative responses related to the non-traditional approach to teaching mathematics that the project took. A number of comments of this type were made in the focus groups:

> What's this [way of teaching] got to do with maths? The calculator gets in the way.
>
> Sometimes I can't see the point.

Lagrange (1996, cited in Pierce & Stacey, 2002) said that in his experience:

> not all students wanted to use CAS. They did not want to be relieved of pen and paper work and that many, in fact, enjoyed doing routine calculation. (p. 576)

One student liked the fact that they were learning how to use the CAS calculator but thought they weren't learning as much maths. In the negative responses, it seemed to be a case of either students or parents believing "It's not real maths" or at least "It's maths, but not as we know it!"

Student attitudes

Students were largely positive in their attitudes towards the CAS project. Their confidence in using the calculator had grown, they found it reasonably easy to use, and they enjoyed using it. The teachers agreed that student attitudes were generally more positive.

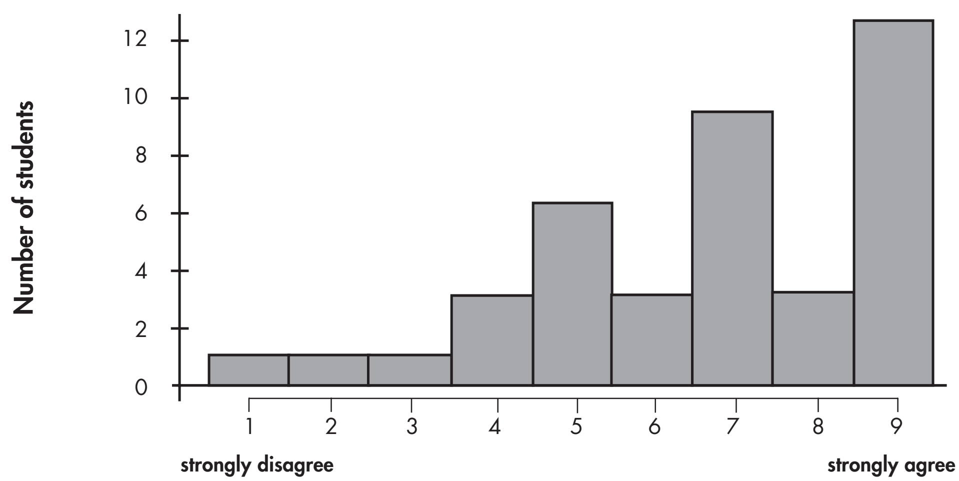

Figure 5. Student response to "I enjoy using the CAS calculator."

There were many aspects of the CAS pilot that students had enjoyed. These included the animations and the games or that the calculator was like a computer. A couple of students liked having less bookwork or writing. The ease of doing things, because the CAS is "doing it for you", was also appreciated. One said, "You can have fun and learn at the same time."

There was a real mix of views from students on whether they felt more positive towards mathematics. Some students felt much more positive, while others were less positive after the pilot than before it. Some saw it as a "dumbing down" of mathematics or as "not being real maths". A number of students had commented that maths was no longer boring. Some students who felt more positive about maths attributed it to the novelty effect of the CAS calculator:

> It's something new. We've done maths since primary school.

Some students shared why they felt less positive:

> [I] really used to like maths, but now it's a mass of confusion.
>
> I really enjoy CAS, but I ... am not learning as much maths.

Professional Development

The key driver in the CAS Pilot Project has been the provision of quality PD. The training sessions were run by PD providers. The underpinning aims and philosophies of the PD professionals have provided much of the intellectual thrust for the project. In the words of the PD co-ordinator for the project, "It's about teaching and learning mathematics."

Both PD presenters modelled an exploratory style of teaching, where real problems were posed and the CAS was used to explore them. This reflected their belief that the project was about pedagogy rather than technology. One teacher commented, "The initial emphasis was philosophical rather than technological. Technology is an assistant rather than a driver."

Teachers' perceptions of the PD

Most of the teachers found the PD very helpful. Some of the benefits they saw included:

- Getting together with teachers from other schools to share experiences and the pooling of resources. For many of the teachers, this was one of the most significant parts of the PD.
- The strong modelling of the appropriate pedagogy, which was the key ingredient of the project. While the pedagogy was modelled, teachers commented that the presenters did not reduce their professionalism as teachers.
- Having lesson plans and "off the shelf" resources, which they could take with them.
- Learning how to use CAS was seen as being an important feature by many teachers. They liked the way this had been blended with ways to teach using the CAS as a learning tool.
- Having two teachers per school involved in the PD.
- Being challenged mathematically and as teachers. Quotes illustrating this included:

  > [There are] challenging titbits. [It has] stimulating thinking.
  >
  > [We have] achieved deeper understanding.
  >
  > [We have been] given material that challenges what we have done in the past and how we have done it.

- Having time to reflect:

  > [I] didn't initially realise the value of the PD. [Now it has] crystallised and affected [my] teaching.

- A more integrated approach to mathematics was seen as being easier to achieve:

  > [We are] developing greater links between the strands, doing maths rather than the strands, [and it is] great making connections. They [students] suddenly realise that it is all connected and the teachers were wrong [to partition it].

Some areas for improvement of the PD were identified, along with areas for future PD requirements. These are covered in the full report (see Neill & Maguire, 2006, in press).

Assessment Of Learning, For Learning

One of the issues that this evaluation addresses is "What are the implications for assessment of student learning as a result of using the CAS technology? Do current forms of assessment need to change, and if so, in what ways?"

Both formative and summative assessment were explored when addressing this issue. Formative assessment, especially informal formative assessment, clearly supports the quality pedagogical approach that the CAS pilot employs. The challenge is that the summative assessments, especially the high-stakes ones, also need to work in harmony with an exploratory, understanding-focused approach to mathematics, rather than encouraging a more procedural approach.

Formative assessment

There has recently been an increasing emphasis on the fundamental role that formative assessment plays in effective teaching and learning. Authors such as Black and Wiliam (1998) have written on this subject. Ironically, Black and Wiliam's publication is entitled *Inside the black box: Raising standards through classroom assessment.* For Black and Wiliam, the black box is the classroom. They state: "present [UK] policy seems to treat the classroom as a *black box*. Certain *inputs* from the outside are fed in or make demands. Some *outputs* follow ..." (p. 1).

This *inputs–outputs* model of the classroom, which lacks a critical examination of what goes on in the process of teaching, is the very reservation that many have with CAS technology: feed in functions to it and out come solutions, without students having any understanding of the underlying mathematical concepts. The black box cannot be escaped by merely ignoring technology. What goes on inside the classroom is what matters, regardless of whether or not technology is used. Algorithms can be taught in a black box way either with the CAS or with pencil and paper. Black and Wiliam emphasise that quality formative assessment illuminates the black box, helping to change it into a white box.

Formative assessment was deeply embedded in the teaching and learning process of the CAS Pilot. One of the PD providers commented:

> If you let the teaching and learning process occur like we've been saying, formative assessment is happening every second of the day. ... [Teachers] will be assessing continually.

The other provider made comments of a similar kind, noting that:

> Good professional teachers can assess roughly where a student is at without doing a formal test. Often [teachers] don't place enough value on what kids are doing in the classroom.

If the pedagogy is of an exploratory nature with an emphasis on understanding, rather than procedural or algorithmic with an emphasis on performance, then formative assessment naturally follows.

The strong influence on formative assessment was borne out by the observations of classrooms, where many of the hallmarks of formative assessment were occurring, especially the informal types of assessment. High levels of student–teacher interaction were observed. Teachers were roving the classroom, observing students' work and mathematical conversations, initiating conversations, questioning students about their understanding, and giving them feedback on their learning.

Ironically, teachers thought that they were doing less formative assessment than they had been prior to the pilot. This was probably because their focus had moved from formal to informal assessment, which is at the heart of formative assessment. One PD provider suggested, "Sometimes [teachers] won't know that they are doing [informal assessment]."

Summative assessment

Summative assessment must not lose sight of the fact that it also influences teaching and learning. It helps define what happens in the classroom. Summative assessment must be for learning, not just of learning. This is particularly true of high-stakes assessment, which sends powerful messages to teachers about the learning that is valued and hence about the teaching that should occur.

Schools in the pilot had a number of different strategies for summative assessment. Four schools reported different forms of common tests across all of year 9. Of these, two thought their students were doing better, with one commenting that the CAS pilot "stretches students to be excellent".

The third school said the students were doing at least as well on the procedural skills, and the fourth made no comment. The form of the common tests varied from school to school. One format used was that some of the paper was in common across the school and some was just for the CAS students. Two other schools had a common test that was used across all year 9 classes, regardless of whether or not they were in the CAS pilot. The remaining two schools had no common test but did a series of teacher-written tests at different points within the pilot. In at least one class, these results were used to refine the teaching. One school said that they would be having an end-of-year exam, but that this would need to be different for CAS students.

Teachers in the CAS pilot schools felt they needed to address a number of issues around their own summative assessments. Many of these same issues also need consideration before CAS-enabled high-stakes assessments, at levels 1–3 of NCEA, become a reality. Summative assessment should be supportive of effective teaching and learning, not just a valid and reliable way of measuring student learning. It is not just formative assessment that supports good pedagogy: summative assessment should as well. If it is valued in teaching, it needs to be reflected in the high-stakes assessment (Harlen, 2005).

Technology in the Classroom

The CAS pilot aims to give a more structured and supportive approach to the introduction of the CAS technology than that which occurred when the graphics calculator was introduced into teaching and assessment. While the primary focus is on teaching and learning, the pilot is also interested in the role that technology plays in the classroom.

The effective and appropriate use of CAS depends on a number of factors. Key factors include the attitudes of teachers, PD providers, students, and their parents/caregivers towards technology in the classroom and its effective use.

Attitudes to technology

The extent of the impact that technology has in the classroom depends to a large extent on the teachers' attitudes, views, or philosophies concerning its use. The following summarises the views of the teachers in the pilot towards technology in the classroom after they had implemented the pilot with their students.

- *Technology is a tool with a purpose.* One teacher stated, "[It's] just another tool in the box of tools you've got to teach kids with."
- Several of the teachers qualified their statements by saying that technology is a tool to deepen learning and understanding.
- *It allows exploration and discovery.* One teacher said that it was "a learning tool to help students discover and learn".

- *It allows more open-ended and realistic investigations.* The technology can deal with real expressions in a range of contexts so that students can do realistic problems, not just ones with "nice" whole number answers.
- *It can scaffold learning.* The students can focus on the mathematical concepts rather than just on the manipulative details, moving between multiple representations of concepts, for example, algebraic, graphical, or tabular ways of expressing a problem. Technology can remove lower-level computational errors, allowing higher-level concepts to be explored. Kutzler (2003) describes this pattern of alternation between higher-level and lower-level tasks and says that by using CAS technology to perform the lower-level tasks, students can still make decisions at the higher level.
- *It's not about technology, it's about enhanced teaching and learning.* Comments such as the following all emphasise that it is about appropriate pedagogy more than about the technology itself:

  It's not about technology but pedagogy.

  [It's] the way you teach with it.

  Use it if [and when] it works.

A number of teachers mentioned some possible drawbacks that technology may have. One observed that some students "go blank with technology". Another was hoping that "it would not undermine important basic skills in mathematics". Used in a "black-box" way, this is certainly a threat. Students need to recognise when to use the technology and when not to. The issues are the same as those that surround the use of arithmetical or scientific calculators. One teacher had observed students in a common test using the CAS to confirm their answers to questions about simplifying trivial algebraic expressions that they could easily have worked out in their heads. This may lead to a dependency on technology rather than sensibly choosing when it is appropriate to use it.

Half the teachers reported that they had changed their views on technology as a result of the CAS pilot. Before the pilot began, three of these teachers had been negative towards technology or at least had reservations about it:

> [I was] resistant to it before ... I used to believe that pencil and paper were most important.
>
> [I] used to be anti, and I didn't want to do it.
>
> [I was] initially somewhat reserved and anxious about [my] ability to teach with it.

The other three who changed their views towards technology use in the classroom had become more positive about its use as a result of using it in the pilot.

Students had also observed that their teachers were positive towards the technology. Quotes included:

> Our teacher goes home and plays around on it and finds new stuff.
>
> He knows we find it more fun and more challenging.
>
> Ours is over the moon.
>
> I think he's more excited about it [than us].

Parents had mixed views on the use of calculators in mathematics. Some parents or caregivers were positive, and some were negative. Some saw the CAS calculators as mysterious, while others were just not interested in using them.

Future issues

What issues will need to be addressed and what support will need to be given to teachers to enable the effective and sustained use of CAS technology? A number of these aspects were identified in the project:

1. *Get parents on board.* Parents displayed a range of different attitudes towards the project. Schools adopted a range of strategies to try to redress the negative attitudes of some parents. The key is, of course, quality communication. Several schools had made it the major focus of their initial meet-the-teacher evening or parent interviews, while others had sent written information home to parents. Some teachers who had seen an initial resistance from parents saw it diminish with time. One teacher said, "[They] are really positive now."
2. *Get teachers on board.* This needs to include not only mathematics teachers but also teachers of other subject areas where the calculators have potential value.
3. *School leadership.* This was a strong feature in each of the pilot schools. There was active support in all the schools from the mathematics head of department. One school reported that the principal had been actively involved in ensuring the school was involved with the project. Strong school-based professional leadership is essential for fully effective implementation in a school. Without this support, individual teachers or even a pair of teachers who had undergone PD could be marginalised.
4. *System leadership.* Both the Ministry of Education (MoE) and the New Zealand Qualifications Authority (NZQA) need to have an ongoing role in the promotion of the values that underpin this project. For the MoE, the call from the PD co-ordinator was "to get it out there and to promote it".

   There was praise for the leadership already being demonstrated. A teacher said that they "applauded the MoE and NZQA for getting stuck into technology before it's everywhere". Significant leadership from NZQA will also be needed as they plan for NCEA assessments.
5. *Resources.* The teachers in the pilot saw a need for an expanding set of resources for teaching, but more particularly for assessment.
6. *Professional development.* Over half the pilot teachers believed that to sustain the project, there would need to be continuing PD. This would ideally be led by trained facilitators with time dedicated to the training.

Conclusion

One thing is certain. Technological advances are going to play a continuing role in our lives. These changes will clearly impact upon the way mathematics is performed in the real world. The debate then has to be: what is the best way of helping students prepare to be critical mathematical thinkers and problem solvers in the twenty-first century?

The major thrust of the CAS Pilot Project was all about quality teaching and learning and focused on an exploratory, self-discovery approach to gaining mathematical understanding. The teachers believed that this pedagogy had not only allowed the students to improve their mathematical understandings and skills, it also had enhanced their own professional skills. Classroom teaching had clearly changed as a result of the training given to the teachers in the project. There was some resistance to the project from a number of parents/caregivers and students, mainly because of concerns that it might undermine mathematical skills; some teachers in the pilot had initially shared these views. Effective assessment models will inform this debate. Assessments, both school-based and high-stakes, need to reflect the values of exploration and of understanding as well as acquiring mathematical skills.

The PD emphasised this pedagogy, as well as giving teachers sufficient confidence and knowledge in how to use the technology. Without quality PD, it will be hard to communicate this approach to using CAS in the classroom to the wider mathematics education fraternity. New Zealand has a world-class model now for professional development, namely that developed for the Numeracy Development Projects (NDP). One of the schools in the pilot was debating whether to become involved with the CAS pilot in 2005 or to begin the NDP instead. Ironically, both projects share many common beliefs. The PD co-ordinator said, "[Assessment] is more in line with *numeracy*, where students are exploring and gaining understanding."

Some of these common beliefs can be seen in *The Number Framework* (Ministry of Education, 2004).

- Numeracy talks about a "dynamic and evolutionary approach to mathematics" (frontispiece), and CAS talks about exploration and discovery.
- Numeracy values "children's learning and thinking strategies" (p. 1) and values strategies other than the algorithmic. The CAS pilot also values multiple representations and understanding, rather than an algorithmic approach (see Piez and Voxman, 1997).
- Numeracy values "professional development systems that change teaching practice; and effective facilitation" (p. 1). This has been a major focus of the CAS pilot.

Because of these strong similarities, we believe that it would be fruitful to explore synergies between the CAS pilot and the NDP.

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