An evaluation of the CAS Pilot Project 2006–2007

Report for the Ministry of Education and the New Zealand Qualifications Authority

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Background

In 2005, the Ministry of Education and the New Zealand Qualifications Authority began a pilot programme in six schools to trial the use of the latest generation of calculators, which included Computer Algebraic Systems (CAS) capabilities. The intent was to give quality professional development (PD) to effectively use this new technology in classrooms, and to eventually allow the calculators in CAS-enabled National Certificate of Educational Achievement (NCEA) assessments in the same way that graphics calculators currently are used. Both agencies recognised that the introduction of graphics calculators had not been given adequate attention, and that this pilot was a way of addressing this. The pilot also aimed to influence pedagogy towards a more constructivist style. The 2005 pilot was evaluated by the New Zealand Council for Educational Research (NZCER), and its findings have been published (see Neill & Maguire, 2006a, b).

The pilot was extended into 2006 and 2007 to include 16 new schools. In their first year, two mathematics teachers and two Year 9 classes from each school took part in the study. The two teachers received PD on effective teaching that utilised the CAS calculators. The major focus of the PD was on algebra, geometry, and probability. In the second year, these same two teachers received more PD aimed at teaching at the Year 10 level, and a second pair of teachers received the Year 9 PD. By the end of the pilot, this meant that each school had four teachers who had received PD and were implementing teaching with the CAS in their Years 9 and 10 classes. Each of these classes would be given the option of sitting a CAS-enabled Level 1 mathematics external exam.

The evaluation

The evaluation of the 2006–2007 extension of the pilot was undertaken by NZCER. A multi-method design was used, with both quantitative and qualitative data being collected. The evaluation explored changes to:

- teaching and learning practices;
- student achievement; and

- student and teacher attitudes to the pilot, to technology, and to mathematics.

The study also examined: the contribution of the PD to classroom practices; assessment issues; and sustainability of the project. See Chapter 1 for a list of the research questions.

Qualitative data were gathered during visits to all 22 of the schools involved in the pilot, which were visited on at least one occasion. Eight target schools were visited twice, and a wider range of data was collected from these. During all school visits, interviews were held with teachers in the pilot, and classroom observations were conducted. Focus groups of students were also held at each visit to the eight target schools. Baseline questionnaires and follow-up questionnaires that asked their opinions of the pilot were also sent to all the teachers in the 2006–2007 pilot. The questionnaires gave both qualitative and quantitative information.

Quantitative information was collected from each student in the 2006–2007 pilot. Each school also provided two control classes of students that were matched to the CAS classes at each year level. This allowed comparisons to be made in changes of attitudes and achievement levels between students who had, or had not, been involved in the pilot. Achievement levels were obtained for each student both pre- and post-pilot. Students also responded to a pre- and post-questionnaire on their attitudes to schools; mathematics; the pedagogical approach of teachers; and technology.

Principal messages

The major themes that emerged from the report are briefly outlined below.

Changes in teaching and learning practices

Teachers reported marked changes in their mathematics teaching practices, and that these changes had flowed on to the non-CAS classes they taught. Many were moving away from a rules-based, traditional behaviourist approach to a constructivist, exploratory approach. They were giving a greater emphasis to technology, and rich tasks were more evident. Our observations of lessons also confirmed the CAS classrooms had very few instances of traditional teaching, much lower than what we believe happens in the typical mathematics classroom.

Teachers who were comfortable with the technology appeared to be more likely to use an exploratory, constructivist approach. They were more likely to empower students to become the experts rather than seeing that they needed to have all the expertise themselves. Many of the more effective teachers seemed to be able to clearly and accurately verbalise the correct sequence of actions to take on the calculator.

Levels of interaction in CAS classrooms were high, both in whole-class discussions, teacher–student interactions, and in the informal interactions between students. Some of this was related to the actual calculators, as students had a strong need to check with or find out from each other how to use them, but the interactions were also about mathematical content.

Students also commented that there were differences in teaching styles. These included less frequent use of textbooks or exercise books. Some more able students were able to see the underlying pedagogical differences driving the project, and considered that these helped them look at mathematics in a different way. Although some students were less able to articulate change than others, we observed high levels of engagement and on-task behaviour in CAS classes. There were suggestions that differences in teaching were greater in Year 9, and by Year 10 there was some reversion to previous teaching patterns. Certainly the CAS were not being used as much at Year 10 as they were in Year 9.

Changes in student learning and achievement

The quantitative data showed no clear difference in levels of mathematical achievement (as measured by PAT:Mathematics) between students who had the CAS and those who did not. This suggests that students were neither advantaged nor disadvantaged by being exposed to the CAS approach to teaching and learning. This finding is consistent with other studies (Heid, Blume, Hollebrands, & Piez, 2002).

The qualitative data painted a more detailed view. Students thought that their exposure to the CAS-based lessons had increased their understanding, especially in algebra, and to a lesser extent in geometry. Teachers reported little effect upon students' mathematics understanding overall, but they also believed that the CAS approach had increased student understanding of algebra and that this had helped close the gap between Algebra the other mathematics strands. Some teachers noted that it was still too early to say, and that the acid test for an increase in understanding would come at the senior school level. It can often take two to three years before a PD initiative has an impact upon achievement. Ongoing monitoring of student achievement would help address this hypothesis.

Students' attitudes were generally positive, but there was a mix of less positive views towards the effect that the CAS-based approach had on their learning. Some students saw the CAS pilot as helpful, especially those who had visual learning preferences. Other students found them a hindrance, sometimes because they struggled to keep up with how to use the technology. Some preferred a more procedural approach, especially those who had previous success with that approach. This suggests that different students have differing needs, whether these are ability-based, or learning preference-based.

There was little or no evidence that changes in levels of achievement, student attitudes, or the type of mathematics lessons we observed were related to the different types of calculators and their associated PD.

Changes to student attitude and motivation

Student attitudes towards mathematics became more negative during the course of the pilot for both CAS and control class students. It is, however, common for the attitudes of students of these ages to become less positive throughout the academic year, and on a year-to-year basis (Russell, 2003). The CAS students' responses showed that this downwards trend had slowed by Year 10. This slowing was not found for the non-CAS students. Russell defines such a slowing of a trend as an "improvement" in attitudes (relative to where they would otherwise have been). Teachers thought that student attitudes towards mathematics had changed little, but did see that they had become significantly more positive towards algebra. This again points to a slowing of a downward trend, and emphasises the usefulness of the CAS in algebra. These results, coupled with our observations of high levels of student engagement in the large majority of the classes, led us to conclude that the CAS was having a positive effect on students' attitudes towards mathematics, and particularly algebra. Student attitudes were commonly related to their level of mathematics ability, with higher ability students having more positive attitudes.

Other implications

Several other aspects of the study that could aid the roll-out of the pilot to all schools are highlighted.

Overall, teachers found that the PD met their expectations, but they did qualify this in various ways. Some stated that they needed more PD, and others mentioned that they needed more teaching resources, and that the PD needed to be timed to be much closer to when they actually taught the topic covered in the PD. Teachers appreciated the more structured unit plans that one PD provider gave them. Teachers have different learning needs, and the PD should address these. Some needed more about details of how to use the technology, while others needed more about pedagogy. Students also have different learning needs. It would therefore be helpful if the PD gave strategies on how to differentiate teaching. Teachers also asked for PD and resources to help them implement the programme in Years 12 and 13.

While the PD model worked well for the pilot, a full roll-out may benefit from exploring alternative models, especially ones more clearly based around readily available local expertise. Having skilled local people to act as pedagogical and technological backup would be of benefit to teachers. It would be well worth exploring or exploiting the relationship between CAS and the Numeracy Development Project (NDP) model.

This study suggests that to support the constructivist thrust of the CAS pilot, the national assessment system should be aligned with the CAS pilot's values. It is clear that assessment questions need to be of a different type, especially in high-stakes summative assessments, and in particular for NCEA assessments. This is to ensure that the students are being assessed on their mathematical understanding, and not just their ability to obtain answers from the technology. Growing expertise in producing valid and reliable questions of this sort for CAS-enabled assessments is a priority. Teachers need exemplars of these at NCEA Level 1, but also at Levels 2 and 3.

Equity issues is another consideration for a full roll-out, especially around the cost of the technology, both at the school and the individual level. Adequate funding models may need to be in place to accommodate this, or other more accessible options followed.

The major impetus of the CAS pilot was on quality pedagogy which is supported by appropriate technology. The pedagogical approach was widely supported by participants in the trial, and there was also wide agreement that technology is essential in mathematics education in the 21st century. There were, however, some reservations about the particular CAS technology, because of the equity issues mentioned above, but also in terms of whether it was the most appropriate given the steep learning curve required, and the somewhat low reliability of this technology. This study shows that hand-held technology for students has benefits, but for coherence it would be helpful to prioritise one sort of technology rather than adopt a range.

Summary of research findings

Chapter by chapter summaries follow. These are the same as those at the beginning of each chapter.

Classroom observations and perceptions of teaching (Chapters 3–4)

Teachers reported large changes in their teaching style as a result of the pilot, not only in their CAS classes, but also in their other classes. This indicated that the PD had profoundly influenced teachers' perception of their pedagogy. Teachers saw their style moving away from a rules-based approach to one of encouraging students to construct their own personal knowledge and understanding through exploration. They reported that technology was playing a larger role in their classrooms, and rich tasks were more evident, especially in their CAS classes, but also in their other classes as well.

Very few lessons we saw in the CAS classes followed a traditional pattern of "lecture then do examples". The most common style we saw was a cyclical pattern of short teaching slots followed by students working for a few minutes, after which the cycle would be repeated. Classroom discussions were common. Several discussions we observed were particularly rich. We saw CAS in use not only in Algebra, Geometry, and Probability, but also in other strands of the mathematics curriculum. Levels of student engagement, student-to-student interactions, and student–teacher interactions were high. We found no differences between the calculator brands in any of these areas.

Overall, students did not report large changes in teacher beliefs and styles, and tended to categorise the main style as teacher-led, with a focus on emphasising understanding. This differed from our observations, and teachers' views, suggesting that most students did not have a clear understanding about different styles of teaching. It may also be that teacher beliefs were not yet fully integrated into their practice. The 2006 cohort of Year 9 students were more likely to see changes than the 2007 cohort, suggesting that after the initial focus, teachers may tend to revert to earlier styles.

Students in both CAS and control classes did report a decrease in some classroom practices (for example, whole-class discussions) suggesting that some of the changes mentioned were probably a reflection of mathematics classes in general. Students' views on classroom practices were sometimes related to student ability, especially in the CAS classes, where the more able students could identify that the pedagogy emphasised new ways of looking at mathematics, and that they were learning new things. This indicates that able students were able to perceive the pedagogical agenda of the CAS pilot.

Learning issues (Chapter 5)

Growth in mathematical knowledge and understanding (as measured by PAT:Mathematics) was similar for students regardless of whether they were involved in the CAS pilot or were in a control class. It appears that students were neither advantaged nor disadvantaged by being exposed to the CAS approach to teaching and learning. The type of calculator and its accompanying PD had little effect on student achievement as measured by PAT:Mathematics achievement tests.

The qualitative data gathered from students suggested that CAS-based teaching had an impact on understanding, especially in algebra, and to a lesser extent in geometry. Some students found the visual nature of the CAS suited their learning preferences. Not all students shared these views, with a minority reporting that the use of CAS impaired their understanding.

Teachers were largely neutral as to whether student knowledge, skills, and understanding had been enhanced overall as a result of the pilot but, like students, they perceived that the use of CAS did improve algebraic understanding. They had rated this as low before the pilot, but saw that it had increased to a similar level to the other mathematics strands by the end of the pilot. Teachers could see both positive and negative effects on students, and suggested that CAS affected different students in different ways; helping some, but raising barriers for others.

Student attitudes (Chapter 6)

At the beginning of Year 9, students had positive attitudes towards all 15 measures of mathematics surveyed. By the end of the year, they were somewhat less positive towards more than half of these measures. The effects were similar in CAS and control classes. This is consistent with a general decline in positive views in attitudes towards school or mathematics. In Year 10, the CAS classes in particular experienced a smaller decrease in positive attitudes than the control class students. Russell (2003) describes any such slowing or reversal of a trend as indicating an "improvement" in attitudes relative to where they would have been. Other evidence from the pilot supported this. When CAS students were asked if they were more positive towards mathematics as a result of being in the CAS pilot, both cohorts of Year 9 students reported that they were, while the Year 10 students stayed largely the same.

A number of measures of student attitudes were related to their mathematics achievement. More able students were *more* likely to: be confident; do well; gain useful knowledge; see connections with things outside school; get absorbed in their work; and be interested in what they learn. More able students were *less* likely to: be nervous; report that they would drop mathematics as soon as they could; not know how to do the work; and not enjoy mathematics.

Teachers perceived little change in students' attitudes towards mathematics overall. They did believe, however, that students were initially less positive towards Algebra than the other strands. By the end of the pilot, teachers reported that the gap between student attitudes towards Algebra and the other strands had significantly diminished. Again, this emphasises that the pilot supported algebra learning.

Professional development (Chapter 7)

The aims and philosophies of the PD professionals have provided much of the intellectual thrust for the CAS pilot. These beliefs and aims have been covered in the report of the 2005 pilot (Neill & Maguire, 2006a, b), and included emphasising an exploratory, constructivist approach, with modelling of the use of multiple representations and multiple strategies.

The approach to early algebraic thinking, and especially the staged introduction to the concept of pronumerals, was a significant feature of some of the PD. This may well have contributed to the increase in students' algebraic understanding reported in Chapter 5.

The expectations of teachers were largely met by the PD. The majority reported gaining quality resources and teaching strategies to use with their classes. Most reported that they had also gained the skills and the confidence to use the CAS calculator in their classes, though some were still coming to terms with this. Teachers saw a need for more resources than were currently available, as it took them considerable time to write and refine their own.

Some teachers questioned the timing of the PD. Suggestions were made that it needed to be closer to the time when it was actually employed in the classroom, and that more regular, ongoing PD and support would be helpful.

Technology (Chapter 8)

Teachers were already largely supportive of technology use in the classroom before they began the pilot, but no more so than a representative sample of nearly 500 New Zealand mathematics teachers (Thomas, Bosley, de los Santos, Gray, Hong, & Loh, 2007). The CAS pilot did not change their views on this. One reason for their support was the pragmatic response that technology is a reality in the modern world and for the future. The other major reason was that

CAS has affordances for student learning in various areas such as allowing different ways of mathematical exploration; enhancing student motivation; and allowing better or different activities. The visual nature of the calculators was also commented on. Teachers did point out that technology is just one of many tools that they can employ, and that the ideas can also be taught without technology. The biggest constraint for them was around costing and resourcing.

Teachers reported significant increases in their skills with CAS calculators, and also with using data projectors in conjunction with calculators. There was a corresponding increase in the classroom use of these two sets of skills, but there was also an increase in the use of technologies other than the ones indicated at the beginning of the pilot. Teachers did, however, call for technical backup for the calculators in much the same way as there is backup for computers in schools.

Teachers believed that the CAS approach would be of most use in the Algebra strand, and to a lesser extent in Statistics, and of least use in Measurement. This was borne out in their experience of actual use, with the CAS being significantly more useful, and with teachers using them significantly more often, in Algebra compared with the other four strands.

Students were largely positive towards technology, especially at the beginning of the pilot. This was equally true for both CAS and control class students. However, by the end of the pilot, the 2006 cohort of CAS students had become somewhat less positive towards technology compared with the control class students who had maintained similar views. It is unclear what had caused this, but it may be that the CAS required a steep learning curve, and was not as intuitive as other calculators the students have encountered. Many students had gained in their confidence at using CAS, and the majority enjoyed using the calculators. Others were not so keen, and a few were quite frustrated with the CAS calculators.

Assessment (Chapter 9)

Teachers reported that their approach to assessment had not changed as a result of the CAS pilot. They did, however, acknowledge that assessment questions (in particular high-stakes summative assessment questions) needed to change, to ensure that the questions fitted the exploratory, understanding-based teaching approach endorsed by the CAS pilot, and also to make sure that students were neither advantaged nor disadvantaged by having a CAS calculator in high-stakes NCEA assessments.

Teachers were divided in their opinions of the draft NCEA assessment exemplars. Some thought that they were aimed at the more able students, while others saw them as being of comparable difficulty, but of a different style. Teachers agreed that it was imperative to get the draft material sooner, so they could adequately prepare their students for their Level 1 (and also Levels 2 and 3) NCEA assessments. Year 10 students were split as to whether they were confident or not at sitting the CAS-enabled NCEA exams. Many schools were planning to have just one of the two CAS pilot classes sitting the Level 1 NCEA exams in 2008. Some envisaged that both CAS classes would sit them, and others thought that neither class would.

During classroom observations we observed a relatively high level of formative assessment. Students and teachers also reported that this type of assessment was taking place regularly in their classrooms. The introduction of the CAS had supported this, as it created a need for teachers to know where there students were at with both the CAS calculator and their mathematics understanding. Giving feedback on the two aspects was one of the reasons for the high frequency of formative practices we observed.

Sustainability (Chapter 10)

To maximise the usefulness and uptake of the CAS approach, this study suggests some conditions need to be in place if a full roll-out is to take place. Parents, mathematics teachers, other subject teachers, and the wider mathematics community may need some convincing of the value of this approach. This suggests it would be helpful to have ongoing education of stakeholders. This education could communicate that the main driver for the project is a constructivist pedagogy that utilises the affordances that technology offers. Technology is not the driver, but neither can technological change be ignored.

Feedback from participants in the pilot indicates that teachers saw a need for ongoing PD, both for teachers who have been involved in the pilot and for those who have yet to experience CAS PD. To ensure any full roll-out is well managed, it would be of benefit to explore the most appropriate PD model. What has worked in the environment of a pilot may not necessarily be the most suitable. Using local skills would give relevance and credibility to the PD, though expecting teachers be the providers of PD on top of their other commitments was not seen as reasonable. Releasing and training local teachers as facilitators is one option worth exploring, in the same way that the model has been used successfully in the NDPs.

To support a full roll-out, teachers would also require quality classroom resources, and well-considered sequences of teaching units that support the pedagogical approach of CAS. Pilot teachers had difficulty finding time to produce these resources themselves. This points to the need for a system of developing and sharing quality resources.

The costs of the technology will be one barrier to uptake in many schools. Staff and student turnover is another hurdle that will remain until the CAS-based approach to mathematics education is in place in most schools.

The need for a coherent direction that utilises technology effectively as a tool for the teaching and learning of mathematics suggests that one generic device could be adopted. However, the question as to whether CAS calculators are the best way forward needs to be asked. This question may need to be regularly re-evaluated given the ongoing advances in technologies. Many of the pedagogical approaches used in the CAS pilot may well continue to be pertinent to the future use of technologies in mathematics classrooms.

Reading the report

The report comprises 10 chapters. The first two chapters give an introduction to, and the methodology for, the evaluation. Each of Chapters 3–10 follows the same format as that below:

- A brief introduction.
- The research questions addressed by the chapter.
- A summary of major findings.
- Detailed findings of the chapter.
- A bullet list of key points from the chapter.

Generally, subject areas, for example algebra, are not capitalised. The exception is were they refer to a specific strand of the mathematics curriculum, and in these cases they do have a capital letter.

1. Introduction

This research is an evaluation of the 2006–2007 CAS[1] Pilot Project. The project aims to improve the teaching and learning of mathematics through the use of CAS technology in the mathematics classroom. Indicators of effectiveness that have been monitored include changes in teacher practice, changes in student attitudes and motivation towards mathematics, and changes in student learning and/or achievement. This evaluation attempts to determine whether the use of the CAS technology, along with support provided to teachers, is making a change to teacher practice and student achievement and/or learning.

Research questions

The following questions formed the basis of the research:

1. Have changes in teachers' roles and practices occurred in the CAS pilot school mathematics classes, and if so, what are they?
2. How effective have any changes in practice been?
3. Has the learning environment of these mathematics classes been affected, and if so, in what ways?
4. What are the professional development issues that have arisen in the pilot?
5. What issues will need to be addressed and what support will be needed to be given to teachers to enable the effective and sustained use of CAS technology?
6. What are students' current attitudes towards mathematics, and how have these changed as a result of the pilot?
7. How has student learning in mathematics been affected as a result of the pilot scheme?
8. What are the appropriate ways to assess student learning when CAS technology is available?

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[1] CAS stands for Computer Algebraic Systems and refers to mathematical software that has the capability of manipulating algebraic expressions, solving equations, differentiating and integrating complex functions, as well as most of the capabilities of graphics calculators. This technology can be in the form of hand-held calculators (sometimes referred to as SAM) or as software installed in computers.

Background to the CAS pilot

During the first three years of the implementation of the 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* (Ministry of Education, 1992) endorsed 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). The new curriculum also endorses the use of technology, but it does this right across the curriculum. It appears in the key competency *Using language, symbols, and text*, and in particular in the sentence, “They confidently use ICT … to, access and provide information, and to communicate with others” (Ministry of Education, 2007, p.12). This is insufficient for the Mathematics and Statistics learning area. The mathematical and the statistical cycle specifically require students to not just access information, but to also do something sensible with it. We suggest that *organising, analysing, and making sense of information* is as important as the features stated in *The New Zealand Curriculum*, namely “access and provide information and to communicate with others” (Ministry of Education, 2007, p. 12).

Some other countries are using CAS technology in the teaching of mathematics. Officials from the Ministry of Education and the New Zealand Qualifications Authority visited Victoria, Australia in 2004 to investigate the use of CAS in the teaching of mathematics. Reports from teachers and from research there suggested that the use of this technology can improve the students’ conceptual understanding of mathematics. It was decided to initiate a pilot project that would look at ways of improving teaching and learning of mathematics using the CAS technology in New Zealand. This pilot project would focus on the junior secondary school so that any effects of NCEA examinations on classroom practice would be kept to a minimum.

Six schools around New Zealand, each with two Year 9 classes, participated in the initial pilot in 2005. Sixteen further schools joined the pilot in 2006. These are the 22 schools upon which this evaluation is based.

2. Methodology

The purpose of this evaluation was twofold. It set out to capture the stories of students and teachers involved in the pilot, so that elements of effective practice could be identified and replicated. A second aim was to investigate the effect of using the CAS technology in the classroom on student achievement in, and attitudes towards, mathematics. To this end, both qualitative and quantitative data were collected. Interviewing both teachers and students and observing classroom lessons allowed for triangulation of some of the data.

The schools

The project started in 2005 with six schools, each with two Year 9 classes using the CAS hand-held calculators. These schools and their students remained in the pilot until the end of 2007 when the original Year 9 students were in Year 11. These six schools also introduced two Year 9 classes into the pilot in 2006 at the same time as 16 new schools entered the pilot. All these Year 9 students continued in the pilot until the end of 2007 and, in addition, 32 new Year 9 classes started in that year. Table 1 below shows the schools and classes involved.

Table 1 **The schools and classes participating in the CAS pilot project**

2005	2006	2007
Six schools • 12 Year 9 classes	**Six schools** • 12 Year 10 classes • 12 Year 9 classes	**Six schools** • Up to 12 Year 11 classes • 12 Year 10 classes
	Sixteen schools • 32 Year 9 classes	**Sixteen schools** • 32 Year 10 classes • 32 Year 9 classes

An advertisement in the *Education Gazette* in June 2005 invited schools to be involved in the extended CAS pilot project for 2006–2007. Many of the schools that applied in 2005 but missed out re-applied for 2006. Schools were chosen on the basis of several criteria, including experience in the use of technology in teaching mathematics; and the location, decile, and type of school.

The schools in the project were all state or state-integrated schools and they were geographically spread out across New Zealand, with six schools in the South Island and the remaining 16 in the

North Island. The tables below show the range of deciles and school types involved, with a comparison to the national percentage of schools of that decile or type. As can be seen, the sample is broadly representative across both categories.

Table 2 **The deciles of schools participating in the CAS pilot project**

Decile	CAS pilot schools	National profile
Low (1–2)	4 (18%)	15%
Medium (3–8)	11 (50%)	65%
High (9–10)	7 (32%)	20%

Table 3 **The types of schools participating in the CAS pilot project**

Type of school	CAS pilot schools	National profile
Girls	4 (18%)	15%
Boys	3 (14%)	13%
Co-ed	15 (68%)	71%

Case study schools

A sample of eight schools was selected from the schools in the pilot to be case study schools. These schools are representative of the 22 schools in the project. Two were 2005 pilot schools, and six were schools that joined the project in 2006. The sample contained one girls' school, one boys' school, and six co-ed schools. There were two schools in the South Island and the remainder came from the North Island. One school was low-decile, four were medium-decile, and three were high-decile.

These eight schools were visited in both 2006 and 2007, while the remaining 14 schools received one visit during the 2006–2007 period.

The data-gathering instruments

Teachers

All teachers who began the pilot at the start of 2006 or 2007 were given a baseline questionnaire which sought to find out: their views and use of ICT in the classroom; their expectations of the professional development (PD) they would receive during the pilot; their use of formative and summative assessments in the classroom; and their opinion of student achievement and attitudes towards mathematics. In addition, the teachers were asked to rank a series of classroom practices by the priority they believed they should have in the classroom, as well as how often the practice occurred in their own classroom, both pre- and post-pilot.

At the end of 2006 and again at the end of 2007, a follow-up questionnaire was administered. This repeated the questions from the baseline questionnaire and included more in-depth questions about the PD aspects of the project. A total of 69 teachers responded to a baseline questionnaire, and a total of 79 responded to a follow-up questionnaire. These numbers were used in separate analyses of either baseline or follow-up data. Patterns of change in views over the project were based upon the 55 teachers who responded to both the baseline and follow-up questionnaires.

In addition, a semi structured interview was conducted with the majority of teachers involved in the project. This interview expanded on some of the areas covered by the questionnaire, and focused on teaching practice, student learning, assessment, and future issues related to using CAS technology in the classroom.

Students

Baseline data on student performance were collected from all classes involved in the pilot project. A baseline attitudinal questionnaire was also administered to all students in the pilot. A control class who were not involved with the CAS pilot was also provided at each year level from each of the 22 schools, allowing a comparison of changes in attitudes and achievement levels to be made.

The test used to gather the achievement data was the relevant version of PAT:Mathematics. A new version of the test, Test 8, was constructed in conjunction with the PAT development schedule for use in this evaluation. Table 4 shows which PAT:Mathematics test was given to students at different times during the pilot. The attitude questionnaire asked all students to give a response to statements about their attitudes towards mathematics in general, and the use of calculators and computers in the classroom. Additionally, the students in CAS classes were asked to respond to questions about the use of CAS technology in their classrooms.

Table 4 **Schedule of PAT: Mathematics achievement tests administered**

	2006		2007	
	Start of year	**End of year**	**Start of year**	**End of year**
2005 Cohort	Test 7	Test 8	-	NCEA Level 1
2006 Cohort	Test 6	Test 7	-	Test 8
2007 Cohort			Test 6	Test 7

The total number of students in the CAS and control classes over the three years who sat a baseline PAT test was 3417. The total number of students in the CAS and control classes who sat at least one PAT test over the three years was 3648. Of these, 3417 sat the baseline PAT test. A total of 3746 students filled in at least one attitude questionnaire. Some students filled out an attitude questionnaire but did not do a PAT test and vice versa. A few students did not do a baseline questionnaire or PAT test, but then performed subsequent ones. About 70 percent of students who did a PAT test or an attitude questionnaire also did one at the end of that same year. The 2006 cohort of Year 9 students had the potential to sit three PAT assessments, and three attitude questionnaires. Only about 45 percent of these students did all three attitude questionnaires, and just over 41 percent did all three PAT tests.

One further instrument used with the students was the focus group interview. Focus groups were conducted with students at all eight case study schools and were also held in the six original schools, with both Year 9 and Year 10 students. In these sessions, between five and eight students would meet with the researcher and discuss their views on a range of statements about using the CAS technology in the classroom, the teaching methods used in their class, and their attitude and understanding in mathematics.

Classroom observations

Observations of CAS lessons were held in as many schools as possible, with a total of 69 classrooms being visited during the course of the project. One of these was not a lesson but a school-based assessment, and so the effective sample size was 68 lessons. During the observations, notes were made on classroom layout, the content of the lesson, the style of presentation, and student responses to the lesson.

PD providers

Two of the three providers of PD were interviewed as part of the evaluation. The researchers also observed a number of PD workshops and the overall co-ordinator of the PD was interviewed at the beginning of the project.

3. Observations and perceptions of classrooms

This chapter largely centres on observations and perceptions of what was happening in the mathematics classrooms. The initial section focuses on aspects of lessons that we observed during the pilot. The second section looks at students' perceptions of their classroom. A third section is a series of specific episodes of good or innovative practices we encountered, or some innovative uses of technology that we observed.

The chapter focuses on addressing the following research questions:

- *Research question 1*: Have changes in teachers' roles and practices occurred in the CAS pilot school mathematics classes, and if so, what are they?
- *Research question 3*: Has the learning environment of these mathematics classes been affected, and if so, in what ways?
- *Research question 6*: What are students' current attitudes towards mathematics, and how have these changed as a result of the pilot?

Summary—***combined summary for Chapters 3 and 4***

Teachers reported large changes in their teaching style as a result of the pilot, not only in their CAS classes, but also in their other classes. This indicated that the PD had profoundly influenced teachers' perception of their pedagogy. Teachers saw their style moving away from a rules-based approach to one of encouraging students to construct their own personal knowledge and understanding through exploration. They reported that technology was playing a larger role in their classrooms, and rich tasks were more evident, especially in their CAS classes, but also in their other classes as well.

Very few lessons we saw in the CAS classes followed a traditional pattern of "lecture then do examples". The most common style we saw was a cyclical pattern of short teaching slots followed by students working for a few minutes, after which the cycle would be repeated. Classroom discussions were common. Several discussions we observed were particularly rich. We saw CAS in use not only in Algebra, Geometry, and Probability, but also in other strands of the mathematics curriculum. Levels of student engagement, student-to-student interactions, and student–teacher interactions were high. We found no differences between the calculator brands in any of these areas.

Overall, students did not report large changes in teacher beliefs and styles, and tended to categorise the main style as teacher-led, with a focus on emphasising understanding. This differed from our observations, and teachers' views, suggesting that most students did not have a clear understanding about different styles of teaching. It may also be that teacher beliefs were not yet fully integrated into their practice. The 2006 cohort of Year 9 students were more likely to see changes than the 2007 cohort, suggesting that after the initial focus, teachers may tend to revert to earlier styles.

Students in both CAS and control classes did report a decrease in some classroom practices (for example, whole-class discussions) suggesting that some of the changes mentioned were probably a reflection of mathematics classes in general. Students' views on classroom practices were sometimes related to student ability, especially in the CAS classes, where the more able students could identify that the pedagogy emphasised new ways of looking at mathematics, and that they were learning new things. This indicates that able students were able to perceive the pedagogical agenda of the CAS pilot.

The detailed findings are in the following sections of this chapter.

Lesson observations

Altogether, 69 classes were observed from the 22 pilot schools. Nine lessons were observed in 2005, 27 in 2006, and 33 in 2007. One of the 2006 lessons largely constituted a combined class doing a test, and is hence excluded from the analysis. The lessons were mainly of Year 9 or Year 10 classes, but a few lessons were observed in Year 11 classes who were in the original 2005 pilot schools.

Observer descriptors of lessons

A number of attributes of each lesson were assessed by the observers, such as classroom seating, use of textbooks or exercise books, etc. These attributes may well have some bearing on the attitudes and achievements of students. A number of judgements were also made about the lessons such as teaching style, teacher beliefs, classroom behaviour, levels of teacher roving, student–student interactions, etc. These were based on observed ratings of the lesson on either nominal or Likert scales.

Classroom layout

Most of the classrooms (47) had traditional seating, usually with pairs of desks (but sometimes three or more, and one with individual desks) arranged in rows facing the front. In 14 classes, the desks were arranged in groups in various different ways. Another four classes had a mix of groups and pairs of desks, with three classes being in a computer suite. The desk arrangements obviously help shape the patterns of interactions, with the traditionally organised seating leading to pair work more easily than to group work.

Teaching style

The different styles of teaching in the observed lessons have been categorised into five distinct teaching methods described as "stories" below. The first four styles were reported in Neill and Maguire (2006b, pp. 27–29). The fifth style attempts to describe the more traditional approach of one teaching block followed by individual student work. The stories are arranged from most heavily student-led to those with a more teacher-led approach. In some of the classes, the teaching was a mix of more than one method, while other classes primarily followed one pattern.

Story 1. The major emphasis in this approach was using groups working co-operatively. Most often this involved some sort of problem solving or joint exploration.

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 students in quite different parts of the classroom. During the independent explorations, the teachers typically roved and interacted with the students, asking and answering questions.

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).

Story 4. This approach resembles the traditional method of teacher instruction followed by students performing tasks. However, it progresses a number of short cycles of teaching followed by student work. This pattern was then repeated several times during the lesson. Generally, each period of whole-class teaching was short, as was the time when students performed the assigned tasks.

Story 5. This is the traditional lesson format, where the teacher explained to the whole class a particular aspect of mathematics, often for about 15 to 20 minutes. Students then worked through examples using this particular aspect for the remainder of the lesson. This method of teaching was rarely observed in the CAS classes, although it is probably far more common in mathematics classes in general.

Table 5 **Stories of teaching**

Story type	Number	Percentage
Story 1 – Group work	10	15
Story 2 – Individual work	12	18
Story 3 – Whole-class dialogue	14	21
Story 4 – Cycles of teaching	27	40
Story 5 – Traditional	5	7
TOTAL	**68**	**100**

* Totals do not sum to 100% due to rounding

Another aspect of teaching style we monitored was the use of worksheets of examples, or textbook examples. Table 6 shows that using sets of examples from a textbook was less common than the use of worksheets or using neither.

Table 6 **Use of worksheets or textbooks**

	Number	Percentage
Worksheets	29	43
Textbooks	10	15
Neither	29	43
TOTAL	**68**	**100***

* Totals do not sum to 100% due to rounding

The third measure of teaching style was the extent to which the teacher roved around the class during lessons. We observed high levels of roving in the majority of classes, and only a few classes had little or none. This indicates that teachers were interacting with students, which can enable informal formative assessment. The patterns of roving are summarised below.

Table 7 **Level of roving**

Level of roving	Number	Percentage
High	41	60
Medium	16	24
Low or none	10	15
N/A or Don't know	1	1
TOTAL	**68**	**100**

Beliefs about teaching

The different lessons were categorised by an observer, who inferred which of three distinct sets of beliefs underpinned the teacher's style. These beliefs were described in an Australian study of CAS that followed the practice of three teachers over a period of time (Kendal, Stacey, & Pierce, 2005). The descriptions and frequencies of our judgement of these are displayed in the table below.

Table 8 **Beliefs on teaching**

Belief	Number	Percentage
I ensure students have mastery of the **rules** and procedures of algebra	17	25
I focus on the learner's **personal construction** of algebraic ideas (constructivist)	28	41
I emphasise **understanding** of algebraic concepts	23	34
TOTAL	**68**	**100**

These figures differ markedly from the perceptions of students and teachers (see Chapter 4, Table 18). We rated far more classes to be "rules-based" than did teachers or students. We observed instances where the apparent focus of the lesson differed from the fundamental belief system we judged that the teacher operated by. We considered that often teachers believed they taught for understanding but actually had little focus on an exploratory style that allowed students to construct their own meaning. One of these mismatches is outlined further on in this chapter. Teachers reported some shift over the pilot from an understanding focus to an exploratory, constructivist approach (see Table 18, p. 36).

Subject

Observed lessons came from each area of the mathematics curriculum, not solely those for which the teachers had undergone PD. Most of the statistics lessons we observed were in statistical investigations or statistical literacy rather than in probability, even though the latter was a focus of the PD.

Table 9 **Subject focus of the lesson**

Strand	Number	Percentage
Algebra	34	50
Geometry	17	25
Number	5	7
Measurement	1	1
Statistics (incl. probability)	7	10
Trigonometry	4	6
TOTAL	**68**	**100***

* Totals do not sum to 100% due to rounding

Student behaviour

Three judgements of this were made, all on a 5-point scale. These were: overall classroom behaviour; on task behaviour; and time to settle to tasks. Only about 10 percent of lessons were rated at the low end on any of the three scales, suggesting a relatively high level of student engagement.

Table 10 **Student behaviour overall**

Behaviour rating	Number	Percentage
Excellent	20	29
Very good	28	41
Average (some minor incidents)	11	16
Below average (regular minor incidents)	6	9
Poor (many incidents, some requiring significant intervention)	3	4
TOTAL	**68**	**100***

* Totals do not sum to 100% due to rounding

Table 11 **Student time on task**

On task	Number	Percentage
All students/almost all the time	18	26
Most students/most of the time	29	43
Most students/some of the time	12	18
Some students/some of the time	8	12
Only a few students/some or a little of the time	1	1
TOTAL	**68**	**100**

Table 12 **Student speed of settling**

Time to settle	Number	Percentage
Very fast	22	32
Fast	24	35
Medium	11	16
Slow	8	12
Very slow/never	3	4
TOTAL	**68**	**100***

* Totals do not sum to 100% due to rounding

Student participation

The general level of the content of student-to-student conversations was rated, as were the kinds of contributions students were making during whole-class sessions. We based this on a judgement on the conversations we heard as we roved around the class or listened to whole-class discussions. These are summarised in the two tables below which, like the behaviour data, show relatively high levels of engagement.

Table 13 **Nature of student-to-student interactions**

Interactions	Number	Percentage
All or almost all maths focused	13	19
Most maths focused	20	29
Many maths focused	20	29
Some maths focused	11	16
Few or none maths focused	3	4
N/A or Don't know	1	1
TOTAL	**68**	**100***

* Totals do not sum to 100% due to rounding

Table 14 **Nature of student contributions to class discussions**

Student contributions	Number	Percentage
Mainly discussing mathematics or demonstrating how to do the maths	36	53
Mainly sharing answers or results with the class	22	32
Little or no discussion	10	14
TOTAL	**68**	**100***

* Totals do not sum to 100% due to rounding

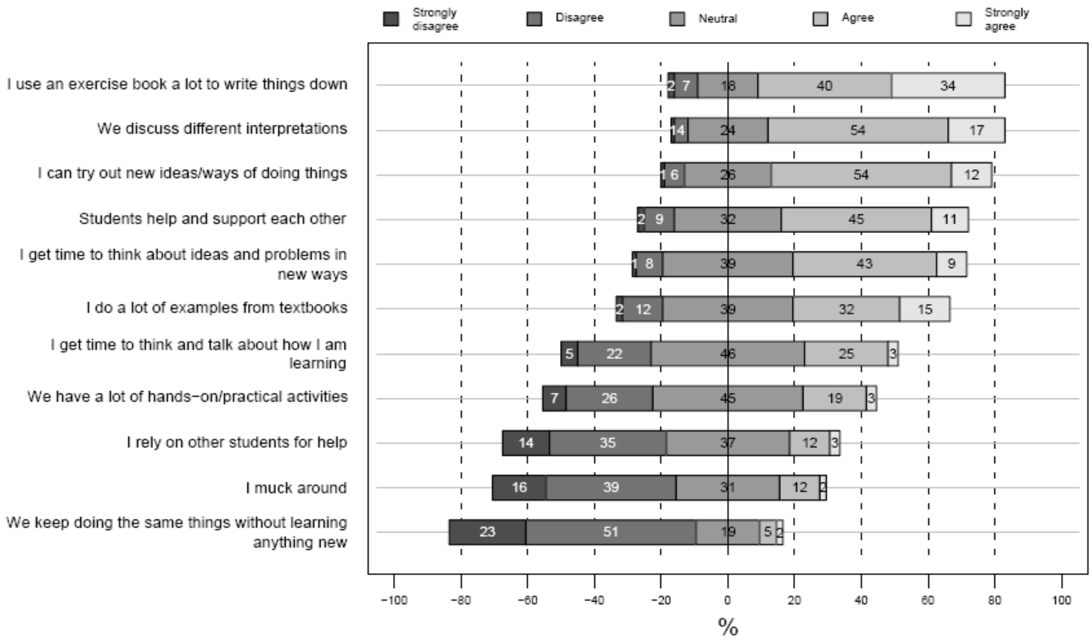
There were a few instances where the above patterns (in Tables 4–14) changed between different cohorts of students. The use of worksheets had a statistically significant relationship to the year of the observation (2005, 2006, or 2007), with less use of textbooks or worksheets in 2005, but more textbook use in 2007. Significantly more of the 2005 lessons were based on geometry than they were in 2006 and 2007. There was a small nonsignificant effect for teaching style. There was more rule-based teaching in 2005, more constructivist teaching in 2006, and more teaching for understanding in 2007. This indicates that there may have been a shift in mathematics teaching occurring over time.

None of these measures was statistically significantly related to the brand of calculator used in the class, and therefore the style of PD that the teacher had undergone. This means that all the measures were far more likely to be teacher effects or school effects rather than effects that were due to the PD.

Student perceptions of their mathematics classrooms

Eleven questions in the student questionnaire were related to aspects of the classroom, ranging from student views on their level of engagement, through to the types of resources they used. These were asked before they began the project, and again after they had been involved for one or two years. Figure 1 shows the descriptors in descending order of levels of agreement for the students at the beginning of Year 9, before they began the pilot. These baseline patterns were very similar for the 2007 students, and for both CAS and control class students, and so just the 2006 data for CAS students are shown.

Figure 1 **2006 baseline responses to descriptions about classrooms (2006 Year 9 CAS)**



- Three of the five most commonly supported statements related to aspects of new ways of looking at things, either through discussion (71 percent of CAS students in agreement), trying out new ways of doing things (66 percent), or time to think in new ways (52 percent). These reflect a more varied approach to mathematics than we would expect to see in a typical mathematics classroom.
- The most highly rated theme was that there was frequent use of exercise books (with around 74 percent of CAS students in agreement). On the other hand, only about half agreed that they did a lot of examples from textbooks.
- Respondents rated “Students help and support each other” relatively highly (about 56 percent in CAS classes, but only 44 percent in control classes), but much lower percentages were “relying on other students for help” (with about 15 percent agreeing).
- Less frequent use was noted in: getting time to think about learning (metacognition), with only 28 percent of CAS students agreeing that it occurred; and practical activities, with about 20 percent agreement.

- Negative responses such as "I muck around" or the one related to the repetitive nature of lessons were the lowest rated, with only around 14 percent and 7 percent respectively in agreement.

Student perceptions for several of these indicators moved significantly over the course of the pilot. In most cases, CAS and control class students changed in similar ways. The changes over each year are given in Table 15. This tracks the changes for the 2006 cohort of Year 9 students, and gives the amount of change over Year 9 (2006), and for those same students in Year 10 (2007). The changes that are clear and consistent are summarised below, but these need to be compared against the baseline data in Figure 1.

- There was an increase in the number of students agreeing that they mucked around. This was observed in the Year 9 CAS and control classes, and was particularly marked in the Year 10 control classes, but was not the case in the Year 10 CAS classes. This indicates that Year 10 CAS students stayed more engaged than the control class students.
- There was a decline for both sets of students during Year 9 in both having time to think about, and opportunities to try doing things in new ways. This drop persisted through Year 10 for the CAS students. This is counter to the expectation that CAS students in particular would be experiencing doing things differently in mathematics. There was also a significant drop in discussing different interpretations, but this was only significant for Year 9 control class students, and Year 10 CAS students.
- Significantly more CAS and control class students agreed that there was a lower emphasis on practical activities by the end of Year 9, with a further drop by the end of Year 10.
- An increased reliance on other students was reported by Year 9 control class students and all Year 10 students.

Table 15 **Changes in classroom practices of CAS and control class students (2006 Year 9 cohort)**

Attitude in class	2006 Yr 9 CAS	2006 Yr 9 Control	2007 Yr 10 CAS	2007 Yr 10 Control	Overall CAS	Overall Control
Discuss different interpretations	-0.02	**-0.28**	**-0.27**	-0.06	**-0.30**	**-0.34**
Use exercise books a lot	-0.06	-0.04	-0.01	**-0.18**	-0.07	-0.18
Try out new ways	**-0.17**	**-0.18**	**-0.14**	-0.05	**-0.31**	**-0.22**
Students help each other	-0.06	**-0.11**	0.09	0.10	0.02	0.01
Thinking in new ways	**-0.17**	**-0.26**	**-0.15**	0.00	**-0.31**	**-0.25**
Use textbooks a lot	0.03	0.00	0.08	**-0.11**	0.11	-0.09
Time to think about learning	-0.10	**-0.12**	-0.07	-0.02	-0.16	-0.15
Lots of practical activities	**-0.23**	**-0.21**	**-0.17**	**-0.23**	**-0.41**	**-0.48**
Rely on other students	0.07	**0.14**	**0.17**	**0.13**	**0.22**	**0.28**
I muck around	**0.19**	**0.20**	0.06	**0.31**	**0.25**	**0.52**
Keep doing the same things	0.04	0.04	**0.13**	**0.11**	0.17	0.15

Note: Bolded figures are indicative of significant differences of above 0.10 for one year, and 0.20 for two years.

Student perceptions of the classroom compared with their achievement levels

A number of these perceptions of classroom practices were related to the ability of the student (measured in patm units). For a relationship to be deemed to be meaningfully related to ability, there needed to be a statistically significant association, as well as a consistent upward or downward trend of results. For the 2006 and 2007 cohorts of Year 9 students, their ability and perception of the classroom had a meaningful relationship in six of the 11 variables measured. While the trends were significant, there was considerable variation (as can be seen by the whiskers on all of the graphs of this sort that appear in the rest of this report) and hence the relationships were weak.

More able students were *less* likely to report that they muck around (see Figure 2). The trend was similar for both CAS and control class students. It was present in both the 2006 and 2007 cohorts of Year 9 students, as well as for the students who were in Year 10 in 2007. The box plots are the combined responses for both CAS and control class students. The dots (which are joined by lines to help highlight trends) represent the mean ability for CAS and for control class students within each level of agreement with the statement.

Figure 2 **Relationship between student ability and whether they say they muck around (2007 Year 9 cohort)**

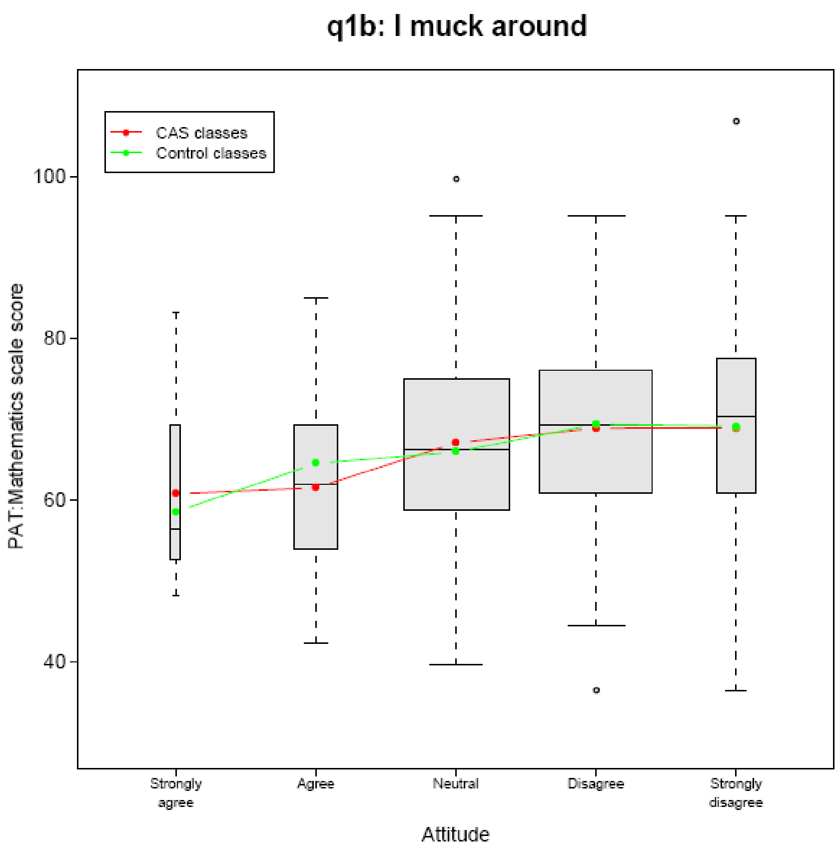
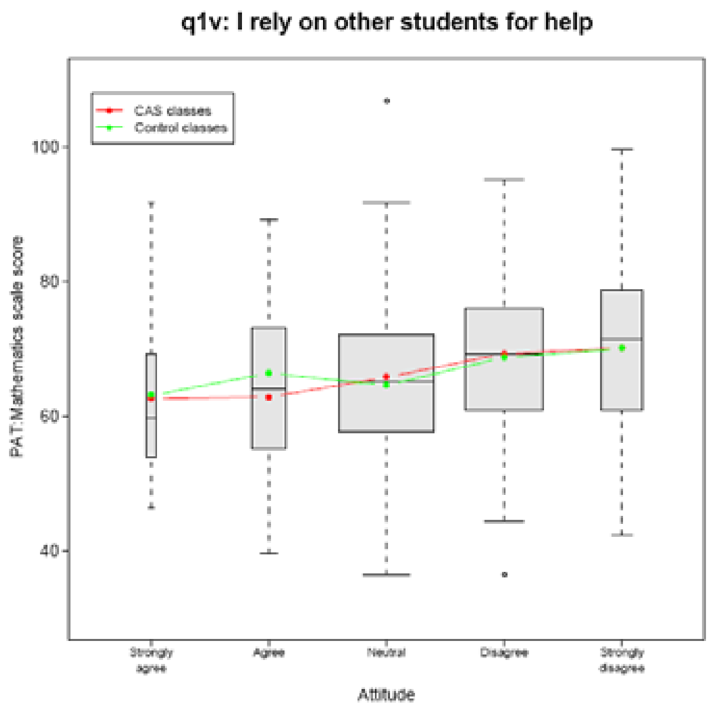


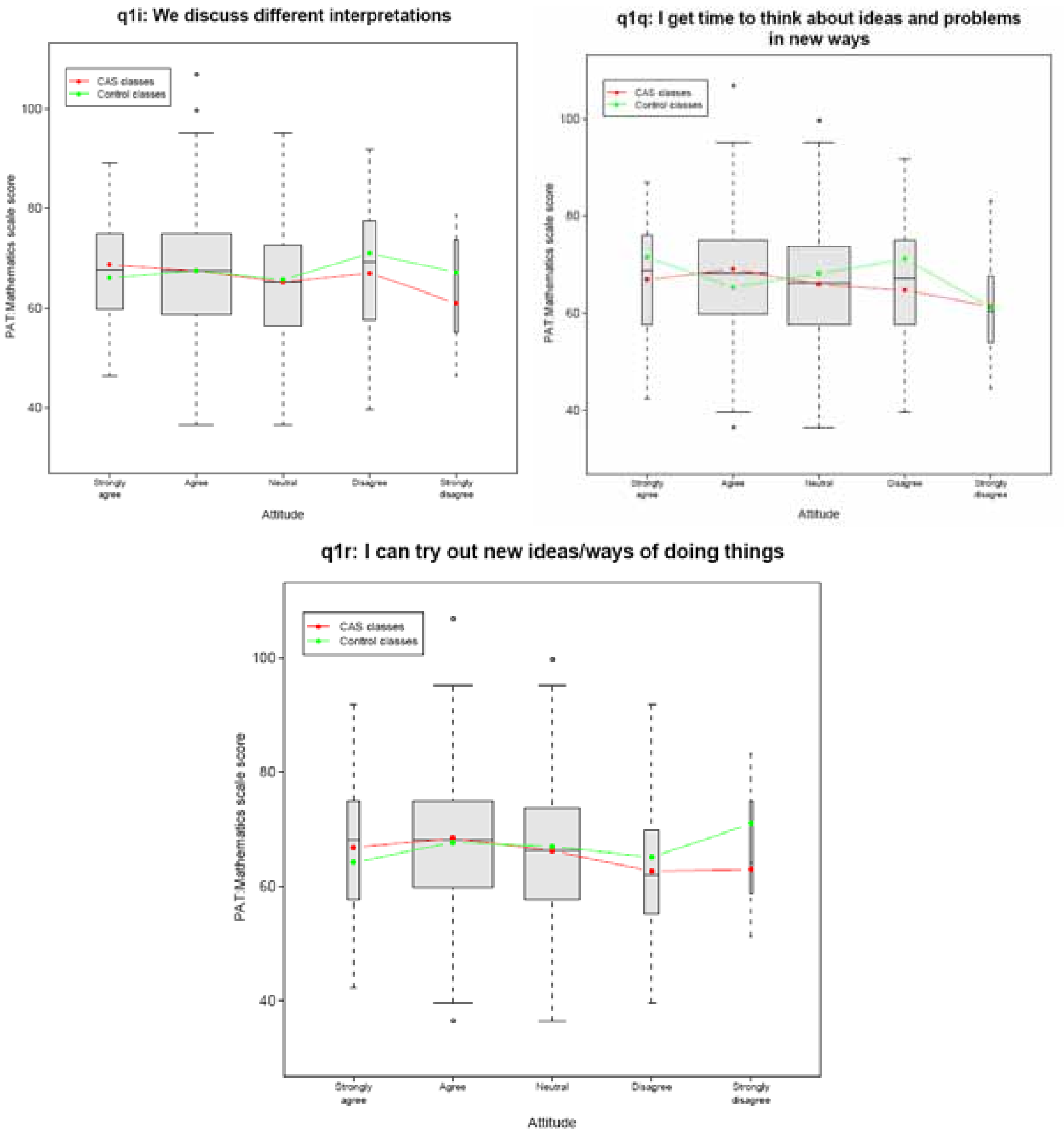
Figure 3 **Relationship between student ability and whether they rely on other students (2007 Year 9 cohort)**



Less able students were more likely to report that they rely on other students for help. This was equally present in both the CAS and the control classes, and occurred in the two Year 9 cohorts and for the Year 10 students (see Figure 3).

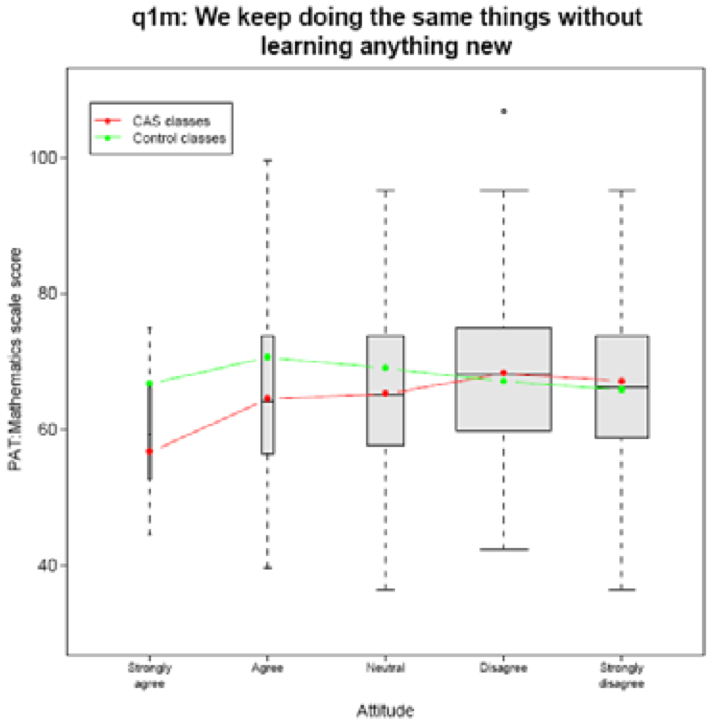
More able students were more likely to report differences in discussing different interpretations; and in thinking about, and in trying new ways of doing mathematics. In each case, this was evident across the CAS classes, but not in the control classes (see Figure 4, where there is downward ability-related trend in the CAS classes, but no trend in the control classes). It appears that the more able CAS students were more likely to have spotted the different approach to mathematics teaching in their classrooms.

Figure 4 **Relationship between student ability and discussing, thinking, and doing things new ways (2007 Year 9 cohort)**



In CAS classes, the less able students were more likely to report doing the same things without learning anything new. In the control classes, there was no relationship between ability and their level of agreement (see Figure 5). Again, the more able CAS students report higher levels of new learning than the less able students.

Figure 5 **Relationship between ability and not learning new things (2007 Year 9 cohort)**



Examples of classroom teaching

In the 69 classrooms observed, we saw a number of lessons that had features worthy of consideration by teachers in other classrooms. Excerpts from the lesson observations follow, with a commentary of the salient features for consideration. The first of these has already been reported in the earlier evaluation of the project (Neill & Maguire, 2006b), but is repeated and expanded here.

Example 1: Expert group exploration

The major emphasis in this approach was using expert groups that each performed an exploration that helped the whole group to discover a specific geometric property. This teaching strategy has been referred to as the expert jigsaw method (see Kagan, 1994). This approach was demonstrated in the classroom observations of School C in 2005, and took up the majority of each of the lessons observed.

The Year 9 students moved from their original desk groups into separate expert groups. Each expert group was given a comprehensive instruction sheet that described how to use the CAS to do a specific exploration. The emphasis was to learn something so that each student could teach it to the others from their original desk group. Within the expert groups the students worked individually, in pairs, or as a whole group. Students who had made faster progress helped the other group members to do the activity. This involved making sure they could all undertake the task on the CAS as well as understanding the geometrical property that was being explored. Each group demonstrated highly on-task behaviour. There was lots of talking that was almost entirely on the mathematical ideas being explored. During this process the teacher roved between the groups, interacting with individuals or whole groups. Each expert group member had to have a sufficiently thorough grasp of the geometrical property to be able to return to his or her original desk group and describe the geometry to them.

Here is a conversation within one expert group, who were exploring the relationship between the exterior angle in a triangle and the sum of the two opposite angles:

S1: What do you do?

S2: I think that the exterior angle is GHI.

S3: How do you do that?

S2: Touch that, then move it. … You haven't got it (the calculator) set up right … Have you done that?

S3: Yes.

S2: Good!

Students then added the two opposite interior angles for their own triangle and repeated it for other triangles. One student acted as the teacher by explaining things to others in the group both one-to-one and to the whole group.

S2: Do you get it now?

Each expert group member returned to their original desk group, and had to describe the mathematical property they had discovered to their desk group. The other group members then had to complete a cloze task relating to the geometry property that had just been shown to them. In this way, each student found out about all the explorations without necessarily having to complete them all.

Example 2: What does "=" mean, and "proof" by technology

This was a rich example of a whole-class discussion led by the teacher, but with significant student input. The lesson began with the teacher asking the Year 10 students to discuss whether the following statements about fish were always true, sometimes true, or never true by matching the statements:

Fish live in water	Never true
Fish are blue	Always true
Fish have five legs	Sometimes true

The students easily agreed that "Fish are blue" is sometimes true. There was some discussion about the other two statements mainly quoting counterexamples about some fish not living in water (axolotl, flying fish), or that there might be a fish with five legs (a mutation perhaps). The point was largely taken by students that statements may be always true, sometimes true, or never true. This applies equally to algebraic statements containing an equals sign. Three equations were given to the whole class to decide if they were always, sometimes, or never true. The class was asked to reach a consensus about the following statements. After some debate it was agreed that some statements are sometimes true, some are never true, and some are always true.

Question 1: $3x - 4 = x$
Question 2: $x + 1 = x$
Question 3: $x^2 \times x^3 = x^5$

T: Which one is always true?

S1: Question 1 is true.

T: Why?

S1: Because if $x = 2$ it is true.

T: So is it always true or only sometimes true?

S2: It's not true if $x = 3$.

T: So if we can find one counterexample we know it is not always true.

T: Which one is never true?

S3: Question 2.

T: How do you know?

S3: It didn't work for all the numbers I tried.

T: Does that mean it can't work for any number?

S4: The CAS came up with 'no solution' [for Question 2].

T: OK. Why do you think it did that?

S5: Well, one more than a number can't be the same number.

T: What about Question 3?

S6: We usually do question and answer. Meaning $2x + 3x = 10$, i.e., the answer is 10

S7: Are we solving?

T: Well is it 'solve', 'factorise', 'simplify', or 'expand'?

S3: [Is it] simplify?

The teacher leaves the question hanging.

The teacher then distributed envelopes with equations in them to students who worked in pairs or small groups. Students needed to classify each equation as to whether it was always, sometimes, or never true. They had to justify **why** they decided which it was, in a way that would convince others.

The teacher roved, prompting students for their reasons for classifying equations, and making it clear that arguments that involved the CAS were acceptable (e.g., using tables, graphs, "solve", etc.). After about 20 minutes the class got back together and discussed these equations:

A. $x + x + x = 3x$ Class agreed that this is always true.

B. $2x + 1 = 7 – x$ Class agreed that this is sometimes true.

The following is a selection of some of the exchanges that took place:

T: How do you know **B** is only sometimes true?

S1: Look at the graphs!

The teacher showed the class on the emulator how to show the values of two functions in a table and how to then look at the graphs. Some students then tried it and made the following comments to the whole class.

S3: If they [the graphs] are both the same line then they are always true. (referring to A)

S8: If they meet once then they are only sometimes true. (referring to $x = x + 2$)

S4: What if they meet twice, are they then still 'sometimes true'? (referring to $x^2 = x + 2$)

S5: If they never meet, they [the equation] are never true—if they are parallel.

T: What about $x^2 = -9$?

S9: That's never true.

T: Is he right?

S10: Yes because two minuses makes a plus!

Concepts of proof by counterexample were hence developed, and also the idea of "proof" using technology to obtain graphs and tables was developed. The students generalised that if graphs (or tables) intersected then the statement was sometimes true, if they were identical then the statement was always true, and if they never intersected then the statement was never true.

Example 3: A mismatch between a teaching style and beliefs

The following Year 9 class observation demonstrates a mismatch between the style of the lesson, and the underlying beliefs of students and their teachers. While the example does not exemplify good practice, it does illustrate a real classroom tension. The lesson was on angle properties in geometry, and the class was arranged in seven seating groups. After a whole-class teaching time that demonstrated how to draw shapes and measure angles, each group was given a series of geometrical properties or propositions to investigate by using features of the CAS calculator to measure and record angles, and to generalise the properties they observed. This clearly fitted the investigative/constructivist approach to learning.

In one of the groups, a student started doing the suggested investigation. Another student, who already knew the properties, just wrote them down in their book, while the remaining three chatted about other things. The student who already knew them dictated the properties to the other students with no explanation about why the properties were true. The student actually doing the investigative approach stopped his investigation, and also wrote down the properties in his book. The group then spent the remaining quarter hour just chatting on nonmathematical themes.

At the conclusion of the lesson the teacher praised this group as the best performed as they all had the relevant properties recorded in their books. This indicates that the basic belief of the students and the teacher was that rule acquisition is paramount. The teacher may well have believed that the lesson was investigative/constructivist, but the clear underlying message was that knowing mathematical rules (without necessarily understanding them) was the true aim, and the students responded accordingly.

Example 4: Preparing students for examinations

One particular lesson showed the deep attachment some students had made with their CAS calculators. The Year 11 class was revising trigonometry for their school and NCEA exams. Only two of the students did not have their calculators. Almost all of the others were using them. No other calculators were in use. Many of the calculators were decorated with neat and intricate patterns, and often they had emblazoned their names on them. This personalisation of the calculators appeared to us to be an indication of the strong attachment these students had developed over the three years they had been using them.

The teacher introduced a previous exam question to the class and reminded them how to use the CAS calculator using the degrees mode. Stressing correct settings to use is vital in exams. He also discussed the real-world context of the problem and its mathematical content, as well as how to find the New Zealand Qualifications Authority (NZQA) website.

He got the class to work on a merit part of the question while giving prompts to the whole class in response to any questions they had. At one point, this short exchange took place:

T: Not all of you have got it. We have a problem.

S: Should we use the draw method [on the CAS] because it doesn't use SOHCAHTOA?

T: Well, it [the exam model question] doesn't say you have to do it that way.

S: We could use the draw method to check.

T: Yes, you could. We've been using SOHCAHTOA so we may as well use it.

After about 15 minutes, one student demonstrated their method on the board. A whole-class discussion followed. This shows that the teacher had made a space for students to choose which approach to take, rather than just "telling" them.

Observation of complementary technologies

In some classes, different technologies were used in conjunction with CAS calculators (other than the common use of a data projector).

Example 1: Using a tablet in conjunction with a laptop

The teacher, who had health issues which prevented him from writing on traditional boards, had been provided with a tablet for their laptop. He had set up his laptop on a desk half way down the class and on the extreme right by the windows. The tablet allowed the teacher high flexibility and he had opened up access to it by allowing the students to use the tablet to demonstrate what they were doing either using the CAS emulator, or using it to write on. The students also accessed it to use other applications such as Google to search for information. The technology hence resided within the class rather than being "on display" at the front of the class.

The Year 9 students had been exploring the use of ratios in the Number strand, and the teacher aimed to consolidate their learning on this topic. He challenged them to use the CAS to show a Year 9 student who hadn't yet learnt about them, what ratios are and how to calculate them. The response from one student was an incredulous "Are you serious?"

The calculators were handed out and most students immediately started using them to perform the task, mostly as individuals but some worked in pairs. The teacher roved and regularly intervened by giving students possible leads. At one point he stopped the class to highlight one student's idea about exploring vectors on the CAS, which the student demonstrated to the class on the emulator. Students looked in manuals, used the "Help" feature on the calculator, or used the tablet to surf the Internet trying to find ways to perform the task.

After a time, only a few students were making progress on how to use CAS for ratios, so the teacher changed the brief to writing down an explanation of how to simplify ratios so a Year 9 student could do this with understanding. Some students continued to explore the task on their calculators, while the majority started a written explanation. The teacher gave a homework challenge to see if students could find a way to use the CAS calculator to simplify ratios.

This free exploration on their calculators, with access within the class to the Internet, demonstrated an effective use of technology, and highlighted the potential of a tablet. While students found it hard to make progress because of the open-ended nature of the task, it did enable students to engage in rich exploration. Perhaps at Year 9, more scaffolding could have been of value so students were directed to useful avenues of investigation.

Example 2: Linking CAS and Interactive Whiteboard use

The distinctive feature of this lesson was that instead of projecting the CAS emulator onto a screen, the emulator was linked to an Interactive Whiteboard (IAW). This allowed the teacher to give a verbal instruction and then activate it by physically touching the relevant button on the IAW. The students followed what the teacher did on the IAW on their own CAS calculators. The class found it easy to stay in step with the teacher with the extra impetus of the IAW acting as if it were the CAS calculator itself.

Students had already collected data on text message usage on a Saturday and a Sunday for eight students. The conversation below includes the most significant excerpts from about 22 minutes of exchanges between the teacher on the IAW and students. There were several significant gaps when students worked with their own calculator and the teacher roved.

T: How will I enter the data?

S1: Press 9 <enter>, 3 < enter>, etc.

Wrong number of data points entered by some students.

T: How many pieces of data do I have? We'll need to go back.

S2: How do I do that?

T: Just do this (*presses relevant buttons)* Mmm, I'm not getting it (*changes settings).* Is this what you got?

S2: Yes.

T: [Can you] show me how to get a box plot?

S3: I got a different graph.

T: I'll have to show you how to change the settings for a plot. I'll set the range as 0 to … What should I set the upper limit to?

S4: Try 10.

The teacher discusses the meaning of the box plot by asking questions about percentages, quartiles, etc.

T: In column 2 we are going to put the data for Sunday.

The teacher and students enter the data (teacher on IAW, students into CAS). They keep in step with each other.

T: We now want to plot both box plots.

The teacher showed how to change the settings.

S5: How?

S6: Do you have to check it as well? (*checked that both columns were correct*)

T: Yes, that means the calculation will work on two bits of data. … Now <plot> gives both box plots. … Have you got it? … Who has got a problem?

S: Yes, I have. (*teacher goes and helps this person*)

T: What can you tell me about the two box plots? Which has the highest median?

S: Saturday.

A teacher at another school also made significant use of an IAW, but they used it as a tool quite separate from the CAS calculators, and primarily as a class demonstration device. A study by Zevenbergen and Lerman (2008) indicated, however, that the IAW was often used for teacher-directed learning rather than the more exploratory style advocated in the CAS pilot.

Key points of Chapter 3

Overall in CAS classes, our observations indicated that teaching styles were largely nontraditional. Constructivist beliefs or teaching for understanding were more common than a rules-based approach, but the latter was observed more often than the data on teachers' beliefs predicted that it would. The classrooms we observed had low levels of textbook use, and high levels of teacher roving and interactions between the teachers and students. There was also a lot of student–student interaction. Much of this interaction was a natural consequence of new and unfamiliar technology. There were no significant differences between the classes we observed due to the particular type of calculator and the associated PD. The teaching styles we observed were:

- Short, repeated cycles of whole-class teaching followed by individual and pair work. This was the most common teaching style.
- Group work, classroom dialogue, and individuals working at their own pace were all common.
- The traditional lecture approach of one teaching block followed by individual or pair work was the least evident style.

In the classes we observed, CAS was most commonly used in algebra, followed by geometry. It was also used for number, and for statistics, but rarely for measurement.

The CAS and the control class students initially had very similar perceptions of classroom practices. This contrasted with the views of teachers who reported large changes (see Chapter 4). Changes in both groups of students were seen over Year 9, although this was more pronounced in the control classes than in the CAS classes. There were decreases in practical activities, and a lesser emphasis on thinking about or trying new ways of doing things in mathematics. This could be partly due to time pressures building towards the end of the year. More able CAS students, however, were more likely than other students to report they were thinking about or trying out new ways of doing things and were less likely to believe they weren't learning new things, indicating that they were more likely to see the underlying values of the pedagogy that was driving the pilot. The students in general reported that they were "mucking around" more than at the beginning of the pilot. This was more pronounced for control students than for CAS students, which supports the view that CAS students had higher levels of engagement than other students.

We observed numbers of instances of effective teaching, although this was not always the case. While it is hard to pinpoint what equates to effective teaching that utilised technology, it appears that being comfortable with the technology is an important ingredient. This leads to a willingness for the teacher to "let go" and to be relaxed at not knowing everything themselves. This, in turn, allowed the students to explore, and to become the experts themselves. Teachers with the ability and confidence to handle malfunctioning calculators and general troubleshooting were able to prevent technical problems getting in the way of teaching and learning. These specific skills need to be on top of the range of skills and practices which make an effective teacher, such as good classroom management skills, quality feedback to students, and the ability to motivate students and capture their attention. We also observed effective use of complementary technologies, such as the IAW, and tablets.

4. It’s all about the pedagogy—teacher and student perceptions of teaching

This chapter reports on the views of students and teachers who participated in the CAS pilot project. It includes information from interviews, small student focus groups, and questionnaires. The chapter focuses on addressing similar issues as the previous chapter, but largely through different lenses, those of teachers and students. It focuses more on the teacher and their style rather than on the actual classroom, which was the main focus of the previous chapter.

The relevant research questions are:

- *Research question 1*: Have changes in teachers’ roles and practices occurred in the CAS pilot school mathematics classes, and if so, what are they?
- *Research question 3*: Has the learning environment of these mathematics classes been affected, and if so, in what ways?
- *Research question 6*: What are students’ current attitudes towards mathematics, and how have these changed as a result of the pilot?

Summary—*see joint summary at the beginning of Chapter 3*

The detailed findings are in the following sections of this chapter.

Student perceptions of mathematics lessons

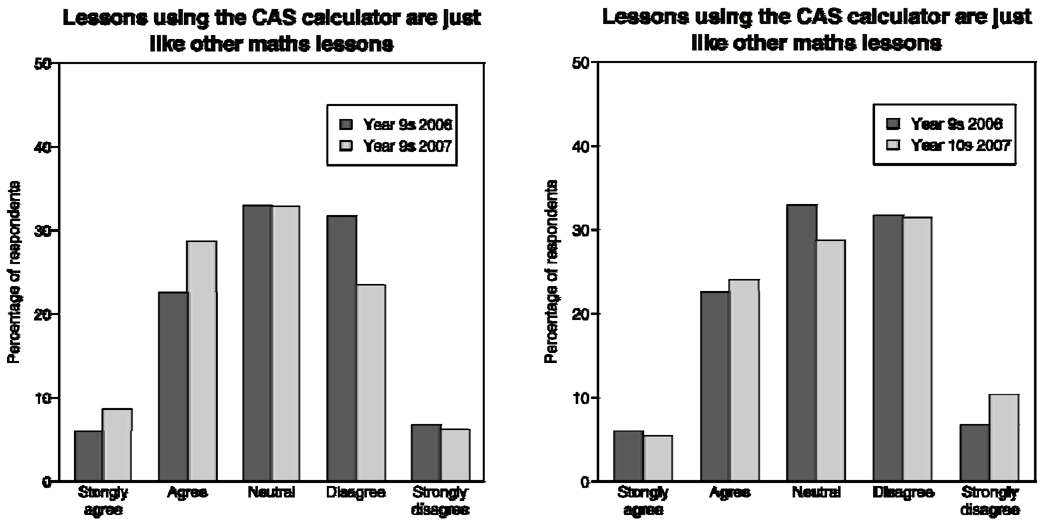
CAS students’ views on mathematics

Students were asked a number of questions about their mathematics lessons, both before they started in the CAS pilot, and after they had been participating for one or two years.

Students were asked if they thought that lessons using the CAS calculator were like other mathematics lessons. Figure 6 shows that, although students’ views were widely distributed on this, there was a reasonable balance, with roughly as many students agreeing with the statement as disagreeing. The left-hand graph in Figure 6 shows the comparison between the 2006 and the

2007 cohort of Year 9 students. The right-hand graph shows the attitudes of the 2006 Year 9 students compared with their attitudes in 2007, when they were Year 10 students.

Figure 6 **Students' comparisons between CAS and non-CAS lessons**



There were significant differences between the groups. The 2006 Year 9 group was significantly less likely to agree with the statement than the 2007 Year 9 students (see the left-hand graph).[2] The Year 10s in 2007 were also significantly less likely to agree than the 2006 Year 9s (see the right-hand graph).[3] While there was a marginally significant difference between the 2006 Year 9s and the 2007 Year 10s,[4] this was only because the Year 10s were a little more likely to strongly agree than the 2007 Year 9s. There was no relationship between students' perception of lessons and their ability measured on the patm scale.

This means that students who began the pilot in 2006 as Year 9s (who were then Year 10s in 2007) were more likely to perceive CAS-based lessons as different from non-CAS lessons than students who began in 2007. This pattern persisted and, if anything, strengthened when these same students were in Year 10. Overall, the 2007 Year 9s reported little difference between CAS and non-CAS lessons. It may be that teaching styles using CAS were reverting to previous teaching patterns, or that non-CAS lessons were changing to become more like the CAS ones. Figure 11 shows that teachers reported that they have changed their practice both in CAS and in non-CAS classes, so it is most likely that a real change in pedagogy has occurred.

[2] Chi-squared = 18.14, 4 d.f. $p = 0.0017$

[3] Chi-squared = 24.46, 4 d.f. $p < 0.0001$

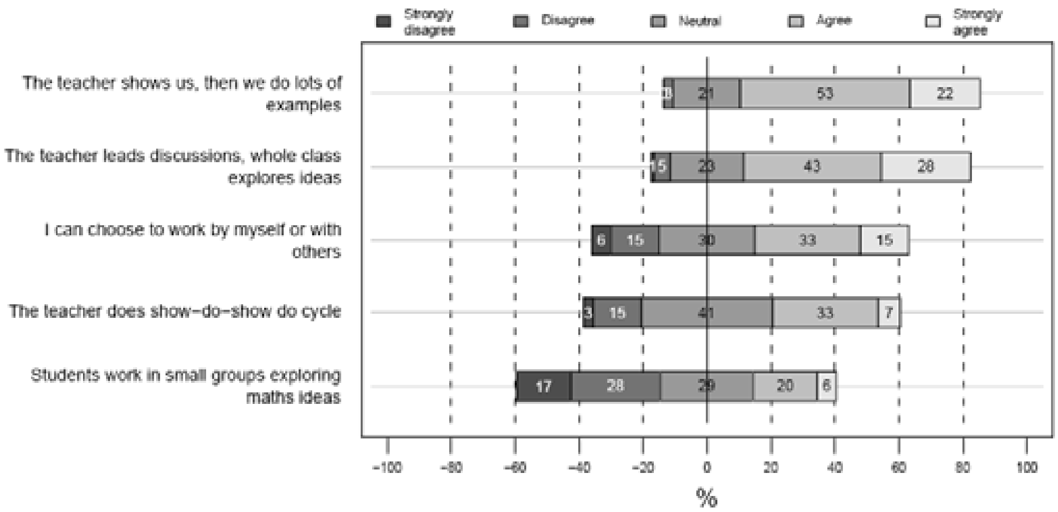
[4] Chi-squared = 9.66, 4 d.f. $p = 0.0470$

CAS and control students' views on pedagogy

Lesson style

Students' perceptions of their lessons were compared using descriptors of five distinct teaching styles identified in the initial report on the 2005 CAS pilot (Neill & Maguire, 2006b). The following graph gives the baseline data for the 2006 and 2007 Year 9 students. The patterns in 2006 and 2007 were very similar as were those for CAS and control classes, and therefore only the 2006 CAS data are shown.

Figure 7 **Baseline responses to descriptions of the style of mathematics lessons (2006 Year 9 CAS)**



This shows that the two most common styles reported by students before the trial began were either that the teachers led discussions and then students explored ideas (about 75 percent agreed or strongly agreed); or the traditional approach of one teaching slot followed by students doing examples (about 70 percent in agreement). The least commonly reported style was doing group work (with about 25 percent agreement). There was only one consistent and significant difference between the control and the CAS classes. Control class students were more likely than CAS students to say that they never used group work. Overall, students perceived a teacher-led focus much more than a student-led approach.

These findings did not match our observational data, where we rated the most common style as cycles of teaching followed by student work (40 percent of lessons). In our observations, the traditional approach was by far the least common, with just 7 percent of lessons following this format. The other three styles were noted in 15 percent to 21 percent of the lessons we observed (see Table 5 of Chapter 3). One reason for this could be that students did not correctly gauge their teachers' intent, and focused on the teacher-led elements of the lesson. They may well have classified lessons which followed the show-do-show cycle as being "teacher shows and we do". It may also have been that teachers modified their approach in the lessons knowing they were to be observed. Our impression from the classroom dynamics was that this was not a major factor.

Student perceptions for several of these teaching styles had moved significantly over the course of the pilot. In most cases, CAS and control class students changed in similar ways. The changes over each year are given in Table 16. This gives the changes for the 2006 cohort of Year 9 students, who were Year 10 in 2007.

Table 16 **Changes in teaching styles in CAS and control class students (2006 Year 9 cohort)**

Lesson styles	2006 Yr 9 CAS	2006 Yr 9 Control	2007 Yr 10 CAS	2007 Yr 10 Control	Overall CAS	Overall Control
The teacher shows us, we do …	-0.05	**-0.12**	**0.11**	**0.17**	0.05	0.06
Teacher leads discussions	**-0.11**	**-0.24**	**-0.24**	0.01	**-0.38**	**-0.21**
I can choose to work by myself	**-0.18**	0.07	0.04	**0.19**	-0.16	**0.26**
Show-do-show-do cycle	**-0.12**	-0.03	-0.01	-0.01	-0.13	-0.02
Group work	0.06	0.09	-0.02	0.01	0.03	0.11

Note: Bolded figures are indicative of significant differences (above 0.10 for one year, and 0.20 for two years).

The only change that was clear and consistent in both 2006 and 2007 was that students reported less teacher-led discussion by the end of the year. This happened in all but the 2007 Year 10 control classes. Both the CAS and control classes in Year 10 reported an increase in the traditional approach to teaching ("the teacher shows us and then we do …"). The other bolded changes showed no consistent patterns.

The Year 10 students' baseline results showed a similar pattern. The main exceptions were that by the end of the year, the control class students reported much higher levels of traditional teaching, and lower levels of a discussion-based approach than the Year 10 CAS classes. Both Year 10 CAS and control classes also reported lower levels of independent work. This may be the result of teachers needing to rush to finish all the curriculum elements that they need to cover by the year's end.

There were no meaningful relationships between students' perception of the style of teaching and student ability (measured in patm units).

Teacher beliefs

Students were asked to rate their teacher's pedagogical approach according to three descriptors that were used in an Australian study of CAS (Kendal et. al., 2005). This study followed the practice of three teachers over a period of time and typified their teaching as follows:

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.

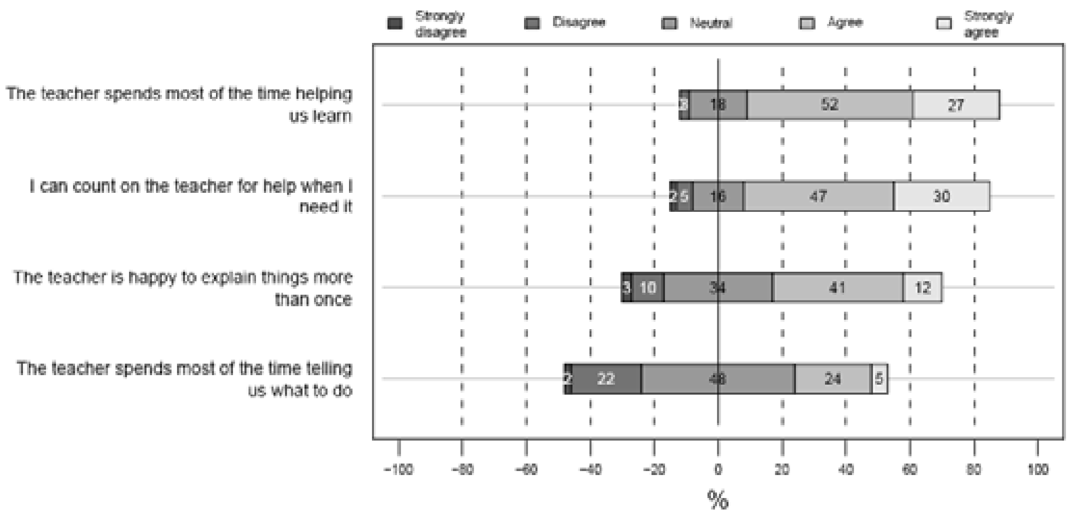
C: I emphasise understanding of algebraic concepts.

Students were asked which of these three different teaching styles best reflected their teacher's practice at the beginning of Year 9, and again at the end of Year 9. There were no significant differences between the CAS students and the control class students either at the beginning or at the end of Year 9. This was true for both the 2006 and the 2007 Year 9 groups. There were no significant differences either between Year 9 and Year 10 students. The end-of-year perceptions of students can be seen in Table 18 (p. 36). Most students (65.3 percent) saw their teachers as emphasising understanding, with 14.6 percent perceiving a rules-based approach, and 20.2 percent reporting an emphasis on personal construction of ideas.

Teacher input

Students also answered four questions about aspects relating to their teacher's interaction with students. Again, the pattern of these was very similar for the 2006 and the 2007 Year 9 students, and for CAS and control classes, so just the graph for 2006 Year 9 CAS students is shown in Figure 8.

Figure 8 **Baseline responses to descriptions about teachers (2006 Year 9 CAS)**



Most students agreed that teachers spent most of their time helping them learn, or that they could count on their teacher for help when they need it. About half of the students thought teachers were willing to explain things more than once, with up to a quarter of students disagreeing. Students were largely neutral in their responses to whether their teachers spent most of the time telling them what to do. This reflects that students had a positive view of the help and support that teachers gave them both in the CAS and control classes.

Student perceptions for several of these teacher inputs had moved significantly over the course of the pilot. In most cases, CAS and control class students changed in similar ways. The changes over each year are given in Table 17. This tracks the changes for the 2006 cohort of Year 9 students, and gives the amount of change for these students over Year 9 (2006), and in Year 10 (2007).

Table 17 **Changes in teacher inputs, CAS and control class students (2006 Year 9 cohort)**

Teacher input	2006 Yr 9 CAS	2006 Yr 9 Control	2007 Yr 10 CAS	2007 Yr 10 Control	Overall CAS	Overall Control
Spends time helping us learn	**-0.21**	**-0.41**	-0.09	0.08	**-0.30**	**-0.33**
I count on the teacher for help ...	**-0.12**	**-0.35**	**-0.11**	0.03	**-0.24**	**-0.35**
They are happy to explain …	**-0.14**	**-0.21**	0.07	0.05	-0.07	**-0.15**
Spends time telling us …	-0.05	-0.06	-0.10	**0.17**	0.05	0.12

Note: Bolded figures are indicative of significant differences (above 0.10 for one year, and 0.20 for two years).

In Year 9 (2006), both CAS and control class students reported a drop by the end of the year in all teacher inputs except “the teacher spends time telling us what to do”, which stayed roughly constant.

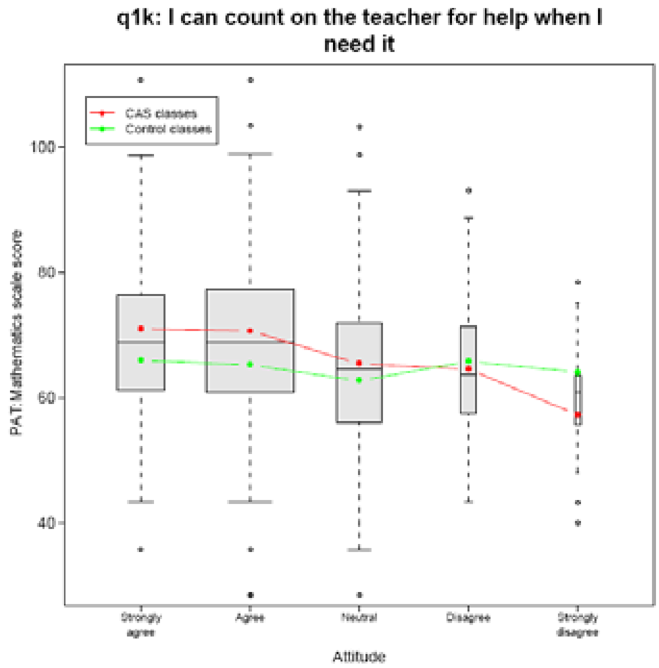
In Year 10 (2007), there were few changes, with control class students more likely to agree that the teacher was telling them what to do; and fewer CAS students reporting that they could count on the teacher for help. Perhaps this again may be the result of a crowded work plan.

The Year 10 students’ baseline data showed fewer CAS and control class students were in agreement that they could count on the teacher for help when they needed it. The Year 10 control students were far more likely to report that the teacher was telling them what to do most of the time than were any other groups of students.

Student responses to teacher input varied consistently according to student ability (measured in patm units) on these aspects of teacher input:

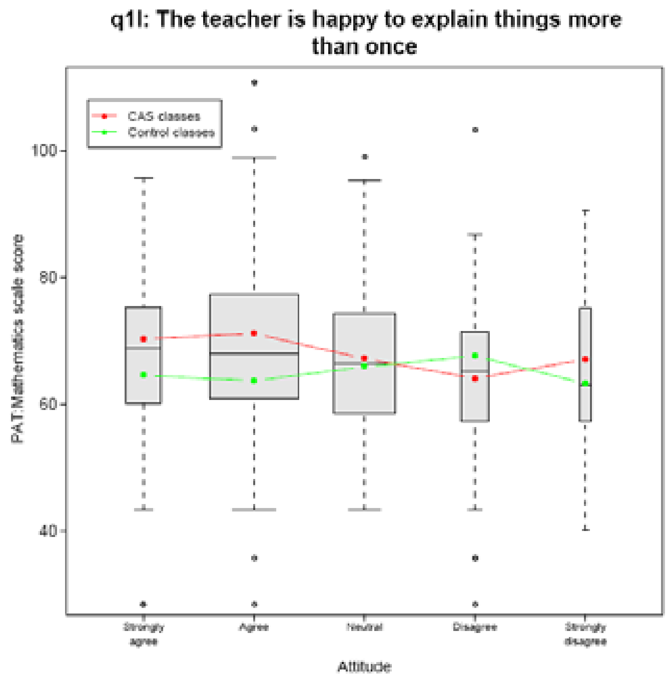
- The more able CAS and control class students were somewhat more likely to agree that the teacher spent most of the time helping them learn.
- The more able CAS students reported that they could count on their teacher’s help if they needed it. Control students showed no meaningful trend in this. This was most pronounced in the 2007 Year 10 students (Figure 9) but was also true in both Year 9 groups.

Figure 9 **Relationship between ability and reporting that the teacher tells us what to do (2007 Year 10 cohort)**



More able CAS students were more likely to agree that the teacher was happy to explain things more than once, but control class students showed no relationship between ability and their response to this question. This occurred for both groups of Year 9s and the Year 10 group.

Figure 10 **Relationship between ability and reporting that the teacher tells us what to do (2007 Year 10 cohort)**



Responses from focus groups on classroom teaching

Students in the focus groups were asked what changes in classroom practice they thought had taken place as a result of being in the CAS pilot.

- *Pedagogical change:*

  Some students picked up on the different focus of teaching when they made such statements as:

  > We learn new concepts through exploring with the calculator.
  >
  > More understanding—more on the 'why', not just the answer.
  >
  > Much more fun because we are not watching the board but we are actually doing which is much better.

  Others, however, saw lessons as being somewhat the same:

  > Some [lessons are the] same and some are different. It balances out. Number [is] the same, Algebra is different.
  >
  > Yes [they are different] because there were no books and pens, but the style of the lesson is similar.

- *Speed of learning:*

  Significant numbers of students mentioned either that they could "get more done", that they could "get answers quicker", or that is was "easier to do more complicated problems":

  > More things were possible because we could do them quicker.

  Some, on the other hand, found that the pace of learning was slower:

  > [It] takes an hour learning what buttons to press rather than the underlying principle.

- *Textbooks, exercise books, and board-work:*

  Students consistently commented that less work was being set from textbooks; there was less writing down in exercise books; and less use of the whiteboard than was usual in mathematics. These findings were all consistent with our classroom observations (see, for example, Table 6 of Chapter 3).

- *More frequent use in Year 9 than Year 10 classes:*

  Numbers of students in the focus groups, and several teachers, commented that they had made more frequent use of the CAS in their classroom in Year 9 compared with Year 10. One Year 10 student found this to have a downside when they said, "I'm [only] kind of confident [using the CAS] because we don't use them enough."

These qualitative responses reflect that many students in the focus groups saw that there were considerable changes in teaching that were occurring as a result of the introduction of the CAS calculators, and the style of teaching that accompanied it. This contrasts with the quantitative data which do not so strongly indicate change. It could be that focus groups allowed for prompting or interactions between students that elicited a more reflective and considered opinion.

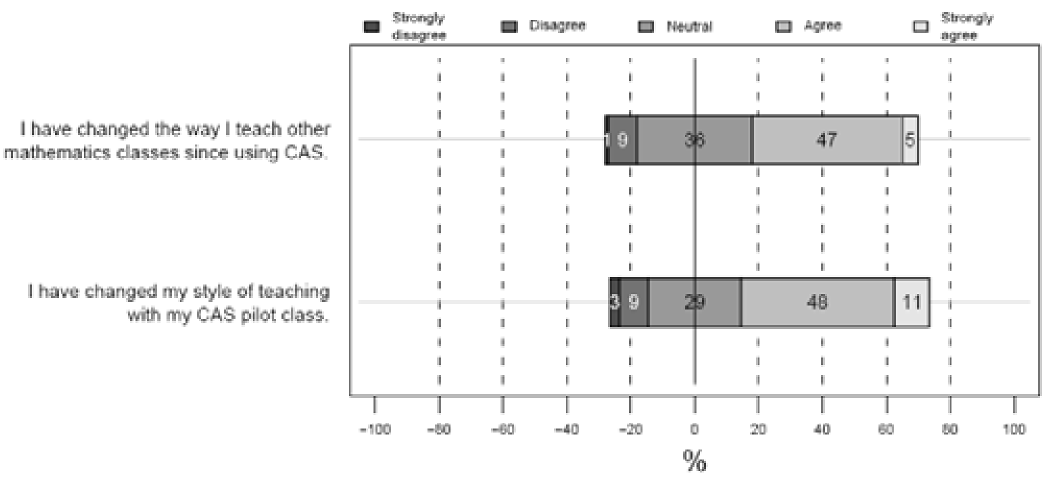
Teachers' perception of their teaching

Teachers' opinions of their teaching and what they value in teaching were gathered both by pre- and post-pilot questionnaires, as well as by face-to-face interviews. Evidence of changes in teaching is reported from the teacher questionnaires. This is followed by responses from the interviews about issues in teaching.

Evidence of change from the teacher questionnaires

Teachers were asked whether they had changed the way they taught either in their CAS classes, or in other classes. Figure 11 clearly shows that teachers thought their teaching had indeed changed. There was about as big a change for non-CAS classes as for CAS classes. This shows that the shift was not related just to the CAS technology, but reflected a broader pedagogical change. This may have been triggered by the stimulus of the CAS PD and their classroom experiences of it.

Figure 11 **Teachers' views of whether their teaching had changed**



Over half of teachers agreed that their teaching style had changed. It seems the pilot has had an impact on classroom teaching. Teachers were asked to comment on why they had or had not changed their style of teaching in CAS or in other classes. A substantial set of comments concerned adopting a more investigative or constructivist approach to their teaching, or using technology more widely in both CAS and non-CAS classes. A few teachers said that they had been reflecting more on their teaching practices. Reasons for not making changes were mainly lack of confidence, skills, or time. Some teachers stated that they were already using this approach. Some also commented that they used the CAS only in some areas.

Teachers were asked to classify their own teaching style according to the three measures from the Australian study of Kendal et al. (2005). They did this before they began in the pilot, and again after either one or two years. The results are shown in Table 18, which also includes the end of the year perceptions of the Year 9 CAS students. (Note: these are largely the same as their baseline data, and for the control class students.) Personal construction of ideas often went hand in hand with an exploratory approach. Teachers may well have classified an understanding-based approach either as classroom discussions, or as the more traditional style of the teacher explaining the mathematics to students followed by independent student work.

Teachers' responses indicate a swing away from rules-based teaching (with the percentage of responses almost halving to about 15 percent) to an emphasis on personal construction of ideas (where the percentage more than doubled to almost 30 percent). The percentage of responses on teaching for understanding stayed reasonably constant at about 55 percent.

Students were more likely to see their teacher's style to be understanding-based than the teachers' self-reports. The students and teachers were largely in agreement at the end of the year on the prevalence of rules-based teaching (close to 15 percent). The students were less likely than their teachers to report a teaching emphasis on personal construction of knowledge (20 percent vs 30 percent respectively). This may be because students did not recognise the teacher's intention, or confused this style with an understanding-based approach.

Table 18 **Teacher and student perceptions of teaching styles**

Styles	**Teachers[1] pre-CAS**	**Teachers[1] post-CAS**	**Students post-CAS**
Rules	28 (29.8%)	14 (15.1%)	195 (14.6%)
Personal construction	14 (14.9%)	27 (29.0%)	270 (20.2%)
Understanding	52 (55.3%)	52 (55.9%)	874 (65.5%)
TOTAL	**94**[1]	**93**[1]	**1339**[2]

[1] Some teachers gave multiple responses so percentages are of responses.

[2] For 2006 students only.

The nature and extent of teachers' reported changes in their classroom practice

This section reports on patterns of teachers' responses to the self-reflective questionnaires concerning their classroom practices and priorities. Baseline information was collected on the frequency and priority of 20 classroom practices prior to their involvement in the pilot (see Table 19 for the actual descriptors). These descriptors were used in a study of teachers' attitudes towards NCEA (Hipkins & Neill, 2006), and were based on a larger list of descriptors used by Tytler (2003). Teachers in the CAS pilot responded to the same questions after being involved in the project for either one or two years. Their perceptions of the value that they attached to the various classroom practices identified on the self-reflective questionnaire are compared with their perceptions of actual changes in classroom practice. The 2005 teachers were asked to *retrospectively* rate their classroom practices and priorities prior to the pilot, whereas the data for the 2006 and 2007 teachers began with actual baseline data, which was then contrasted with data at the end of the pilot.

Table 19 **The descriptors used for the teacher self-reflective questionnaire**

Number assigned	Descriptor as modified from SIS research
1	Providing stimulus materials that challenge students' ideas and that encourage discussion, speculation, and ongoing exploration.
2	Using strategies (such as co-operative learning, and strategic selection of groups), to establish an atmosphere of co-operation and collaboration.
3	Encouraging students to make their own decisions in planning and carrying out investigations.
4	Focusing on the learner's personal construction of mathematical ideas.
5	Allowing time for discussions to arise naturally and be followed in class.
6	Including frequent open-ended investigations, short-term open explorations, or tasks that have an open-ended aspect.
7	Ensuring higher order tasks involving the generation, application, analysis, and synthesis of ideas, are well represented.
8	Encouraging students to actively clarify their own ideas and assumptions, and to think about their learning processes (e.g. by using concept mapping, model making, learning journals, exploration of alternative strategies, etc.).
9	Setting a variety of types of tasks during each unit.
10	Involving students in making decisions about what should be assessed, how assessment should be carried out, and what the next steps are.
11	Using a variety of methods to assess student understandings, at various points in a unit (e.g. open-ended questioning, checklists, project work, problems, practical reports, role plays, journals, mind mapping, brainstorming).
12	Ensuring assessment incorporates a range of levels and/or types of thinking.
13	Probing student understandings and perspectives early in a learning sequence to help plan subsequent lessons.
14	Ensuring students have ongoing feedback which indicates their strengths and weaknesses and their next learning steps.
15	Discussing and developing an understanding of language conventions in mathematics.
16	Using learning technologies to support quality learning behaviours such as exploration, conjecture, or collaboration (e.g. spreadsheets, Internet, data loggers, graphics calculators).
17	Creating a classroom environment where ICT is an integral component.
18	Being a guide, facilitator, and co-learner with students learning ICT in the classroom.
19	Providing opportunities for students to engage in activities enhanced by ICT which are essentially self-evaluating, co-operative, and collaborative.
20	Exploring different attitudes, values, and perspectives that students bring to their classroom learning.

A total of 55 teachers from the 22 pilot schools responded to both the baseline and follow-up questionnaires, allowing us to track changes in their attitudes. This sample is of sufficient size to apply parametric statistical tests based on mean scores for the 20 variables. This contrasts with the 2005 pilot where the small sample size meant that analyses were performed on ranked score nonparametric statistical tests (using the Wilcoxon signed-rank test for matched pairs—Wackerly, Mendenhall, & Schaeffer, 1996).

Quantifying responses to the provided scales

Teachers were asked to assign a priority to each descriptor of a teaching practice using a 5-point scale from "very low" (scored as 1) to "very high" (5). Responses to the frequency of each descriptor of classroom practice were similarly collated using a 5-point scale from "hardly ever/never" (1) to "all/most of the time" (5). Once all responses had been collated numerically, the scores for each descriptor were averaged. In the discussion that follows, some of the results will be analysed by the themes of assessment, rich tasks, teaching and learning, and technology.

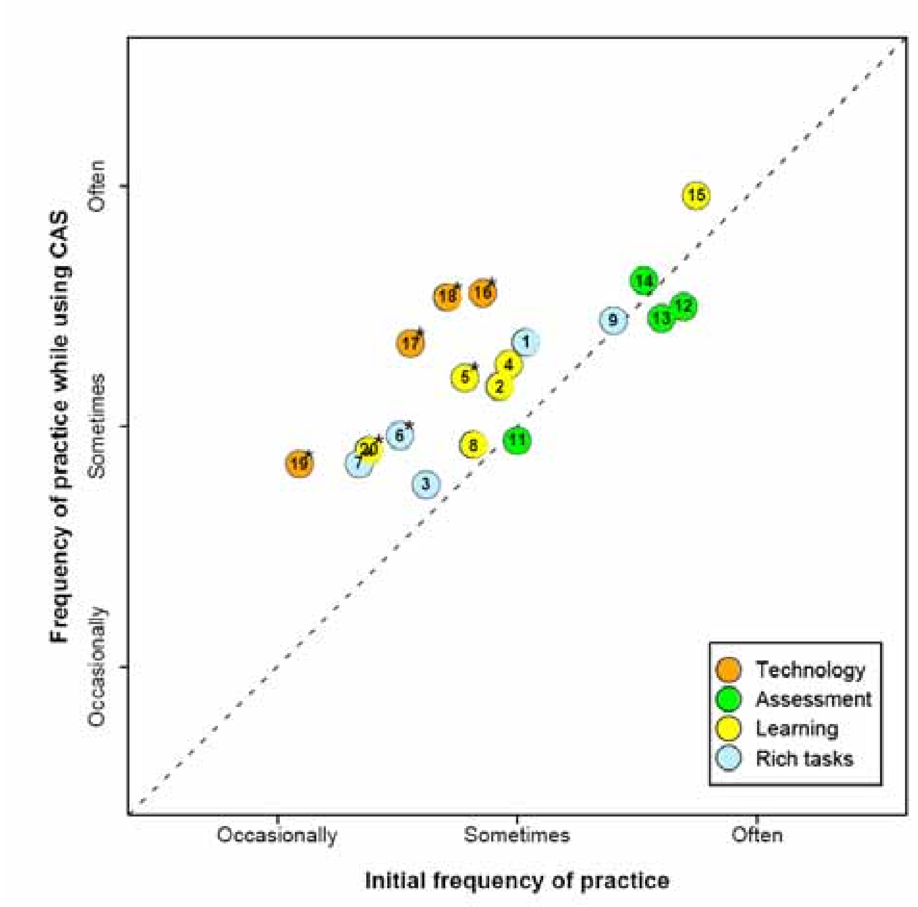
Table 20 **Themes addressed by self-reflective descriptors**

Theme	Sub-themes	Descriptor numbers
Assessment	Formative assessment	13, 14
	Variety of assessment tasks	11, 12
	Student input into assessment decisions	10
Rich tasks	Types of rich tasks	1, 6, 7
	Variety in tasks	9
Teaching and learning styles	Co-operative learning	2, 5
	Personal construction of knowledge	3, 4, 20
	Metacognitive skills	8
	Mathematical language	15
Use of new technologies		16, 17, 18, 19

Changes in frequencies of teaching practice pre- and post-CAS while using CAS calculators

Responses show a modest increase in teachers' practice for the majority of the 20 descriptors. Figure 12 compares teachers' perceptions of the frequency of their practices before the CAS pilot and the perceptions of their frequency of their current practices, based on the average score for each set of responses. Points on the diagonal line represent practices that have not changed in frequency since the CAS pilot began. The movement in score is shown by the vertical distance from the diagonal line to the descriptor number. The majority of practices showed an increase in frequency, and this was statistically significant for eight of the practices (using the t-test for matched pairs).

Figure 12 **CAS pilot teachers' perceptions of changes in practice while using CAS**



* Statistically significant shift in practice

As might be expected, the group that falls furthest above the line are the items about technology (coloured orange). All four aspects of technology use were performed significantly more often after the CAS pilot began.

Use of rich tasks increased by the next greatest amount, with two of four related practices increasing significantly. These are shaded in blue. Teachers believed there were more open-ended investigations or explorations; and that more higher order tasks were being performed in their CAS classes.

Statements relating to teaching and learning styles (shaded yellow) showed a slight increase, with two of the seven increasing significantly. Teachers reported an increase in class time for discussions; and more opportunities to explore students' attitudes, values, and perspectives.

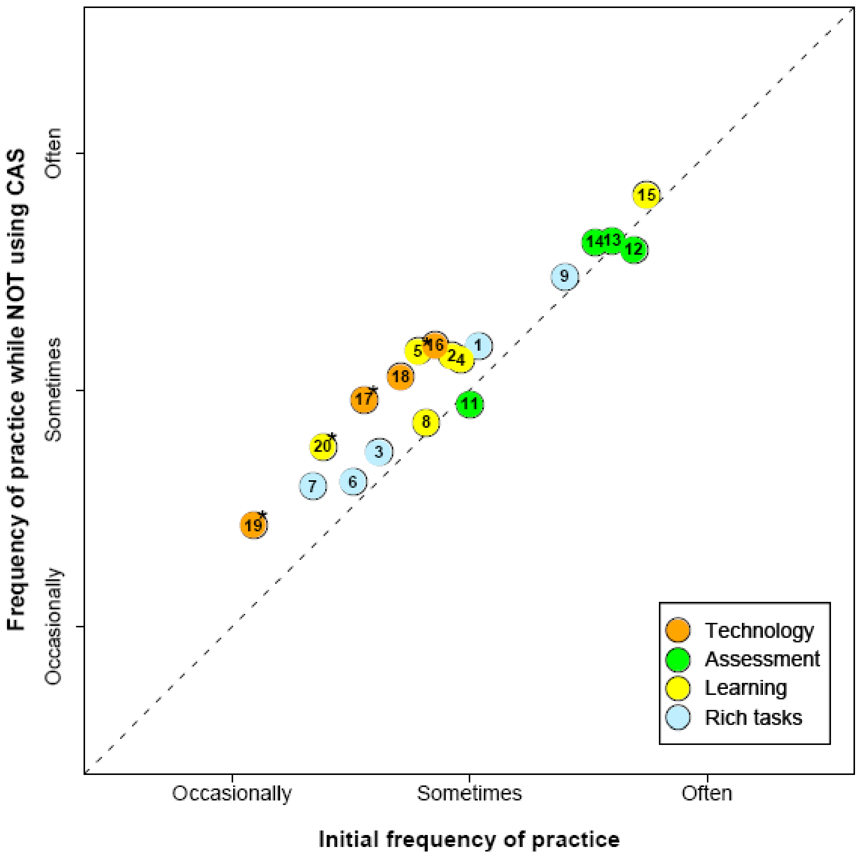
The assessment practices (shaded green) were about as common before and after the CAS pilot began. There appeared to be no shift in the amount of time spent on them. Descriptor 10, about giving students choice in assessment decisions, has dropped off the lower left-hand corner, as it is rarely practised. Two of the assessment practices were scored as being less common, but these were not statistically significant. Descriptor 13, on formative assessment, was seen as slightly less frequent after the pilot began. However, the discussion in Chapter 8 and our observations outlined in Chapter 3, suggest that there had not actually been a decrease in the use of formative assessment. If anything, we believe that we had observed higher levels of formative assessment than what we would expect in a typical mathematics classroom. The difference between teacher perceptions and our observations could be a consequence of teachers holding a narrow view of practices that constitute instances of formative assessment. Descriptor 12, which relates to assessments showing a variety of levels or types of thinking, was also rated slightly lower.

The pattern of all these changes is remarkably close to the finding from the 2005 pilot, even though the latter asked the teachers to retrospectively rate their practices, whereas the 2006 and 2007 teachers rated their practices before they joined the pilot and after participating in it for one or two years. This provides strong evidence that the 2005 teachers' *recollection* of prior practice was accurate.

Changes in frequencies of teaching practice pre- and post-CAS when NOT using CAS calculators

The teachers were also asked how often the 20 practices occurred in lessons that did *not* involve the CAS calculator. Their responses are displayed in Figure 13. The points on this graph are far closer to the diagonal, which shows that teaching practices when teachers were not using the CAS were far closer to their practice prior to the CAS pilot. Compared with teachers' prior practice, only four of the descriptors were reported to happen significantly more often when the class was not using the CAS. Two of the statements were about technology (orange, 17 and 19), and the same two learning statements as when they were using CAS (yellow, 5 and 20) were used significantly more often, but not to the same extent as they had been in CAS lessons.

Figure 13 **CAS pilot teachers' perceptions of changes in practice while NOT using CAS**



* Statistically significant shift in practice

Teacher priorities

The ratings of teachers' priorities can be seen in Figures 14 and 15. The further to the right a point is in either graph, the higher its priority. Descriptors relating to assessment issues (shaded in green) were mainly of high priority, especially the one on giving feedback (descriptor 14) and assessments with different types or levels of thinking (descriptor 12). However, student involvement in decision making about assessment (descriptor 10) had the lowest priority and is not on the graphs as it is so far removed from the other points. Questions relating to the theme of rich and varied tasks within the classroom (coloured blue) had two descriptors of higher priority (stimulus materials, and variety of tasks), and two of lower priority (open-ended tasks, and higher order tasks). Issues of technology were given average priority rankings. Descriptors relating to learning issues (shaded yellow) were typically of a low to average priority except mathematical language (descriptor 15), which was ranked fifth highest. Exploring different attitudes, values, and perspectives that students brought to their classroom (descriptor 20) was the second lowest priority apart from including students in decision making about assessment (descriptor 10). This suggests that student perspectives are relatively lowly regarded in these classrooms.

The rankings were largely similar to those of the twelve 2005 pilot teachers. The two exceptions were descriptor 18 (being a guide, facilitator, and co-learner with students), and descriptor 3 (encouraging students to make their own decisions in planning and carrying out investigations), both of which were more highly valued than they had been in 2005. This is consistent with teachers' views that a constructivist approach is now more common (see Table 18). On the other hand, allowing time for discussions to arise naturally and be followed in class (descriptor 5) was less highly valued than in 2005.

Comparing priority and practice

The relationship between teachers' priorities and their practices can be seen in Figure 14 (before the CAS pilot) and Figure 15 (after one or two years in the CAS pilot). Priority and practice are reasonably strongly correlated. For example, descriptor 6 (open-ended tasks), had a low priority and a low level of practice before the pilot, while descriptor 12 (assessments with range of levels) was both high priority and high practice. Most statements were in reasonable balance both before and after the pilot, with the following exceptions:

- Descriptor 1 (providing challenging stimulus materials) was practised less often than its high priority suggests it should have been, both prior to and during the CAS pilot. Descriptor 15 (discussing the language and conventions of mathematics) was practised more often compared with its priority both before and after the pilot. Clearly, the pilot has not helped either of these mismatches.
- Priority and practice for descriptor 20 (exploring different attitudes, values, and perspectives) were more in balance before the CAS pilot than they were after it.
- Providing opportunities for activities that are self-evaluating, co-operative, and collaborative (descriptor 19) were in a far better balance during the CAS pilot than before. Even though it was practised more often, it was still the lowest of all the technology items for both priority and practice.

Figure 14 **A comparison of CAS pilot teachers' priorities and initial practice**

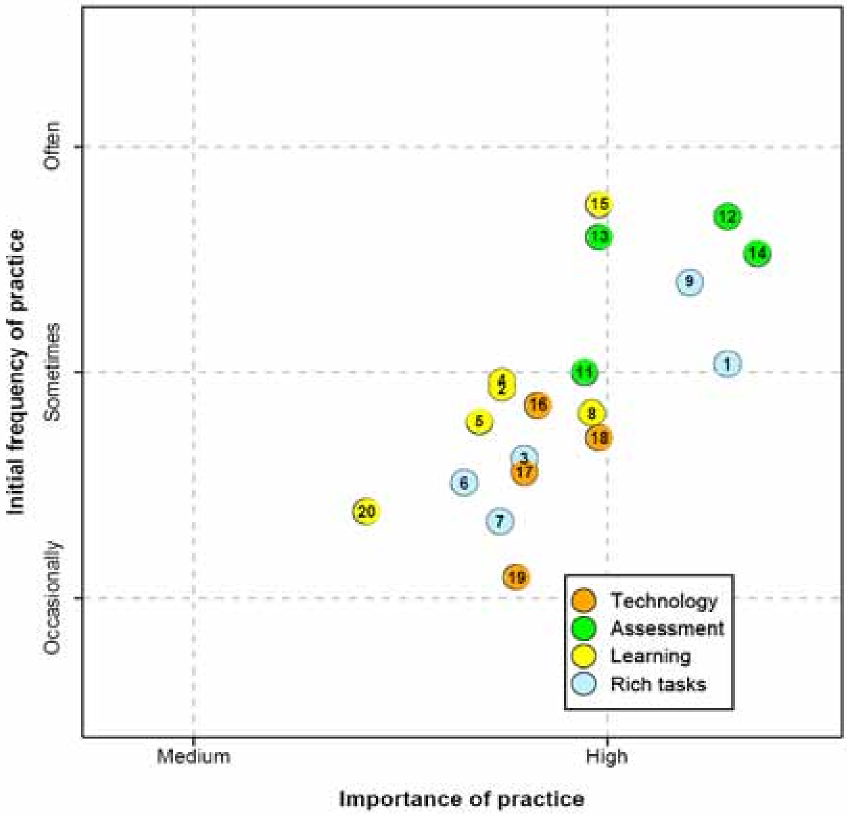
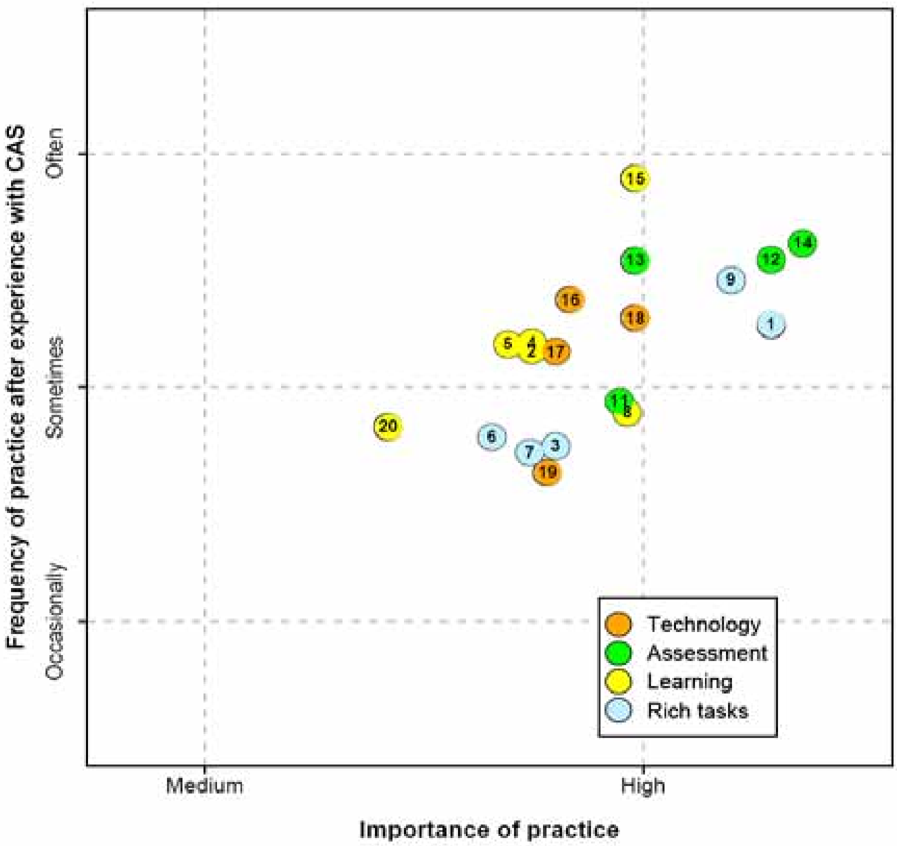


Figure 15 **A comparison of CAS pilot teachers' priorities and current practice**



Evidence of effects on teaching from the interviews

A sample of teachers was interviewed, largely from the eight case-study schools, but also from some of the other schools. Numbers of issues arose from these, many of which mirror the findings from teacher questionnaires. A number of open-ended responses from the questionnaire are also included in this subsection. These aimed to ascertain teachers' views on the effect the CAS pilot had on their teaching.

Pedagogical issues

Many comments were made about the movement towards a more investigative, problem-based, constructivist approach to teaching. While for some this was not new, there were still comments that this approach had been consolidated:

> [A] more investigative/exploratory approach incorporated into teaching of all [my] classes now.

> I have always tried to do problem-based learning, but have focused on this even more since using CAS.

> Excellent pedagogical approach to Algebra. Pedagogy moved further down the same line and made me think about how students learn things. We will modify how we teach Algebra as a result of this.

> The CAS technology has made me think more about how and what we teach; especially in terms of the emphasis we place on obtaining skills. Also teaching the topics holistically (especially Algebra and graphs overlapping together). This has impacted my teaching in non-CAS classes too.

A few teachers had reservations about the investigative approach. One teacher had a low ability class with a significant ESOL mix, and they found that "even the paper folding stuff (and families stuff) didn't work. [I] needed to start with what they can do rather than problem solving."

Traditional versus investigative approaches

The teachers were somewhat split on this issue. Some believed that teaching should start with the more traditional way of acquiring "by-hand" skills, while others preferred to begin with a more exploratory style. There are no rights and wrongs in this, but the dichotomy is clear. The following quotes indicate the spectrum from a traditional to investigative approach:

> [My] instinct is to teach as I did before. I don't want to just teach how to press buttons.

> I err on the safe side. Do things bit-by-bit and as things work embed them into my own approach and style. Start with 'by hand' then move to calculator.

> [Students] have used the calculator to 'discover' principles then use them.

> In the last month I have been encouraging students to do things on [their calculators] and then explaining them rather than the other way around.

Classroom interactions

One clear effect of the CAS technology is that it appeared to increase student–student or student–teacher interactions and group work. A number of teachers commented on this, and our classroom observations also confirmed this (see Chapter 3). Part of this relates to the investigative pedagogy being adopted, as these quotes show:

> More group work—students help each other and discuss the maths. One boy tried to work by himself and found he was floundering.
>
> Kids help each other. Kids ask the 'What if' questions.
>
> There are more opportunities for interaction with students. At first it was mainly operational difficulties but later on questions/discussions on concepts took place.

Students also need to interact with each other because of the details of how to use the technology:

> Some students in class have not used them so [I] have to pair up students so they can learn from each other.

General management issues

Some teachers commented on the high intensity of input they needed to put into lessons, and the less predictable nature of the classroom:

> [It is] so much more exhausting. It takes a lot more energy in class.
>
> Need flexibility, subject knowledge, and passion. It all comes back to teachers. They need to think on their feet.
>
> [The] classroom [is] less structured and [it is] less predictable where [the lesson] goes.
>
> I don't like being the centre of attention [and CAS had that effect].

A few teachers also commented on both the positive and the negative effects on classroom behaviour, with one saying that their low ability class had "quite a few behavioural problems, [and these were] extra with CAS". Another, on the other hand, thought that "with CAS [I am] keeping them together as a class more".

Higher use in Year 9

Quite a few of the Year 10 teachers commented that they had used the CAS more in Year 9 than they were currently doing. This was consistent with what students reported. This suggests some reversion to prior patterns of classroom teaching.

Key points of Chapter 4

The findings of this chapter closely parallel those in Chapter 3. That chapter looked at our observations of the classroom, and students' views of it, while this chapter looked more explicitly at teaching. Teachers reported that their pedagogy was changing as a result of their involvement in the CAS pilot. They were moving away from a rules-based approach towards a more constructivist approach, focusing more on exploration and self-discovery. Teachers reported changing their teaching practices not only for their CAS classes, but also to an equal extent for their non-CAS classes. The biggest changes that teachers noted were in:

- the technology practices, where teachers reported significantly more frequent use of these in the CAS pilot;
- providing rich activities, which had seen the next biggest increase in practice during the pilot;
- allowing time for discussion to arise in class;
- exploring attitudes and values that students brought to class; and
- an increase in classroom interactions.

Students reported only modest changes in the type of teaching they were receiving, and this changed little over the course of Years 9 or 10. They saw the teaching style as largely traditional.

Student perceptions did not match our observations, or those of their teachers. This may in part reflect the transition from a primary to a secondary environment, where the latter does tend to be more formal in its approach. It may also reflect that students did not have a clear understanding about different styles of teaching. Students did, however, note various shifts in teaching, some of which follow:

- Students noted the predominant pedagogical approach was teaching for understanding. A rules-based, or a constructivist approach, was reported far less often by students.
- Students in both CAS and control classes reported high levels of teacher input to their learning, but this decreased throughout Year 9.
- There was less use of textbooks and exercise books, and less board-work in CAS classes.
- Teacher-led discussions were happening less often than they had been initially, and this was more pronounced in CAS classes.

5. It is not like other mathematics: Learning issues

This section of the evaluation addresses two separate questions about student learning. The first question asks if there is evidence that mathematics achievement has been affected as a result of the CAS pilot scheme. Achievement was measured directly using PAT:Mathematics tests. Secondly, we asked teachers and students in the pilot to make judgements about how student learning and understanding had been affected as a result of involvement in the CAS pilot project. This data was obtained from interviews with teachers, discussions with small focus groups of students, and by questionnaires completed by both students and teachers.

This chapter addresses the following research question:

- *Research question 7*: How has student learning in mathematics been affected as a result of the pilot scheme?

Summary

Growth in mathematical knowledge and understanding (as measured by PAT:Mathematics) was similar for students regardless of whether they were involved in the CAS pilot or were in a control class. It appears that students were neither advantaged nor disadvantaged by being exposed to the CAS approach to teaching and learning. The type of calculator and its accompanying PD had little effect on student achievement as measured by PAT:Mathematics achievement tests.

The qualitative data gathered from students suggested that CAS-based teaching had an impact on understanding, especially in algebra, and to a lesser extent in geometry. Some students found the visual nature of the CAS suited their learning preferences. Not all students shared these views, with a minority reporting that the use of CAS impaired their understanding.

Teachers were largely neutral as to whether student knowledge, skills, and understanding had been enhanced overall as a result of the pilot, but like students, they perceived that the use of CAS did improve algebraic understanding. They had rated this as low before the pilot, but saw that it had increased to a similar level to the other mathematics strands by the end of the pilot. Teachers could see both positive and negative effects on students, and suggested that CAS affected different students in different ways; helping some, but raising barriers for others.

The detailed findings are in the following sections of this chapter.

Student achievement

Student achievement was measured with the PAT:Mathematics scale score (patm). Achievement that is assessed by different PAT tests maps onto this patm scale score, which is a true interval scale. It thus measures growth in a linear way, so increases in the patm score are independent of the position on the scale (Darr, Neill, & Stephanou, 2006). In the 2006 baseline data, students in the CAS classes generally scored higher on the PAT:Mathematics tests than did students from the control classes. This reflects the fact that in several of the schools, one or more of the CAS classes were made up of higher ability students. We would expect the control classes to be slightly below the average of the national reference sample, and the CAS classes above it.

No baseline data had been collected on the 2005 cohort, and so no meaningful data of mathematical achievement prior to their involvement in the project were available. PAT Test 6 was used as the baseline measure of Year 9 students in both 2006 and 2007, and was administered before the students had lessons that involved use of the CAS calculators or the areas of mathematics that the CAS PD had addressed. The following table shows the tests that students undertook.

Table 21 **Mathematics achievement data collected**

Cohort	Early 2006	Late 2006	Early 2007	Late 2007
2005	Test 7	Test 8		
2006	Test 6[a]	Test 7		Test 8
2007			Test 6[a]	Test 7

[a] Baseline information

The following measures of growth in achievement can therefore be made for:

- the 2005 cohort, the growth in Year 10 (comparing Tests 7 and 8 scores);
- the 2006 cohort, the growth in Years 9 and 10 (comparing Tests 6, 7, and 8 scores); **and**
- the 2007 cohort, the growth in Year 9 (comparing Tests 6 and 7 scores).

Improvements in student achievement were analysed by comparing students' baseline patm score with their patm score measured at the end of the year. This could only be done for students who had responded to both PAT tests. The greatest amount of information was available for the 2006 cohort of Year 9 students, who had measurements at three points in time.

Appendix F shows detailed box plots of growth in achievement for all CAS and control classes in the study. The first two figures show growth in the two Year 9 cohorts (2006 and 2007), while the third shows changes for the Year 10 students in 2007. Clearly, some schools and some classes made more significant progress than others.

CAS versus control class improvement for Years 9 and 10 students

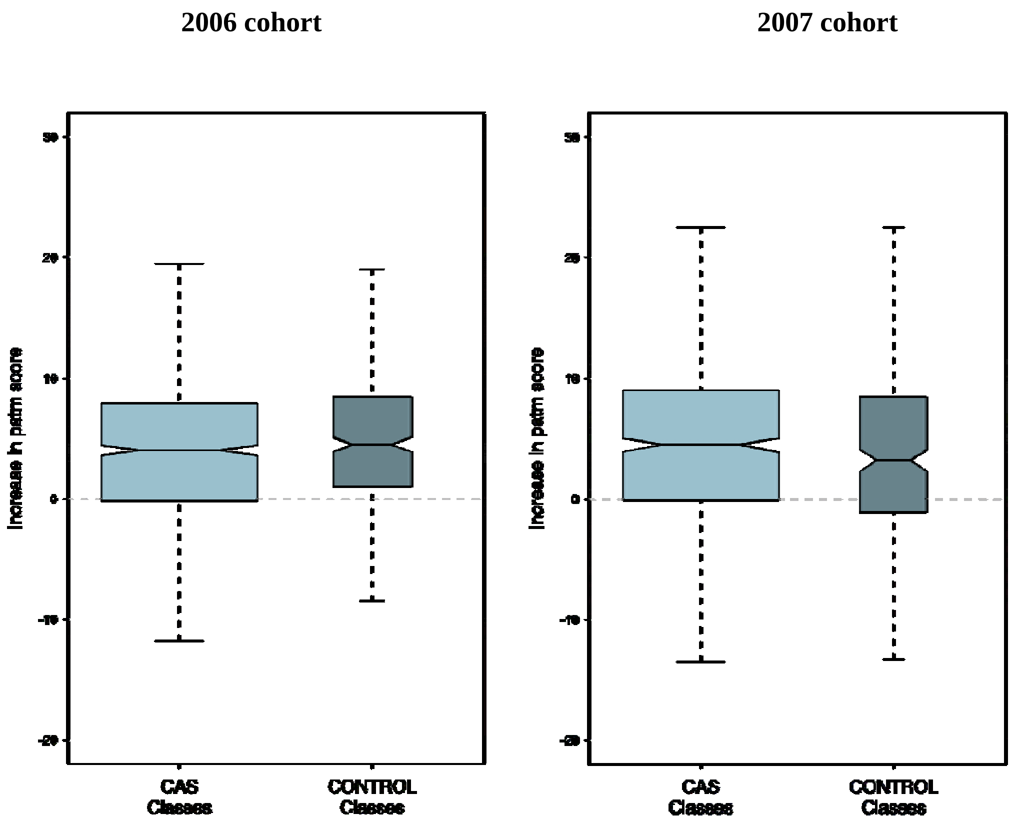
In 2006, the average score for students in Year 9 control classes went up by 4.83 patm units compared with an increase of 4.03 patm units for Year 9 CAS classes. The difference of 0.80 patm units is small, but is statistically significant at the 5 percent level ($p = 0.024$). A number of different factors may have influenced these results, including the exclusion of calculators from the PAT:Mathematics tests.

These increases indicate that both the CAS and the control class students experienced growth on the patm scale of mathematical understanding that was close to the expected growth of about 5 patm units in a year. This happened to both the 2006 and the 2007 cohort of Year 9 students.

For the 2007 cohort of Year 9 students, the control classes had a smaller increase in patm scores than did the CAS classes. The average score of control classes went up by 3.91 patm units compared with an increase of 4.53 patm units for CAS classes. The difference of 0.62 patm units was in the opposite direction of what happened for the 2006 cohort, but this difference is not statistically significant at the 5 percent level.

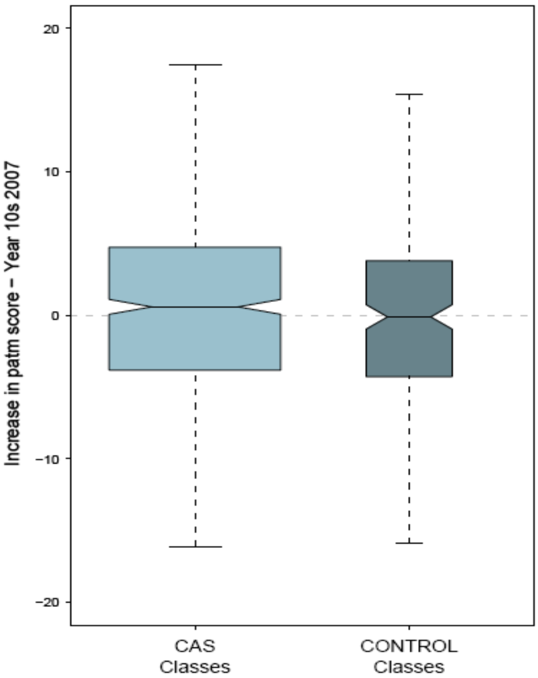
Taking the results of both the 2006 and 2007 Year 9 cohorts, we can conclude that CAS and control class Year 9 students had similar growth in mathematical knowledge and understanding.

Figure 16 **Gain in achievement measured in patm scale points—Year 9 cohorts**



For the 2007 Year 10 students, the average score of control classes went down by 0.55 patm units compared with an increase of 0.53 units for CAS classes. The difference of 1.08 patm units was in the opposite direction of what happened for the same students when they were in Year 9 in 2006 (see Figure 16). Neither change is statistically significant at the 5 percent level. Hence, growth over the two years was very similar for CAS and control classes who began the pilot in 2006.

Figure 17 **Control versus CAS class improvement (2007 Year 10 cohort)**



It was a surprise to us that the level of achievement of the Year 10 students did not increase in either the CAS or the control classes. A new PAT:Mathematics test, which is under construction, was used to measure student achievement at the end of Year 10. This test appeared to pass all the psychometric criteria that we use in developing such tests. In particular, it fitted the overall patm scale, and was also composed of items that were appropriately more difficult on average than the preceding test in the series. One possible explanation is that Year 10 students do not make gains on the patm scale overall. Another possibility is that the sample was not representative in some way. It may be that better students are re-routed to accelerated options. We propose to do further investigations of this before the PAT: Mathematics test is published. This will not compromise the finding that CAS and control class students have made roughly equal progress.

Student achievement and calculator brand for Years 9 and 10 students

The relationship between increases in student achievement and the type of calculator, and the PD that accompanied it, were explored for each group of students. In Figures 18–20, "None" refers to control class students.

- For the 2006 cohort of Year 9 students, no significant differences were found (see Figure 18, p. 53, and Table 22, p. 54).

- For the 2007 cohort of Year 9 students, only one small but significant difference was found. Classes using Type A calculator had a significantly greater amount of growth than those using Type C. This just reached significance at the 5 percent level (p = 0.047), and represents about a fifth of a year's extra growth which in educational terms is small (see Figure 19 and Table 22).
- For the 2007 cohort of Year 10 students, those using Type A showed a small but significant growth in patm units, whereas those using Types B or C did not (see Figure 20 and Table 22).

Figure 18 **Gain in patm achievement scores by type of calculator and PD (2006 Year 9 cohort)**

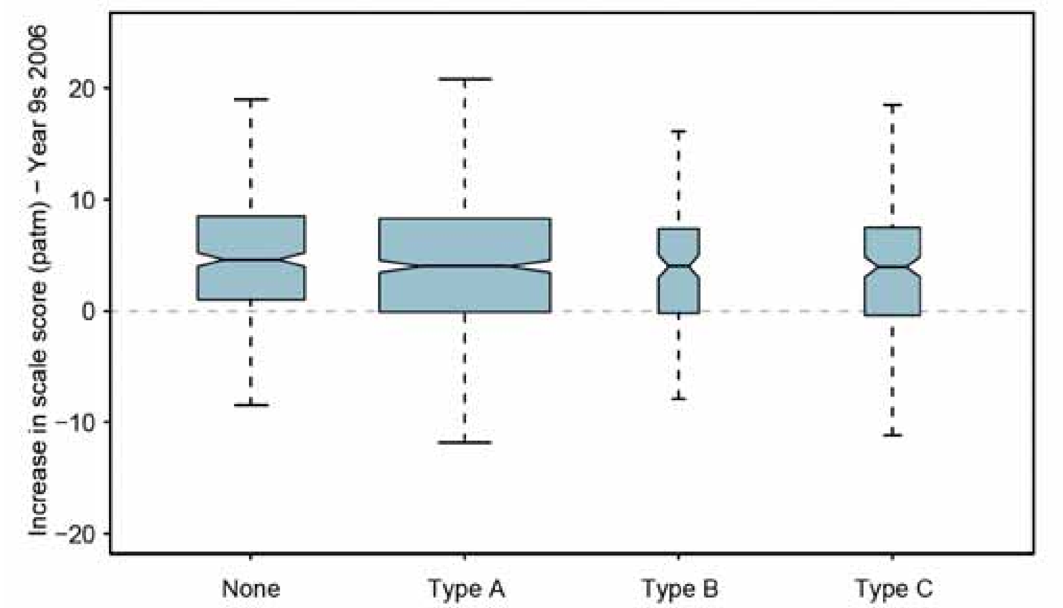


Figure 19 **Gain in patm achievement scores by type of calculator and PD (2007 Year 9 cohort)**

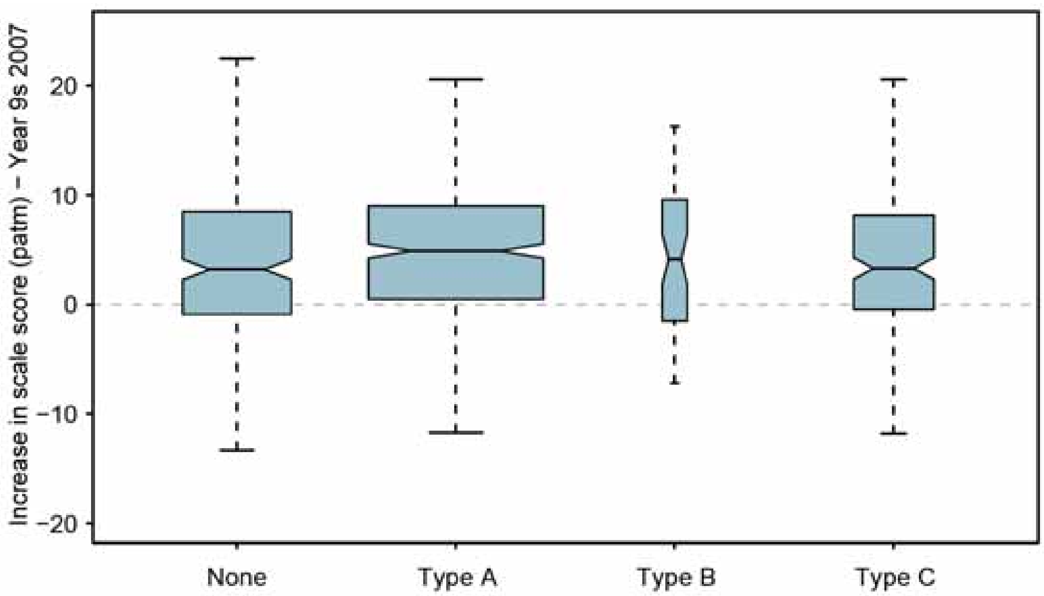
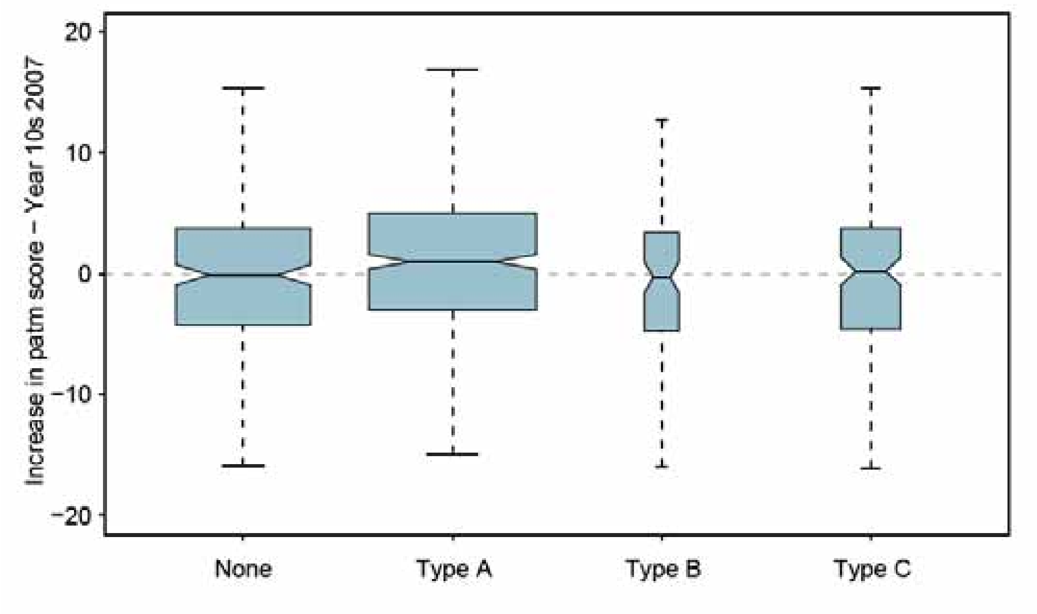


Figure 20 **Gain in patm achievement scores by type of calculator and PD (2007 Year 10 cohort)**



The increases over the three cohorts are summarised in the following table. The national reference sample grew by 4.0 patm units between Year 9 and Year 10 (Darr et al., 2006). This is in line with the increases observed during Year 9 in the CAS pilot.

Table 22 **Increase in achievement (in patm units) by calculator and PD type**

Cohort	Type A	Type B	Type C
2006 Year 9	4.42 patm	3.53 patm	4.24 patm
2007 Year 9	4.64 patm	4.17 patm	3.69 patm
2007 Year 10	1.59 patm	-0.26 patm	0.43 patm

Overall effects of CAS pilot

While there are slight differences between Year 9 CAS and control class students, these were not consistently in the same direction. The 2006 control class students grew a small but significantly greater amount in their mathematical knowledge and understanding than the CAS students. The effect was in the opposite direction in 2007. There was no significant difference between CAS and control class students in the levels of growth during Year 10. Looking at these results overall, it is fair to conclude that CAS and control class students increased their understanding at approximately the same rate in Year 9, and in Year 10.

The explanation is unclear for the difference between 2006 and 2007 Year 9 students' increases in achievement. One highly likely contender is that there is a considerable teacher effect, as well as a lesser school effect. An inspection of the individual box plots in Appendix F shows reasonable variation between the distribution of scores in different classes. This gives a prima facie case for a teacher effect, or of a class composition effect.

Similarly, the CAS and control class students at Year 10 grew by approximately equal amounts. This means that the CAS pilot students were neither advantaged nor disadvantaged. This is consistent with findings from Heid, Blume, Hollebrands, and Piez (2002) who identify that in eight out of nine studies, students who had used CAS did at least as well as students who had not used CAS, even though the tests did not allow the use of CAS. They go on to cite studies that show students who used CAS had the same or better conceptual understanding, and also better problem-solving skills, than students who had not used CAS calculators in their classrooms.

For the calculators, Type A showed a small but significant advantage in Year 10, and a slight advantage over Type C in the 2007 Year 9 cohort. This was about 1 patm unit, which is barely educationally significant. The brand of calculator fully determined the PD that teachers received, so it is not possible to disentangle the brand effect from the PD effect (i.e., they are fully confounded). It may also be that other background factors may account for any differences. For these reasons, it would be inadvisable to single out any one calculator–PD mix as giving better growth of mathematical understanding.

Caution must be taken in interpreting the findings that there is no difference in achievement between the CAS and the control classes. One reservation is that this is based on just the one measurement instrument. It may be that there are differences that other instruments may detect. Having accurate measurement of deep understanding is not trivial. Dependence on just the quantitative evidence of formal measurement also limits the scope of an evaluation. Lynch (2006) emphasises this in her paper on assessing the effects of technology on mathematics learning.

Future tracking of student achievement

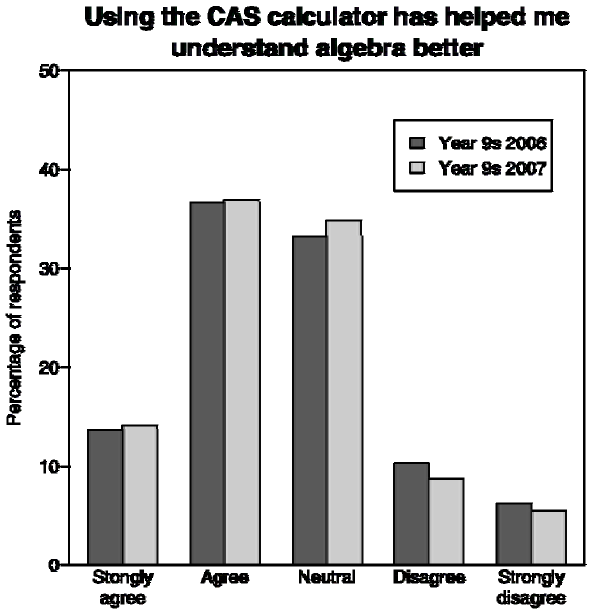
The pilot has produced longitudinal data on student achievement, in particular for the 2006 cohort of Year 9 students. We have data for these students at three points in time, early Year 9, late Year 9, and late Year 10. These students' NCEA results could be interpreted in light of these prior measures of achievement to further illuminate the longer term effects of the CAS pilot, as well as assisting comparisons between the CAS-enabled externally assessed results, and the non-CAS assessment. There is an opportunity to repeat this for the 2007 cohort of Year 9 students, but this would entail re-testing them with a PAT:Mathematics test at the end of 2008. These opportunities would need further funding.

Student perceptions of their own learning

All the CAS students were asked to rate how they thought their own mathematical understanding had changed during the pilot project. They were asked this separately for both algebra and geometry. Figures 21 and 22 respectively show the pattern of responses.

For algebra, both the 2006 and 2007 cohorts of Year 9s reported an overall increase in their understanding as a result of using CAS. This can be seen by noting that both distributions in the left-hand graph of Figure 21 are positively skewed and virtually identical, so the mean response lies about halfway between "agree" and "neutral". There was a similar, but less pronounced, increase for geometry. The distributions in the left-hand graph of Figure 22 are positively skewed, but to a lesser degree, and are not significantly different from each other. The left-hand graph in Figures 21 and 22 compares the two Year 9 groups, and the right-hand graph compares the 2006 Year 9 students with their views as Year 10s in 2007.

Figure 21 **Effect on algebra understanding of CAS calculator use—student views**



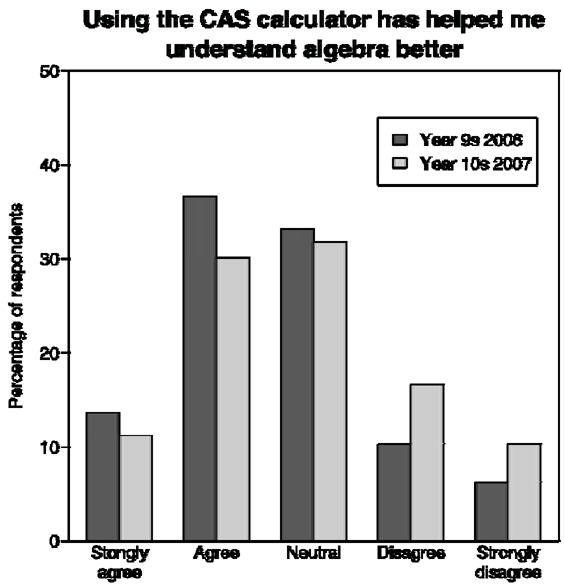
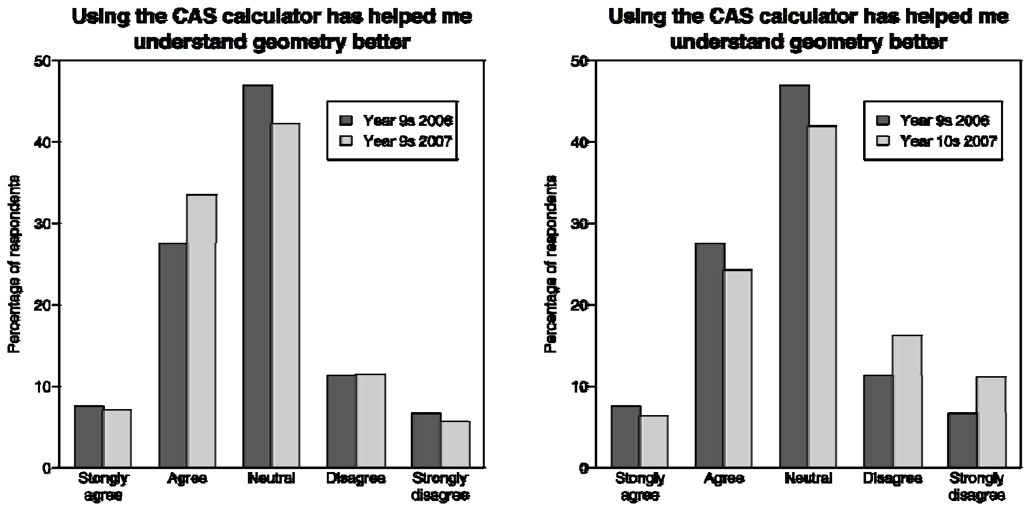


Figure 22 **Effect on geometry understanding of CAS calculator use—student views**



There was, however, a statistically significant difference between the way Year 9 and Year 10 students responded in both algebra and geometry:

- For algebra, significantly more Year 9 than Year 10 students reported improved algebraic understanding, with fewer students disagreeing or strongly disagreeing that their understanding had improved compared with those who agreed it had.[5] Nevertheless, the Year 10 students also saw a slight improvement. This was analysed by testing if the distribution for Year 10s in the right-hand graph of Figure 21 is symmetric.[6]
- For geometry, Year 10 students did not report any significant improvement in their understanding (the distribution for Year 10s in Figure 22 is symmetric). The Year 9 students did report improvement in their understanding more than the Year 10 students did.[7]

Relationship between student ability and perceptions of learning

The more able 2006 Year 9 CAS students (as measured in patm units) were somewhat more likely to agree that using the CAS calculator had helped their understanding of both algebra and geometry than were less able students (see Figure 23). The more able 2007 Year 10 students also reported that CAS had increased their understanding of algebra, but no relationship was found for geometry.

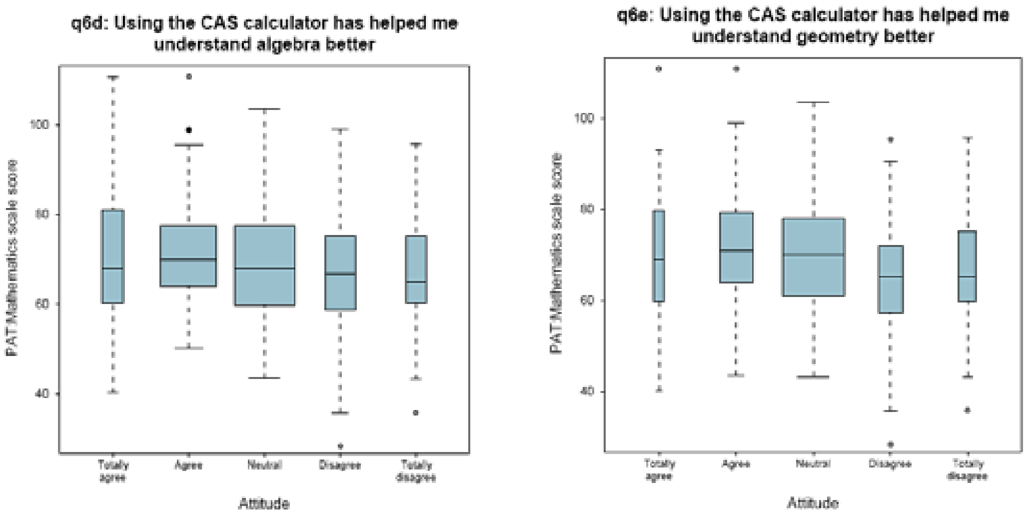
---

5 Year 9 2006 vs Year 10 2007 Chi-squared = 29.66, 4 d.f. $p < 0.0001$
Year 9 2007 vs Year 10 2007 Chi-squared = 34.76, 4 d.f. $p < 0.0001$

6 chi-squared = 11.97, 4 d.f. $p = 0.0075$

7 Year 9 2006 vs Year 10 2007 Chi-squared = 27.30, 4 d.f. $p < 0.0001$
Year 9 2007 vs Year 10 2007 Chi-squared = 22.27, 4 d.f. $p = 0.0002$

Figure 23 **Relationship between ability and perceived effect on understanding of the CAS calculator—2006 Year 9 student views**



Students' verbal responses

Students in the small focus groups and individual students in classrooms were also asked if using the CAS calculator had helped them understand mathematics better, especially algebra. Students made a variety of comments, both positive and negative.

Influence of visual displays

The technology has visual affordances, but these are more useful for some students than for others. Other researchers report similar advantages related to visual displays, for example Thomas et al., (2007). Students who said that CAS had helped their understanding were most likely to relate this to their individual learning preferences. Several said that the visual features of the CAS had been a major positive influence. This was identified directly, as in the first two quotes below, or indirectly. The latter two quotes suggest that these students did not like a pencil-and-paper approach:

> I can see pictures of graphs rather than seeing it in my head.
>
> [It] helps me understand it because it is visual.
>
> [It has helped on] how to work problem out. [I get] frustrated on paper.
>
> [It] helps do things I couldn't write down.

Other students found that writing things down helped their understanding or their recall as the following quotes show:

> [I'm] better off when writing things down especially for exams.
>
> Helped a bit for understanding, but better to write it down.

Influences that assist learning

Students identified some other advantages of the CAS approach:

- *Constructivist approach*: “The teacher let us find out how to find out the answer, so [we] get a better understanding.”
- *Technology feedback loops*: “It helps. It showed you the step that was wrong.”
- *Reinforcement of ideas:* “It has changed [for the better] because we go over it more often.”

Influences that hinder learning

The following negative consequences of CAS were noted by students:

- *Technology as a “black box”*: “I haven’t really learnt how to do it myself”, or “[It is] worse because I didn’t have to work it out”, or “I don’t get how it [the CAS calculator] gets the answer.”
- *Over-emphasis on technology:* “[We are] focusing on what buttons to push rather than why.”
- *Difficulty with technology:* “[It’s] more confusing [for example] how to make a formula.”

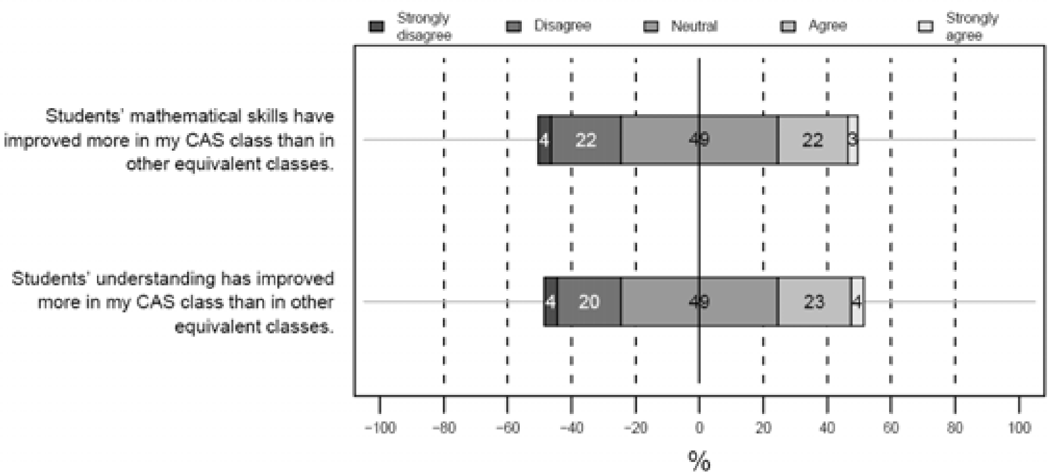
Teacher perception of student learning and understanding

Teachers were asked both in interviews and in the questionnaire about the effect of the CAS-style teaching on student learning, skills, and understanding.

Results from follow-up questionnaire

Figure 24 shows the responses of teachers when asked to what extent they agreed with statements about improvement in students’ mathematical skills and understanding.

Figure 24 **Effect on mathematics understanding of CAS calculator use— teacher views**



This graph clearly shows that, overall, teachers have not perceived any significant difference in student mathematical skills (top bar), or on their understanding. About half the teachers gave a neutral response, and the others were equally distributed on each side of this, with very few strongly agreeing or disagreeing.

Only a small number of teachers made a comment that elaborated on why they made their decision (with a total of 29 comments spread over both questions). The only comments to stand out were: that it was too early to say if either skills or understanding had changed (six comments); that there may be improvements in some areas, especially algebra (five comments); and that students gave up because of poor attitudes or lack of confidence (four comments).

Teachers were also asked to rate their students' relative abilities in the five different strands of mathematics defined in the then curriculum (Ministry of Education, 1992). They were asked this in the baseline survey, and then again after they had been involved in the project. The mean rating was obtained by scoring very high as 5, through to very low as 1. Comparing these two data sets gives a measure of teachers' perceptions of the increase in students' achievement. Table 23 shows the breakdown by strand for the baseline data, and Table 24 gives the breakdown for the follow-up data.

Table 23 **Teachers' rating of student ability at the beginning of the pilot**

Ability	Number	Algebra	Geometry	Measurement	Statistics
Very high	1	0	0	2	2
High	23	8	11	12	14
Medium	38	25	47	39	35
Low	5	29	8	12	12
Very low	1	5	1	2	3
TOTAL	**68**	**67**	**67**	**67**	**66**
Mean rating	**3.26**	**2.54**	**3.01**	**3.00**	**3.00**

At the beginning of the pilot, teachers rated students' ability as different in the five strands.[8] They rated student ability significantly lower in Algebra than in the other four strands (it was the major contributor to the high chi-squared value). Once Algebra was removed, the remaining four strands were not significantly different.

[8] Chi-squared = 47.69, d.f. = 12, $p < 0.0001$—High and Very high were pooled

Table 24 **Teachers' rating of student ability after the pilot**

Ability	Number	Algebra	Geometry	Measurement	Statistics
Very high	6	7	6	4	3
High	30	26	24	18	30
Medium	28	26	35	38	26
Low	6	9	3	10	9
Very low	0	2	0	0	0
TOTAL	**70**	**70**	**68**	**68**	**68**
Mean rating	**3.51**	**3.39**	**3.49**	**3.24**	**3.40**
Increase from baseline data	**0.25**	**0.85*** **	**0.48** **	**0.24**	**0.40***

*** Significant at the 0.1 % level

** Significant at the 1 % level

* Significant at the 5 % level

There were no significant differences between teachers' rating of student abilities across the five strands by the end of the pilot.

We tested if teachers perceived gains in student ability in each strand by looking at the contingency table of before and after data for each strand separately. To get sufficient numbers, High and Very high responses were pooled, as were Low and Very low. Teachers reported significant growth of about a full rating point for Algebra (see final row of Table 24). They also perceived significant, but smaller, growth in students' ability in Statistics and Geometry, but nonsignificant growth in Measurement and Number. Students in the pilot were seen as making good overall progress, and in particular their Algebra ability had caught up with the other strands.

These figures cannot be compared to any meaningful national norm. The point of interest here is that these teachers saw no overall difference in increased skills and understandings in CAS classes compared with non-CAS classes, but they did identify areas of gain, particularly in Algebra and to a lesser extent Geometry, and Statistics.

Teacher interview responses

Teachers have a range of views on the effectiveness of the CAS pilot for students' learning and understanding. A preponderance of comments from the interviews were either positive or neutral, though a number were negative. The positive impact upon algebra was also confirmed in the teacher interviews.

Positive effects on algebraic understanding

A number of teachers commented on the positive effect from the use of the CAS and the related pedagogy, especially as it affected algebraic understanding. This is consistent with the literature.

For example Shaw, Jean, and Peck (1997, cited in Leung, 2006) argue that CAS students were in a better position to expand "their mathematical skills by freeing themselves to focus on understanding the problems and doing the mathematics" (p. 179):

> It has encouraged their participation. If they are doing more and discussing more it must have an effect. There is much more discussion in class. The discussions that kids have in Algebra make me think that Algebra is not so foreign.

> Year 9s have picked up Algebra better than any other class. Struggling students have benefited and higher achieving students are inspired to 'play' with calculators, exploring and extending themselves.

> There is a big difference especially for students who said 'I can't do Algebra' [but now] are feeling more encouraged.

> It allows students to think. Students are getting understanding … but need reinforcement.

Some teachers thought that, while it was still too early to say, improved understanding and performances may only be observed once students were taking senior school mathematics:

> It may give benefits at Year 12. It has real potential to do this. Students have the idea of a 'variable' better. We don't see the spin-offs yet.

> [It] may make a difference at Year 12 and 13 for the mathematically able.

Some teachers who thought that student achievement had improved considered that there could have been other reasons. One teacher from a school involved in the Te Kötahitanga project (Bishop, Berryman, Tiakiwai, & Richardson, 2003) said that the improvement may have also been related to this project. A teacher at another school involved with Te Kötahitanga also commented that this programme had dovetailed very neatly with the CAS project. Such comments are a useful reminder that it is almost impossible to separate out the impact of just one initiative in times of school change generally.

Negative effects

A number of teachers commented on potentially negative effects that may eventuate from the CAS pilot. The first concern was that students may become over dependent on calculators, or may undervalue the role of being able to perform algebraic manipulation manually:

> I don't want students to be over-dependent on CAS calculators.

> Concern the kids will not value being able to do it by hand if the calculator can do it.

The other main concern was that the mathematical content may get lost in the details of actually using the calculator:

> With the animations, some were so focused on how to do it that the concept was lost. I found it better when students were watching on the screen.

> [I am] worried that in algebra—will [students] learn the right thing? What are we supposed to be doing? What sort of knowledge do they need? Maths skills or calculator skills?

Effects on different student groups

Teachers who compared the progress of groups of students with different ability mostly thought that CAS was more effective for students who had moderate or above average mathematical ability. There were some teachers, however, who thought that weaker students could be helped by the CAS approach:

> I thought it was going nowhere, then it fell into place, especially on the better students.
>
> [It was] not effective on a weak class. [There were] too many who couldn't get the CAS working for them.

The second quote was from a teacher who was very comfortable and skilled with technology, but who had a class of students with lower mathematics abilities and who also had behaviour issues. The teacher had consequently reverted to a traditional, less constructivist approach with the class. There is, however, evidence from the literature that technology may be of help to weaker students by providing scaffolding that is fast, visual, and nonjudgemental. Studies such as Yerushalmy (2006), and Kutzler (2003) mention this. Kutzler describes a pattern of alternation between higher level and lower level tasks, by using CAS technology to perform the lower level tasks while the student makes decisions at the higher level. This allows students to move on to higher thinking even when their lower level procedural skills are not fully developed.

Some teachers thought that the CAS approach suited a different type of student. This may explain some of the negative comments that previously successful students had made in student focus groups:

> It is a different cohort excelling, but the same overall distribution. It requires a different skill set.
>
> [It is] hard to get students out of their comfort zones and approach maths in a completely different way that requires more problem solving and thinking. Initial hard work starting to see progress.

Key points of Chapter 5

The quantitative data showed no difference in the amount of growth in student achievement (as measured by the PAT:Mathematics scale) for students who had taken part in the pilot compared with non-CAS control class students. CAS students were neither advantaged nor disadvantaged in the amount of growth in their mathematics knowledge compared with students who were in control classes. Some teachers suggested that the real benefits would only become evident in the senior school. There were small changes that are noted below, but the cumulative effect of the first two of these shows that CAS and control students' achievement did not differ overall:

- The 2006 control class students showed greater growth than the CAS students (of about 0.8 patm units), however the 2007 control class students showed lower growth than the CAS students (of about 0.6 patm units). These were roughly equal but in opposite directions, implying there was no overall effect for CAS at Year 9.
- The 2007 Year 10 students showed broadly equal growth regardless of whether they were in the CAS or control classes, with growth being about 1 patm unit greater for the CAS students. Again, this roughly cancelled out the amount the CAS students were behind in 2006.
- Few differences were evident between the different types of calculators (and accompanying PD) and these were of little educational significance.

The CAS pilot impacted upon individual students' learning in different ways. Some students' performances increased, but others had dropped. Student achievement was to some extent influenced by how they reacted to the changes towards the more constructivist pedagogy used with CAS, as well as how they interacted with the technology. Students recognised both positive and negative influences of CAS on their mathematical understanding. Technology has visual affordances, but these were more evidently useful for some students than for others.

It may have been that if any changes in learning and understanding occurred, they were not detectable by the measurement instrument we used. In contrast, the finer grained qualitative data indicated that there were some areas in which the CAS pilot had enhanced student learning. Both teachers and students agreed that algebraic understanding in particular had been enhanced as a result of the pilot. Areas of improvement for CAS students were:

- In general, students thought that their algebra understanding had improved, especially the Year 9 students, and to a lesser extent the Year 10s.
- Year 9 students reported a smaller increase in their geometry understanding. The Year 10 students reported no such increase.
- Teachers perceived that students' understanding of Algebra was low before the pilot, but had caught up with the other strands by the end of the pilot. They reported a smaller increase for Geometry and Statistics understanding.

Teachers also identified positive and negative effects of the CAS pilot on student understanding, and suggested that these affected different students in different ways, helping some but providing barriers to others. Some students who previously had done well at mathematics were not always performing as well. Our feedback from participants indicated that this was often the case for students who were procedurally highly competent, and had been successful previously in mathematics. Teachers suggested that these students may not have been challenged to develop their thinking skills to the same extent.

Ongoing tracking of CAS pilot students and control class students could allow richer longitudinal data on the effects of the pilot on student learning. The PAT:Mathematics measure of mathematical skills and understanding would be a very direct way to compare the relative difficulty of the CAS-enabled NCEA external assessments. The individual NCEA grades of students could be correlated with these previous measures of mathematical skills and knowledge. Comparisons could then be made between the CAS-enabled, and the non-CAS-enabled exams.

6. Student attitudes towards mathematics

This chapter reports on student attitudes towards mathematics, and on the manner in which these impacted upon student achievement. It also discusses teachers' perceptions of student attitudes and abilities.

Students responded to a questionnaire on their attitudes to mathematics before they began the CAS pilot project. This same questionnaire was repeated after they had been involved in the project for one or two years. A similar questionnaire was also given to the students in the control classes at each school. The questionnaire was split into six sections. The first five sections were answered by all students, while the sixth section was only answered by students who had been in the CAS pilot classes. This chapter looks at all students' attitudes towards mathematics, using five questions from the first section, and all 10 from the second section, giving a total of 15 questions. All these questions were posed as statements that students rated on Likert scales from "strongly agree" to "strongly disagree".

This chapter responds to the following research questions:

- *Research question 6*: What are students' current attitudes towards mathematics, and how have these changed as a result of the pilot?
- *Research question 7:* How has student learning in mathematics been affected as a result of the pilot scheme?

The second of these looks at the relationship between student attitude and their learning.

Summary

At the beginning of Year 9, students had positive attitudes towards all 15 measures of mathematics surveyed. By the end of the year, they were somewhat less positive towards more than half of these measures. The effects were similar in CAS and control classes. This is consistent with a general decline in positive views in attitudes towards school or mathematics. In Year 10, the CAS classes in particular experienced a smaller decrease in positive attitudes than the control class students. Russell (2003) describes any such slowing or reversal of a trend as indicating an "improvement" in attitudes relative to where they would have been. Other evidence from the pilot supported this. When CAS students were asked if they were more positive towards mathematics as a result of being in the CAS pilot, both cohorts of Year 9 students reported that they were, while the Year 10 students stayed largely the same.

A number of measures of student attitudes were related to their mathematics achievement. More able students were *more* likely to: be confident; do well; gain useful knowledge; see connections with things outside school; get absorbed in their work; and be interested in what they learn. More able students were *less* likely to: be nervous; report that they would drop mathematics as soon as they could; not know how to do the work; and not enjoy mathematics.

Teachers perceived little change in students' attitudes towards mathematics overall. They did believe, however, that students were initially less positive towards Algebra than the other strands. By the end of the pilot, teachers reported that the gap between student attitudes towards Algebra and the other strands had significantly diminished. Again, this emphasises that the pilot supported algebra learning.

The following sections give the detailed findings.

Student attitudes—baseline

The 2006 baseline results for students' attitudes towards mathematics are shown in Figures 25 and 26. The bars are ordered from "strongly disagree" on the left, through to "strongly agree" on the right.

The CAS and the control classes were very similar for almost all their responses. The only exceptions were that the CAS students were marginally more likely to agree: that they would gain useful knowledge in mathematics; that they were more likely to expect to get help from home; and that they were slightly less likely to drop the subject. The baseline results for the 2007 Year 9 students also showed the same general patterns on each of the questions asked, both for the CAS classes and for the control classes. Because of these similarities we only display the baseline graphs for the Year 9 CAS students in Figures 25 and 26.

Each of these graphs shows the responses in descending order of agreement with each statement. The top six statements were posed positively, and the bottom four negatively (meaning that low levels of agreement correspond to greater levels of positivity towards mathematics).

Figure 25 **Baseline responses to "Maths is a *subject* where" (2006 Year 9 CAS)**

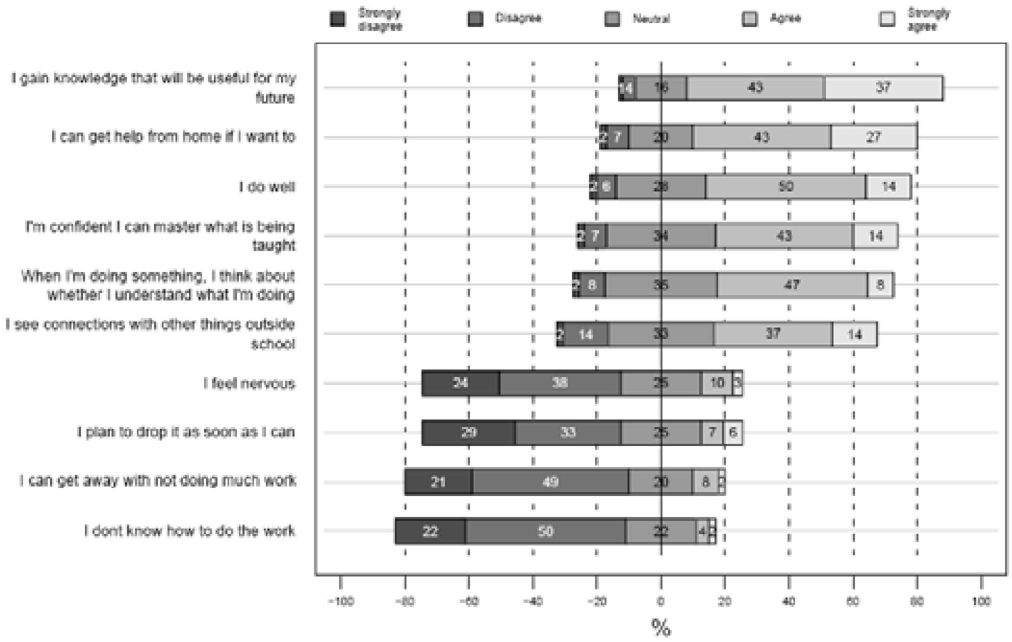
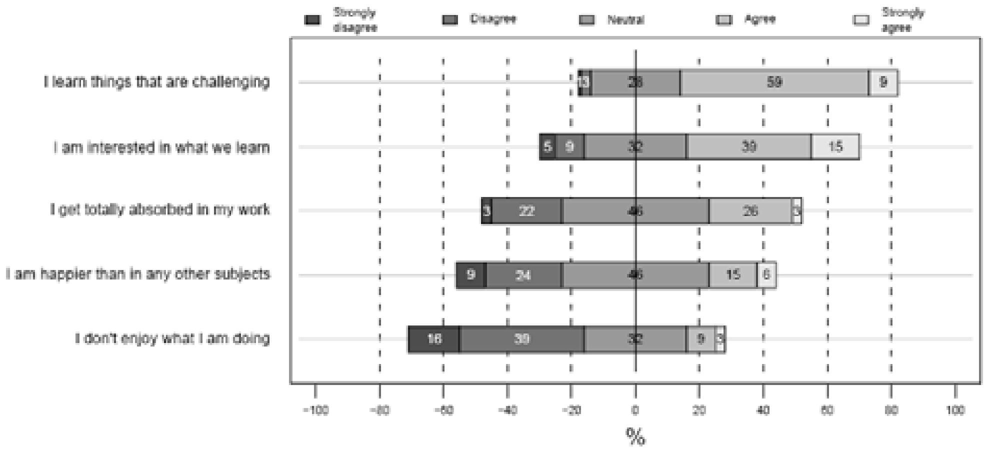


Figure 26 **Baseline responses to "Maths is a *class* where" (2006 Year 9 CAS)**



The following salient features can be seen in these graphs:

- The strongest agreement was about seeing mathematics as useful for the future (with about 80 percent agreement); or that it was a subject that was challenging (rated third highest with just under 70 percent agreement).
- About 70 percent of students expected to be able to get help from home. However, many students in the focus groups said that they were not able to get help on the CAS calculator itself.
- Two questions related to students' views of their ability at mathematics. Around 60 percent to 70 percent thought that they did well or knew how to do the work. Only relatively few students, however, thought that they could get away with doing little work.

- Three questions related to students' enjoyment or interest in mathematics. These indicated that about half the students seem to enjoy it. These statements were: "I am interested in what we learn"; "I don't enjoy what I am doing"; and "I plan to drop it as soon as possible" (about 15 percent agree, but over 50 percent disagree).
- Two other questions about student enjoyment or engagement with mathematics showed lower levels of agreement (20 to 30 percent). These were: "I get absorbed in my work", or "I am happier in mathematics than in any other subjects".
- Two questions about their feelings probed for low levels of confidence, or feeling nervous. Only around 10–15 percent of students felt this way. About 60 percent felt confident or disagreed that they were nervous.
- The final two questions related to wider perceptions around mathematics. About a half of the students reported seeing connections between mathematics and things outside of school. Just over a half reported thinking about their understanding in mathematics (a metacognitive skill).

Genuine baseline data were not available for the 2006 Year 10 students who had been involved in the project in 2005. Their attitudes towards mathematics were generally less positive than the baseline data for the Year 9 students. In more than half the questions, the differences were statistically significant. The CAS and the control class students did not show significant differences on any of these variables. This may indicate a general Year 10 malaise, or a decline from the initial high expectations of Year 9 students, or perhaps an indication that the work was getting more difficult.

Changes in student attitudes

Changes from baseline data

When the questionnaire was re-administered at the end of the year, some student attitudes towards mathematics had altered. Changes are reported here for the 2006 cohort of Year 9 CAS and control class students. These same students were in Year 10 in 2007, and so we have data about changes in their attitudes over two years. Largely speaking, the 2006 and 2007 Year 9 cohorts followed similar patterns, especially for the CAS classes. The 2006 cohort of Year 9 students was followed up about their attitudes at the end of Year 9 and again at the end of Year 10. Hence their changes can be mapped over both years.

Table 25 **Mean differences in student ratings of attitude questions for the 2006 cohort**

Attitude	Yr 9 2006 CAS	Yr 9 2006 Control	Yr 10 2007 CAS	Yr 10 2007 Control	Overall CAS	Overall Control
Gain useful knowledge	**-0.19**	**-0.16**	**-0.20**	**-0.17**	**-0.39**	**-0.33**
Can get help from home	**-0.13**	0.03	**-0.17**	**-0.17**	**-0.30**	-0.15
I do well	**-0.23**	**-0.19**	0.01	**-0.16**	**-0.22**	**-0.36**
I am confident	**-0.18**	**-0.24**	-0.02	0.00	-0.20	**-0.23**
I think about my understanding	0.09	-0.06	0.01	-0.04	0.09	-0.11
I see connections to other things	-0.10	**-0.17**	**-0.13**	0.06	-0.15	-0.07
I feel nervous	0.01	0.06	0.03	0.04	0.05	0.12
I plan to drop it as soon as I can	0.07	**0.20**	-0.06	-0.09	0.01	0.12
I can get away with little work	**0.24**	**0.40**	**0.24**	**0.26**	**0.46**	**0.69**
I don't know how to do the work	0.09	0.10	0.09	**0.20**	0.17	**0.33**
Learn challenging things	-0.04	0.03	0.10	0.09	0.06	0.12
Interested in what I learn	**-0.26**	**-0.20**	-0.03	-0.07	**-0.29**	**-0.25**
Get absorbed in my work	**-0.18**	**-0.27**	0.00	**-0.19**	**-0.18**	**-0.46**
Happier than other subjects	**-0.19**	**-0.17**	0.03	**-0.13**	-0.16	**-0.30**
Don't enjoy maths	**0.17**	**0.16**	0.08	0.08	**0.25**	**0.22**

Note: Bolded figures are indicative of significant differences (above 0.1 for one year, and 0.2 for two years).

Changes in attitudes are summarised in Table 25. This tracks the changes for the 2006 cohort of Year 9 students, and gives the amount of change over Year 9 (2006), and for those same students in Year 10 (2007). Bolded entries are indicative of significant changes in attitudes. Both the CAS and the control class Year 9 students had changed towards being less positive for many of the 15 measures. The Year 9 CAS students experienced significant drops in attitude in nine of these questions compared with 10 for control students. In Year 10, there were significant drops for four questions for CAS students, and seven for control students. Over the two years, control students were more negative than CAS students for four measures. CAS students were more negative only for being less able to get help from home.

Russell (2003) comments that attitudes tend to drop over the course of a year, and also as students get older. She defines "improvement" as lessening or halting a downwards trend as well as increasing positive perceptions. In light of Russell's comments there is a case that CAS has helped an "improvement" in student attitudes insofar as it has lessened the decline.

Changes were fairly consistent within the seven categories described in the previous section:

- Students saw mathematics as being less useful by the end of Year 9, and this continued in Year 10, so overall there was a big drop. Students showed no changes in whether they learnt challenging things in mathematics in Year 9, but showed modest increases in Year 10.
- Year 9 CAS students were less likely to receive help from home by the end of the year. Both CAS and control class students were less likely to receive help from home over the course of Year 10.
- Both CAS and control class students were less likely to see themselves as doing as well, and correspondingly more likely to report that they couldn't do the work in both Year 9 and Year 10 (with the exception of Year 10 CAS students).
- Students showed decreased enjoyment of and interest in mathematics in Year 9, and the control class Year 9 students were more likely to drop mathematics as soon as they could. There were no significant changes in Year 10, so it seems that students had stabilised their perceptions of how much they like mathematics.
- By the end of the year, the Year 9 students were less likely to report being happiest in mathematics classes, and less likely to be absorbed in their work. This was the case for both the CAS and the control class students. For the Year 10 students, the control class students only had made further significant shifts in the same direction.
- The only significant changes relating to confidence or nervousness were that both the CAS and control class Year 9 students were less confident by the end of the year.
- There were minor and inconsistent changes for seeing connections with things outside school, and no changes in student metacognition.

CAS students' changes in attitudes towards mathematics

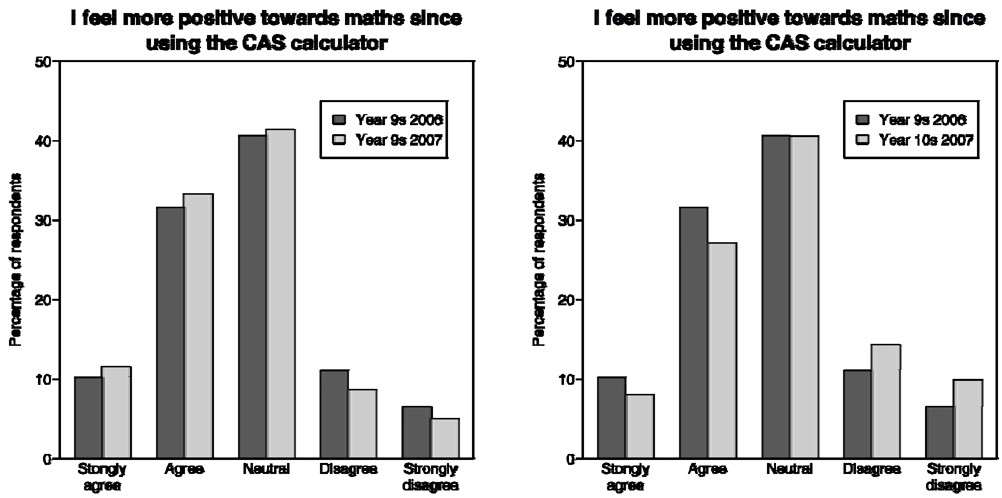
Students in the focus groups were asked directly to rate their level of agreement with the statement "I feel more positive towards mathematics since using the CAS calculator". Responses covered the spectrum from strong agreement, through neutral, to disagreement:

> Yes. [I'm more confident] with CAS than without.
>
> [It] makes it easier to understand.
>
> [It is] easy to use. [It] helps me to understand a lot. It is quick and easy.
>
> [The] calculator doesn't affect my confidence.
>
> [I] feel confident about maths in general due to [my] teacher.
>
> [I'd] just rather study the maths but not the calculator.

The final section of the survey directly asked all CAS students this same question. Their responses indicated that students in the CAS classes generally had a more positive attitude towards mathematics since the introduction of the CAS calculator. Again, this reflects an explicit "improvement" on student attitudes towards mathematics.

While this is somewhat at odds with the findings in the previous section which showed a trend towards poorer attitudes for both the CAS and control class students, Russell (2003) stated that if a downwards trend was slowed down, this itself may indicate an “improvement” in attitudes relative to where they would have been. The 2006 and 2007 Year 9 students followed similar patterns and were not significantly different (see left-hand graph in Figure 27). The Year 10 students were significantly less likely to report increased positivity towards mathematics than they did as Year 9s in 2006.[9] About as many Year 10 CAS students were in agreement with the statement than those who disagreed.

Figure 27 **Students’ changes in attitudes towards maths since using the CAS calculators**



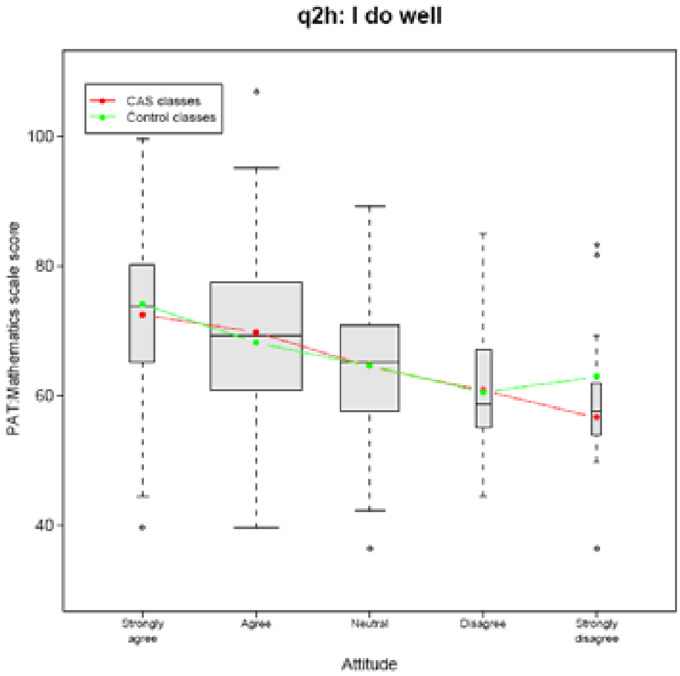
Attitudes and achievement

Many of the 15 attitude questions showed a pattern that correlated with the level of achievement of students as measured on the PAT:Mathematics scale.

Not surprisingly, the more able students were more likely to agree that they: did well; were confident in mastering what they had been taught; gained useful knowledge; were interested in what they learnt; saw connections to things outside school; and got absorbed in their work. These trends are listed in the approximate order of the magnitude of the trend (from about 5 to 15 patm units). These were observed in both the Year 9 cohorts, and also in the 2007 Year 10 cohort. A graphical illustration of the relationship follows in Figure 28. In this case, the pattern is similar for the CAS and control class students. While there is a downwards trend, the long “whiskers” on the graph indicate that there is high variation, and so this relationship was weak.

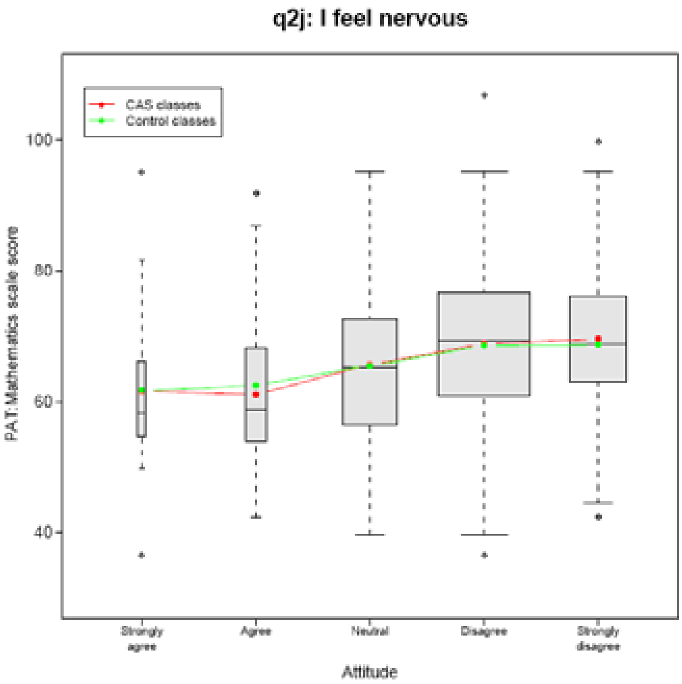
[9] Chi-squared = 14.97, 4 d.f., p = 0.0048

Figure 28 **Relationship between achievement and doing well (2007 Year 9 cohort)**



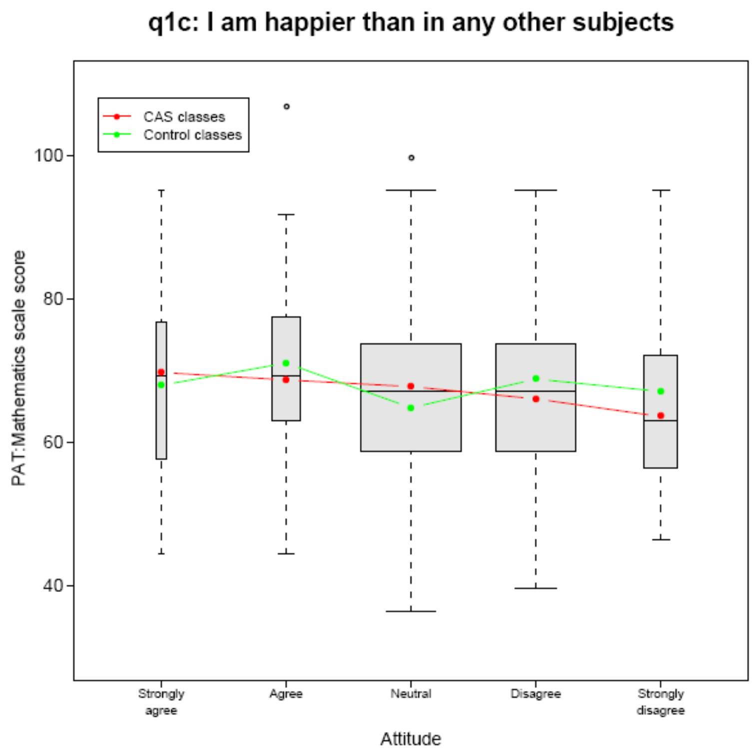
The less able students were more likely to: not know how to do the work; feel nervous; drop mathematics as soon as they could; and not enjoy mathematics. An example of this follows in Figure 29. Again, CAS and control class students showed similar trends.

Figure 29 **Relationship between achievement and feeling nervous (2007 Year 9 cohort)**



In most cases, the patterns were similar in both CAS and control classes. There were, however, a few exceptions. These were: gaining useful knowledge; feeling happier in mathematics than other subjects; and being confident that they could master what they were taught. In each case, the CAS students were more likely to have a meaningful trend between achievement and attitude, whereas in the control classes the trend was not evident. One of these relationships is shown in Figure 30, where being happier in mathematics classes related to achievement level in CAS classes, but not in the control classes. The more able CAS students reported being happier in mathematics than the less able ones. The drop of confidence in just the CAS classes suggests that CAS may not suit lower ability students, or that teachers may need to provide more scaffolding to build confidence.

Figure 30 **Relationship between achievement and feeling happier in maths classes (2007 Year 10 cohort)**



Teachers' views on student attitudes

Teachers were also asked to rate their students' attitudes to mathematics. They were firstly asked to what extent they agreed with the statement "Students' attitudes are more positive in my CAS class than in other equivalent classes". Table 26 shows these results. Teachers were largely neutral, and roughly equal numbers agreed as disagreed with the statement.

Table 26 **Teachers' views on students' attitudes being better in CAS classes**

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	TOTAL
Before	2 (3%)	16 (22%)	32 (44%)	21 (29%)	2 (3%)	73

The teachers were also asked to rate their students' attitudes in each of the five different strands of mathematics as defined in the curriculum that was in place during the pilot project (Ministry of Education, 1992). They were asked this in the baseline survey, and then again after they had been involved in the project. The mean rating was obtained by scoring "Very positive" as 5, through to "Very negative" as 1. Comparing these two responses gives a measure of teachers' perceptions of the change in student attitudes over the pilot scheme. Table 27 shows the breakdown by strand for the baseline data, and for the follow-up data. Algebra was initially halfway between "negative" and "neutral", whereas the others rated between "neutral" and "positive", with Number being the most positive.

Table 27 **Teachers' rating of student attitudes pre- and post-pilot**

Attitude	Number	Algebra	Geometry	Measurement	Statistics
Very positive	7 (8)	1 (6)	3 (8)	3 (4)	3 (6)
Positive	44 (45)	7 (34)	37 (39)	34 (37)	26 (40)
Neutral	11 (13)	19 (18)	25 (21)	31 (25)	33 (20)
Negative	6 (4)	34 (11)	3 (1)	1 (0)	6 (0)
Very negative	0 (0)	8 (1)	0 (0)	0 (0)	0 (0)
TOTAL	**68 (70)**	**69 (70)**	**68 (69)**	**67 (68)**	**68 (68)**
Mean rating (pre)	**3.76**	**2.41**	**3.59**	**3.67**	**3.38**
Mean rating (post)	**3.81**	**3.04**	**3.78**	**3.63**	**3.71**
Increase from baseline data	**0.05**	**0.63*** **	**0.19**	**-0.04**	**0.33***

The figures in parentheses are the numbers post-pilot

*** Significant at the 0.1% level

* Significant at the 5% level

Analysis of the pre-pilot data indicates that teachers rated students' attitudes as being different in the five strands.[10] Attitudes were rated as being significantly lower in Algebra than in the other four strands (it was the major contributor to the high chi-squared value). Once Algebra was

[10] Chi-squared = 146.85, d.f. = 12, $p < 0.0001$—Negative and Very negative were pooled

removed, there was still a significant difference between the remaining four strands.[11] Once Number was removed, the remaining three strands were not significantly different.

By the end of the pilot, there were still significant differences in the teachers' rating of student attitudes between the five strands.[12] Teachers still reported more negativity towards Algebra. Once Algebra was removed, there was no significant difference between the other strands.

There was, however, a significant increase in teachers' rating of positive student attitudes in the Algebra strand.[13] Of the other strands, only Statistics saw a significant, though smaller, increase in students' perceived positive attitudes. While these figures cannot be compared with any meaningful national norm, they do indicate that teachers thought that students in the pilot were becoming more positive towards Algebra and, to a lesser extent, Statistics.

Relationship between perceived abilities and attitudes

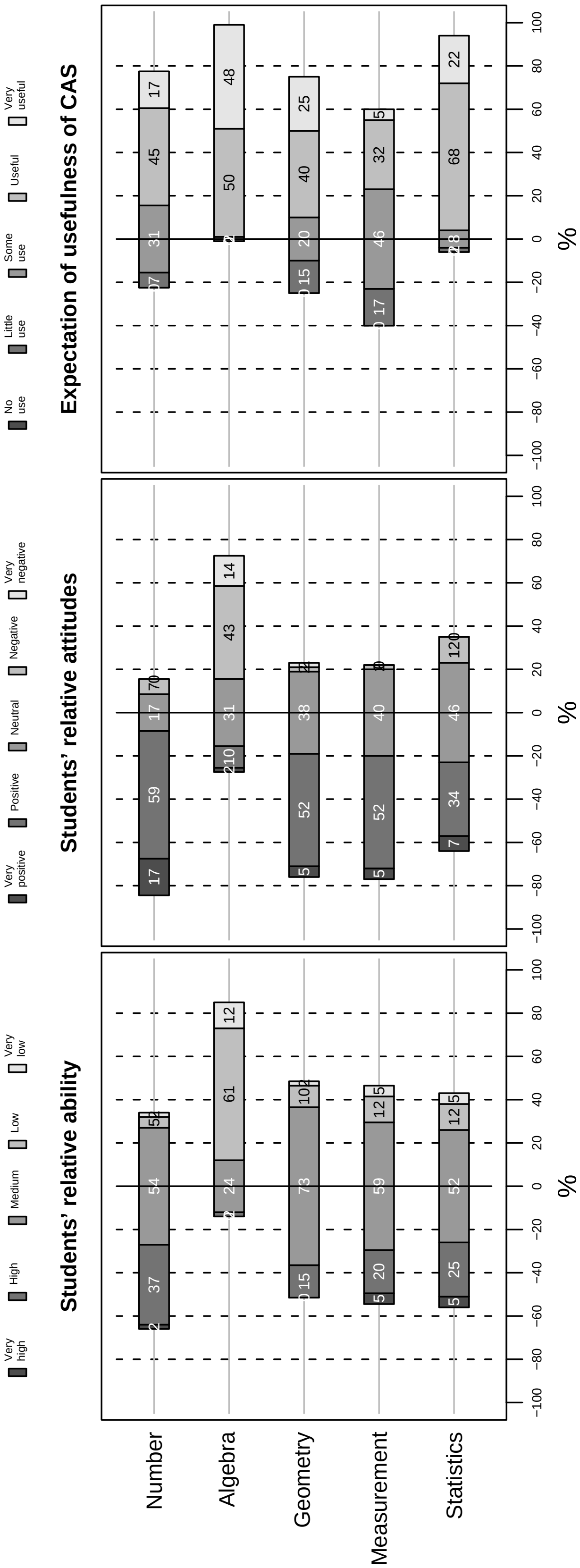
Comparing the patterns of teachers' ratings of student abilities and their ratings of student attitudes showed an interesting relationship. Teachers saw students' abilities and attitudes as being in balance in Algebra. In Number, Geometry, and in Measurement, they thought that student attitudes were significantly higher than their abilities, with Statistics showing a similar pattern, but not significantly so (see Figure 31). This pattern held both in the baseline questionnaire and in the follow-up questionnaire at the end of 2007. It must be stressed that this relationship is not based on actual student ability, but on teachers' perceptions of it, which may have an element of being self-fulfilling.

[11] Chi-squared = 24.09, d.f. = 9, $p = 0.0197$

[12] Chi-squared = 26.41, d.f. = 12, $p = 0.0094$—Negative and Very negative were pooled

[13] Chi-squared = 38.04, d.f. = 9, $p < 0.0001$

Figure 31 **Relationship between teacher perceptions of student abilities, and attitudes; and the potential usefulness for CAS**



Key points of Chapter 6

Before they began the pilot, both CAS and control class students were equally positive towards mathematics. Both groups, however, became less positive over the course of the pilot. This general decline in attitudes throughout the year, and from year to year, has been observed in other surveys; for example, Russell (2003). In their second year in the project, CAS students experienced a smaller decrease in their attitudes than did the control students. This indicated that the downwards trend had been lessened for CAS students. Russell suggests that such a lessening or halting of a downwards trend indicates that an initiative is having a positive effect on attitudes. This is because attitudes are more positive than they would have been if the downwards trend had continued.

When the CAS students were asked directly whether they felt more positive about mathematics as a result of the pilot project, the Year 9 students reported that they were. The Year 10 students' views had stayed about the same. This reinforces the hypothesis that, while there was a general decrease in positive attitudes across classes in general, the CAS students had not experienced this decrease in positive attitudes to the same extent.

There was a relationship between student attitude and achievement for over half the attitudinal questions, though these trends were only weak. Compared with their less able classmates, more able students were:

- more likely to: be confident; do well; gain useful knowledge; see connections with things outside school; get absorbed in their work; and be interested in what they learn.
- less likely to: be nervous; drop mathematics as soon as they can; not know how to do the work; and not enjoy mathematics.

Teachers thought that student attitudes generally had changed little as a result of their involvement in the CAS pilot. They did, however, single out that attitudes towards Algebra had improved markedly. At the beginning of the pilot, teachers perceived that student attitudes were more negative towards Algebra than towards the others strands. By the end of the pilot, teachers thought that student attitudes towards Algebra were becoming more like their attitudes towards the other strands.

7. Professional development

The 2005 Pilot study (Neill & Maguire, 2006a, b) reported that the key to the CAS pilot project had been the provision of quality PD. The training sessions had a different PD provider for each of the three brands of calculators. Each provider had considerable experience as a teacher, and had been working with various classroom technologies for a number of years. The overall PD programme was co-ordinated by a teacher with extensive experience of classroom teaching, and of providing PD to teachers, and who has had a deep involvement with NCEA, and close links with the New Zealand Qualifications Authority (NZQA).

The aims and philosophies of the PD professionals have provided much of the intellectual thrust for the project. These beliefs and aims have been covered in the report of the 2005 pilot. Each provider has largely emphasised a constructivist, investigative approach. This report outlines the expectations that the teachers held prior to the commencement of the PD. These are then contrasted with the teachers' views after they had undergone the PD and had taught in their CAS classrooms. The data were gathered by an initial baseline questionnaire and a final questionnaire of all teachers in the project, and from responses to the teacher interviews.

The following research question is addressed in this chapter:

- *Research question 4*: What are the professional development issues that have arisen in the pilot?

Summary

The aims and philosophies of the PD professionals have provided much of the intellectual thrust for the CAS pilot. These beliefs and aims have been covered in the report of the 2005 pilot (Neill & Maguire, 2006a, b), and included emphasising an exploratory, constructivist approach, with modelling of the use of multiple representations and multiple strategies.

The approach to early algebraic thinking, and especially the staged introduction to the concept of pronumerals, was a significant feature of some of the PD. This may well have contributed to the increase in students' algebraic understanding reported in Chapter 5.

The expectations of teachers were largely met by the PD. The majority reported gaining quality resources and teaching strategies to use with their classes. Most reported that they had also gained the skills and the confidence to use the CAS calculator in their classes, though some were still coming to terms with this. Teachers saw a need for more resources than were currently available, as it took them considerable time to write and refine their own.

Some teachers questioned the timing of the PD. Suggestions were made that it needed to be closer to the time when it was actually employed in the classroom, and that more regular, ongoing PD and support for technical and teaching issues would be helpful.

The following sections give the detailed findings.

Teachers' aims

Teachers were asked about their expectations of the PD prior to the workshops. Two dominant themes stood out. Over half the teachers said they were expecting to gain proficiency in the use of the calculator. Over 40 percent of the teachers also wanted to gain ideas about how to incorporate the CAS calculators into their teaching.

There was also an expectation of learning new ways to teach, with teachers often indicating that they expected to learn a more constructivist approach. An equal number of responses mentioned using the CAS to enhance learning, understanding, or thinking. Table 28 shows the main categories of responses about teachers' expectations from the baseline questionnaire.

Table 28 **Teachers' prior expectations of the PD**

Teachers' expectation	**Frequency**	**Percentage of teachers[1] %**
Proficiency at using CAS	38	55
How to incorporate CAS into teaching	29	42
Learning new or alternative ways to teach rather than traditional ways	14	20
Using CAS to enhance learning, understanding, or thinking	14	20
Getting resources and materials	7	10
Confidence at using CAS	5	7
Other	15	22
TOTAL	**69**	

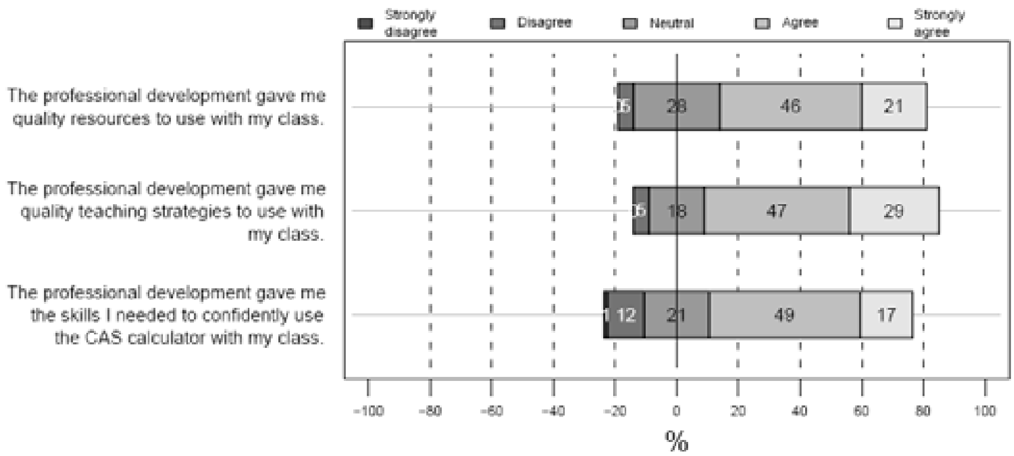
Note: Percentages add to more than 100% as teachers could give more than one response.

Teachers' experiences of the PD

Questionnaire responses

The follow-up questionnaire asked teachers how they rated the PD in terms of three of these aspects: the skills (proficiency) they had gained in CAS use; the teaching strategies they had gained; and the quality of the resources they had received. Figure 32 shows that, in general, teachers either agreed of strongly agreed with each of the three statements with very few who disagreed. Extra help for developing their CAS skills was the biggest need from the PD.

Figure 32 **CAS pilot teachers' perceptions of the PD**



Teachers were also given the chance to write down comments to qualify their rating on the three questions. The numbers in parentheses are the aggregate of responses over the three questions. More time, more PD, and more resources were common unifying issues for teachers.

- **Skills**: There were several comments about the need for more time to develop skills (12); the need for more PD (5); for the refreshing of ideas (4); for more technical support (5); and for the need to gain more confidence in their calculator skills (4). Ten teachers commented on the high quality of the PD providers.
- **Teaching strategies**: There were relatively few comments on this, with four teachers noting that some of the PD was not at a Year 9 level, but was aimed at senior mathematics. Some teachers commented on the fresh teaching ideas they had got (4), or on the appropriate modelling of teaching strategies by the PD providers (4).
- **Resources**: The two main responses teachers made were that they needed more resources (8), or that the resources needed adapting by the classroom teacher (7). The latter was not seen as a criticism, but as an essential part of the teacher's job, though some mentioned problems with implementing the resources in their classes (4). One teacher commented that, "We wrote most of them", underlying the need for more currently available and appropriate resources. Several commented that the resources were motivating for their students (5).

Interview responses

Several of these same issues arose in the teacher interviews. Chapter 6 of the report on the 2005 pilot gives an extensive review of teachers' perceptions of the PD (Neill & Maguire, 2006b, pp. 56–60), and the majority of the feedback from the 2006 and 2007 interviews has already been reported there. Again, the general consensus was that the PD was of a high quality, but that teachers needed more time to assimilate the pedagogy and technology into their lessons, and that more resources were needed. The following discussion highlights areas that did not emerge in that initial study.

Timeliness of PD

Several teachers reflected that the PD was too removed in time from the classroom implementation:

> The PD was great but I still wasn't confident enough. I need more regular, ongoing PD. By the time I'd got to the topic on the scheme, I'd forgotten most of it.

> The 2006 (introductory) sessions were not helpful—frustrating and no instruction books so we couldn't 'play around' over the holidays. I had to start from scratch at the beginning of the year.

> [The] gap between PD and delivery was too long. PD days once a term would be good.

These emphasise not only the need for the PD to be on a just-in-time basis, but also the need for more ongoing PD. Just how this can be achieved when the PD presenters are based in Australia is unclear, as their sessions need to be scheduled well in advance, and costs will obviously be high.

Student preparedness in algebra

A few teachers commented on whether the PD helped students "cross the bridge" between numerical and algebraic thinking. Research both in New Zealand and overseas indicates that students need to be scaffolded in moving towards the generalisations of algebra, and especially into understanding the role of the pronumeral (Carpenter, Levi, & Franke, 2003; Irwin & Britt, 2007; Linsell, in press; Maguire, 2008). Algebraic insight is needed for the effective use of CAS. The calculator is not a panacea but a tool to assist thinking.

Two teachers commented positively that one of the PD providers had actively considered this domain, and that it had affected their views on how algebra should be taught. The third quote is from a teacher who did not see the PD adequately addressing this issue, as it had assumed that students already had an appreciation of pronumerals:

> [The PD] opened my eyes to change in the teaching approach. The approach of an introduction to pronumerals was good.

> [The PD modelled an] excellent pedagogical approach to algebra. Pedagogy moved further down the same line and made me think about how students learn things. We will modify how we teach algebra as a result of this.

> [It was] OK when students had understanding of literal symbols, [but] this was taken as given.

One teacher expressed the irony that you "Need some algebraic understanding to be able to use them [the CAS aspects of the calculators]."

Another teacher shared how they had used ideas of number as a precursor to, and motivation for, moving into generalisations, and algebraic thinking and reasoning. This approach is consistent with the philosophy of the NDPs.

Although the PD involved an introduction on how to operate the CAS calculator, it had a particular focus on how to use it effectively for teaching and learning. The PD thus took account of the recommendation that "the use of CAS technology needs to be accompanied by the development of algebraic insight, including the ability to identify the structure and key features of expressions and to link representations" (Anthony & Walshaw, 2007, p. 139). Multiple representations were a feature of the pilot project PD.

Other issues and suggestions about PD from teachers

Teachers made a number of other specific comments and suggestions about aspects of the PD:

- Resources with screen shots of the calculator were mentioned. More than one teacher said that a brief instruction sheet would be of help. "[Having a] manual [would be] a big plus. It is hard to use online help."
- One teacher had been "trained on one calculator but [was] teaching with another". This moves into the issue of changing technology, which will be touched on in Chapter 8.
- One teacher felt that some of the classroom management issues were not adequately covered, and went as far as to say that the PD presenter "was dismissive of the actual problems". In at least three classes of students involved in the project, behavioural issues seemed to be exacerbated by the use of CAS, and this had led to very limited use of the CAS, or its related pedagogy, or to it being completely abandoned. While such behavioural issues are beyond the scope of the PD, some advice on other management issues could perhaps be incorporated. One teacher, for example, used the strategy of getting the class to turn their calculators face downwards to ensure he regained the attention of the whole class.

Teacher suggestions about future PD models are discussed in Chapter 9. This section also includes a critique of the appropriateness of the pilot model for a full roll-out of the project over all schools.

Key points of Chapter 7

Teachers had a variety of expectations of what they would get from the PD. The three main expectations were:

- to gain skills, proficiency, and confidence at using the CAS;
- to be exposed to alternative teaching strategies, using CAS to enhance learning, and getting ideas of how to incorporate the technology into teaching; and
- to get useful classroom resources.

The teachers were largely very positive about the PD, commenting that it met these three expectations, and that students had found the resources motivating. The teachers did, however, suggest a number of refinements. Ideally, they would like:

- ongoing PD;
- PD happening closer to when it was to be used in the classroom;
- access to local advisers to help on pedagogy and support on issues related to the technology;
- more ready-to-use classroom resources to be made available;
- a wider range of resources, including ones in other areas of mathematics;
- PD and resources for senior classes;
- time to absorb and adapt the units in their own classrooms; and
- some pointers on general classroom management issues, and ideas for classes that have significant behavioural issues.

In addition, teachers generally thought that the PD addressed algebraic thinking well. Some suggested that the PD presenters needed to give a clearer steer to help students cross the bridge between number and algebraic thinking. There were some presuppositions that students were already "pronumerally literate".

8. Technology—skills and attitudes for use

The effective and appropriate use of CAS depends on a number of factors. These include the attitudes of teachers and students towards technology in the classroom and its effective use. This chapter explores these attitudinal dimensions for these two groups. It also explores teacher use of, and skills in, technology in the classroom. The views of the professional providers were explored in the 2005 report (Neill & Maguire, 2006b).

This chapter explores the following research questions:

- *Research question 1:* Have changes in teachers' roles and practices occurred in the CAS pilot school mathematics classes, and if so, what are they?
- *Research question 6:* What are students' current attitudes towards mathematics, and how have these changed as a result of the pilot?

In this chapter, student and teacher attitudes towards technology in mathematics classrooms is the focus.

Summary

Teachers were already largely supportive of technology use in the classroom before they began the pilot, but no more so than a representative sample of nearly 500 New Zealand mathematics teachers (Thomas et al., 2007). The CAS pilot did not change their views on this. One reason for their support was the pragmatic response that technology is a reality in the modern world and for the future. The other major reason was that CAS has affordances for student learning in various areas, such as allowing different ways of mathematical exploration; enhancing student motivation; and allowing better or different activities. The visual nature of the calculators was also commented on. Teachers did point out that technology is just one of many tools that they can employ, and that the ideas can also be taught without technology. The biggest constraint for them was around costing and resourcing.

Teachers reported significant increases in their skills with CAS calculators, and also with using data projectors in conjunction with calculators. There was a corresponding increase in the classroom use of these two sets of skills, but there was also an increase in the use of technologies other than the ones indicated at the beginning of the pilot. Teachers did, however, call for technical backup for the calculators in much the same way as there is backup for computers in schools.

Teachers believed that the CAS approach would be of most use in the Algebra strand, and to a lesser extent in Statistics, and of least use in Measurement. This was borne out in their experience of actual use, with the CAS being significantly more useful, and with teachers using them significantly more often, in Algebra compared with the other four strands.

Students were largely positive towards technology, especially at the beginning of the pilot. This was equally true for both CAS and control class students. However, by the end of the pilot, the 2006 cohort of CAS students had become somewhat less positive towards technology compared with the control class students who had maintained similar views. It is unclear what had caused this, but it may be that the CAS required a steep learning curve, and was not as intuitive as other calculators that the students have encountered. Many students had gained in their confidence at using CAS, and the majority enjoyed using the calculators. Others were not so keen, and a few were quite frustrated with the CAS calculators.

Teacher attitudes

Information about teacher attitudes towards the use of technology, especially the use of CAS calculators, was collected in two different ways: by pre- and post-questionnaires; and by interviewing classroom teachers. Results from each of these follow.

Questionnaire findings

In the pre- and post-questionnaires, teachers were asked about their skills and classroom use of various types of technology, as well as their opinion about the place of technology in the classroom.

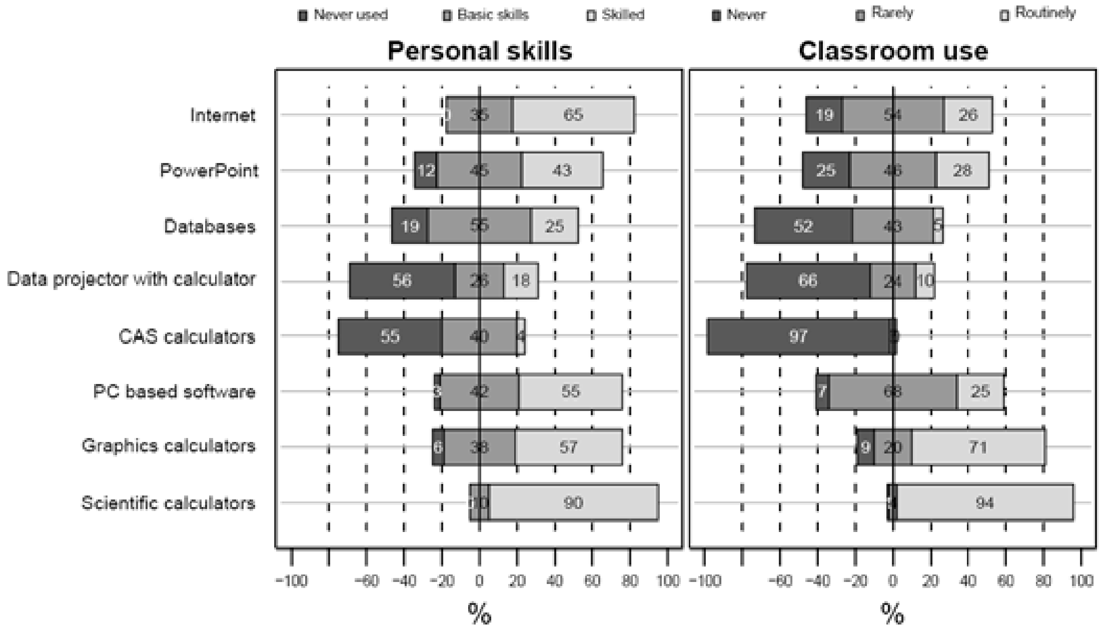
Technology skills and classroom use

Baseline data

Prior to beginning the pilot, teachers were asked about their personal skills, and their current level of classroom use of a number of items of technology. These responses are shown in Figure 32 for the 2006 and 2007 teachers. About 90 percent of teachers reported being skilled in the use of scientific calculators. Most reported either being skilled, or having basic skills in: graphics calculators; PC software; PowerPoint; and Internet use. More than half the teachers reported that they had never used data projectors linked to calculators prior to the project. It was surprising that as many as 40 percent of teachers reported having basic CAS skills prior to the project.

Teachers' skills and their use of scientific calculators; graphics calculators; data projectors with calculators; and PowerPoint were largely in balance. This contrasts with their skills in PC-based software; CAS calculators; databases; and the Internet, which were higher than the level of their classroom use.

Figure 33 **Teachers' baseline skills and classroom use of technology**



Changes

Teachers reported large and significant increases in their skills, not only with CAS calculators, but also with using data projectors with calculators. There were small, but not significant, increases in the skills teachers reported on their use of graphics calculators, and also of PowerPoint skills.

Figure 34 **Changes in teacher skills over the pilot project**

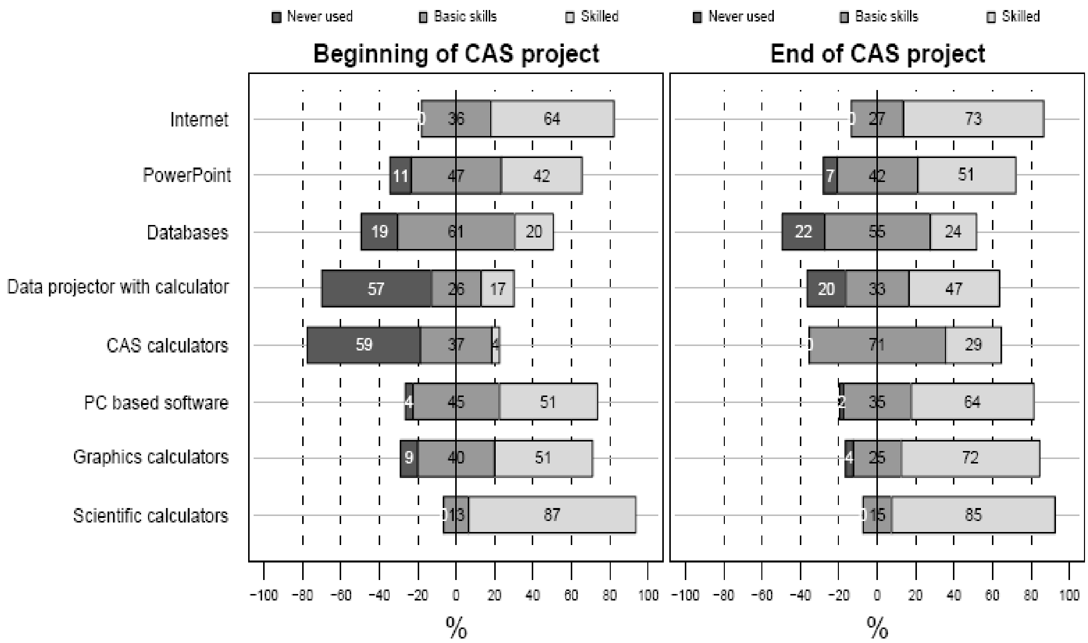
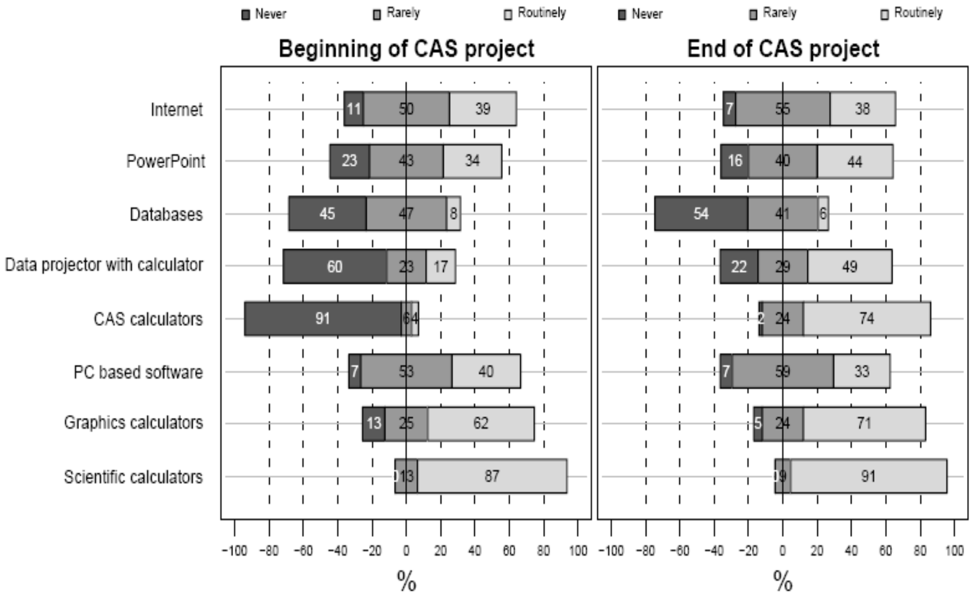


Figure 35 **Changes in classroom use over the pilot project**



Classroom use followed a very similar pattern, with large and significant increases of CAS use in the classroom, and using a data projector with calculators. There was a small number of teachers who reported that they were starting to use other technologies. Some other aspects of teachers' changing practices in technology are shown in Chapter 4. This shows that the frequency of teacher practice had increased in each of the four measures of technology practice (Figure 12). This increase was larger than that for any of the other 16 practices that teachers reported on. The increases in the four technology practices were also large relative to the others even when the CAS was not being used (Figure 13). This demonstrates the higher focus technology was receiving overall by the pilot teachers. With the exposure to new ideas for teaching, gaining new skills, and practising these in the classroom, there is a foundation for change.

Use of CAS in the classroom

Teachers were also asked to predict how useful they thought the CAS calculator would be in the five different strands of mathematics as defined in the curriculum that was in place during the pilot project (Ministry of Education, 1992). They were asked this in the baseline survey, and then they were asked how useful they actually found them after they had been involved in the project. Table 29 shows the breakdown by strand for the baseline data, and Table 30 gives the breakdown for the follow-up data. The mean rating was obtained by rating "Very useful" as 4, through to "Little use" as 1.

Table 29 **Teachers' rating of the potential usefulness of CAS at the beginning of the pilot**

Usefulness	Number	Algebra	Geometry	Measurement	Statistics
Very useful	11	28	13	4	12
Useful	28	36	26	21	40
Somewhat useful	22	3	15	30	11
Little use	6	0	10	11	2
TOTAL	**67**	**67**	**64**	**66**	**65**
Mean rating	**2.66**	**3.37**	**2.66**	**2.27**	**2.95**

This indicates that teachers believed that the usefulness of the CAS would differ between the five strands. Algebra was half way between "useful" and "very useful", Statistics rated close to "useful", whereas the others rated between "somewhat useful" and "useful". The anticipated usefulness in Measurement was the lowest. The main reason for the statistical significance was that teachers anticipated that the CAS would be more useful in Algebra than in the other four strands (it was the major contributor to the high chi-squared value).[14] Once algebra was removed, the remaining four strands were still significantly different.[15] This was largely because teachers anticipated that the CAS would be next most useful in Statistics. Once Statistics was dropped, the remaining three strands were not significantly different.

Table 30 **Teachers' rating of the actual usefulness of CAS during the pilot**

Usefulness	Number	Algebra	Geometry	Measurement	Statistics
Very useful	4	16	9	2	11
Useful	24	34	18	14	17
Somewhat useful	23	19	23	27	21
Little use	15	2	10	13	6
No use	1	0	0	1	0
Total users	**67**	**71**	**61**	**57**	**55**
Not used	4	2	9	11	12
TOTAL	**71**	**73**	**70**	**68**	**67**
Mean rating (of users)	**2.22**	**2.90**	**2.39**	**2.05**	**2.60**

Note: Based on a score of 4 for Very useful" to 1 for "little use", and 0 for "No use".

[14] Chi-squared = 74.29, d.f. = 12, $p < 0.0001$

[15] Chi-squared = 29.47, d.f. = 9, $p = 0.0036$

There was a significant difference between teachers' rating of the actual usefulness of CAS during the pilot in each of the five strands.[16] This was largely because teachers saw CAS being more useful in Algebra than in the other strands. Once Algebra was removed, the four other strands were not significantly different. For Algebra, the rating was "useful" where the others were rated somewhere between "somewhat useful" and "useful".

The actual usefulness was lower than the anticipated usefulness in each of the five strands. The difference was significant in Number, Algebra, and Statistics. This was tested by looking at the contingency table of before and after data for each strand separately.[17] This difference between perceptions and reality may explain the possible disappointment of some teachers, who felt that their expectations had not been met, although this must be seen in the light of Table 30 which indicates that they did acknowledge that they were useful.

Teachers also rated the actual amount of use during the pilot of the CAS calculators in the five different strands of mathematics. Table 31 shows the breakdown by strand. The mean rating was obtained by rating "All/most of the time" as 4, through to "Occasionally" as 1, and "Never" as 0.

Table 31 **Teachers' rating of the actual use of CAS during the pilot**

Actual use	Number	Algebra	Geometry	Measurement	Statistics
All/most of the time	15	15	11	8	10
Often	11	36	14	10	16
Sometimes	25	14	25	24	20
Occasionally	18	6	11	16	9
Never	4	2	11	14	15
TOTAL	**73**	**73**	**72**	**72**	**70**
Mean rating	**2.18**	**2.77**	**2.04**	**1.75**	**1.96**

This indicates that the CAS calculators were used in differing amounts in the five strands.[18] The main reason for this was that teachers used the CAS more often in Algebra than in the other four strands (it was the major contributor to the high chi-squared value). Once Algebra was removed, the remaining four strands were not significantly different in the amount of usage. In Algebra, CAS was rated closest to being used "Often" while in the other four strands it was rated close to "Sometimes".

[16] Chi-squared = 37.12, d.f. = 12, p = 0.0021

[17] Chi-squared (d.f. = 3) Number = 8.14, p = 0.0423; Algebra = 16.86, p = 0.0008; Statistics = 13.71, p = 0.003

[18] Chi-squared = 56.32, d.f. = 16, p < 0.0001

Close to a fifth of teachers reported never using the CAS in Geometry, Measurement, or Statistics. It was far rarer for teachers not to use it in Number, and only two teachers did not use it in Algebra.

Attitudes to technology use

Teachers were asked to what extent they agreed with the statement "Technology in the classroom is essential for teaching and learning mathematics in the 21st century". The pattern of their responses showed no significant change before and after their involvement in the project (Table 32).

Table 32 **Teacher views on "Technology in the classroom is essential in the 21st century"**

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	TOTAL
Before	26 (38%)	33 (47%)	7 (10%)	2 (3%)	1 (1%)	69
After	38 (48%)	34 (43%)	5 (6%)	2 (3%)	0 (0%)	79

This shows that teachers in the pilot were in favour of the use of technology in the mathematics classroom even before they were involved in the project and they had not significantly altered this view. A similar question was asked of a representative sample of 464 New Zealand teachers by Thomas et al. (2007, p. 33), and the pattern of responses is not significantly different from the baseline attitudes of the 69 teachers who provided baseline data in this study. This suggests there was no bias towards technology in the CAS pilot sample of teachers compared with mathematics teachers more generally.

Typically, teachers gave between one and three different reasons for their responses to "attitudes towards technology use" prior to their involvement in the survey. These are summarised in Table 33. Four distinct categories are given within this table. The *pragmatic* response that technology is here now and will be in the future was made by 35 (51%) of the teachers in their baseline responses; *affordances* (advantages) of the technology responses were made for 52 (75%) of the teachers; *qualifiers* to their level of support accounted for 33 (48%) of teachers; and *constraints* accounted for just four (6%) of the teachers.

Far fewer open-ended responses were made by teachers after their involvement in the pilot. While the numbers were small, the overall patterns remained similar. There were relatively fewer responses that suggested that: "Technology allows different ways of mathematical exploration" (9% of comments prior against 2% post-pilot); that, "Technology allows better or different activities" (6% vs 0%); or that they "Needed to teach skills and concepts first" (9% down to 2%). However, rather more comments stated that, "[Technology] develops understanding rather than an algorithmic approach" (3% before, 10% post), or made comments about costs or resourcing issues (3% prior up to 14% after).

Table 33 **Teachers' open-ended comments on the role of technology in maths classes**

Response	Frequency of responses[1]	Percentage of teachers[2]
Pragmatic		
Technology is a reality for today	21 (8)	30%
Technology will be needed in the future	14 (5)	20%
Affordances		
Technology allows different ways of mathematical exploration	11 (1)	16%
Technology enhances student motivation	8 (3)	12%
Technology enhances teaching and learning	8 (2)	12%
Technology allows better or different activities	7 (0)	10%
Technology is quicker (or does the "grunt work")	6 (3)	9%
Technology assists students' strengths or learning styles	4 (1)	6%
Technology help students make links or meaning	4 (1)	6%
It develops understanding rather than an algorithmic approach	4 (4)	6%
Qualifiers		
Technology is a tool (or one of many tools)	12 (3)	17%
Need to teach skills and concepts first	11 (1)	16%
Ideas can be taught without technology	7 (2)	10%
Others (Technology not limited to maths, depends on user)	3 (0)	4%
Constraints		
Costs/resourcing	4 (6)	6%
TOTAL responses	**124 (42)**	**100%**

[1] The numbers in parentheses are the responses made **after** involvement in the CAS pilot.

[2] The percentages do not add to 100% as teachers could make more than one response.

Issues from the teacher interviews

A number of issues were addressed by teachers in their face-to-face interviews. Many practical barriers, such as battery life, the availability of data projectors, and relying on students to bring their CAS calculators to class, were similar to those reported in the 2005 report on the pilot (see Neill & Maguire, 2006b, p. 33, pp. 71–79). Some issues mentioned in Table 33 were also discussed. For example, the role of technology as a tool rather than the driver is illustrated in the following quote:

> Just like the GC is now accepted. [It's] just new technology. Technology is not doing the learning, so it's great. Anyone in a job will have a tool like CAS that will be a tool for the job just like a carpenter will have a hammer. Now the calculator is the focus, eventually it will be a tool.

Use of technology for teaching

What follows is a summary of the key issues that arose largely from the teacher interviews but also from questionnaire responses. The interviews included teachers with Year 9, Year 10, and Year 11 CAS pilot classes.

Assistance for technology

A common complaint from teachers was that the calculator freezes on students, while others mentioned bugs in either the software or the hardware. Two technologically literate teachers referred to the technology as "clunky" as they reflected on this. Some typical responses for this were:

> Some applets [are] fantastic but they do have bugs.
>
> Faulty units—is it a hardware, software, or operator error?
>
> [I] don't feel confident to fix [calculators that freeze] on the spot.

Classroom teachers also had issues with changes to either the software/operating system, or to the model of calculator. This became an issue of time, troubleshooting, and updating resources:

> [We have] two different types of calculators now so need two sets of booklets—has meant extra photocopying costs, and Y9 and Y10 teachers are unable to compare notes, share resources, or support and mentor each other. Teachers have to learn a new calculator.
>
> [The] new software was a problem. It came as a surprise. The actual task of updating the operating system [was a problem]. It took out old files (e.g. Geometry applets) [so I] didn't update students' calculators.
>
> [The] change in operating system took hours.

Some teachers suggested a remedy for some of these issues would be to provide some form of easily accessible technical support:

> [The] biggest hassle is the higher-end technological support (e.g. time for downloads). Currently we get together to resolve issues. [We are] lucky to have a stock of calculators to re-issue.
>
> [We] need technical trouble-shooters [then named a numeracy adviser].
>
> It would be a good idea to have support in the same way as for laptops and computers. Could have a person for all of [the] district. It doesn't have to be a teacher. [It] could be a technician.

Appropriateness of technology

Some teachers questioned whether the current hand-held CAS calculators were the most appropriate form of technology. They were seen as less reliable than scientific or graphic calculators. One teacher who had come from an IT background saw them as "clunky". Another said:

> [I have] mixed feeling on the technology. [It is] not as flexible as other technology. Technology will continue to change, [so the] motivation to master this calculator is not as high for students.

These ideas have been commented on by Hawthorn (2008). He argues for the use of laptops with CAS software rather than hand-held CAS calculators. Interestingly, he too uses the term “clunky” with respect to them. Two teachers’ comments showed similar sentiments:

> [The CAS calculator is] too fiddly as it is. Laptops etc. is the way to go. Laptops and computers [have] more things like mind maps.

> [I have] mixed feeling on the technology. [It is] not as flexible as other technology.

These views need to be offset against some of the advantages that teachers saw with having powerful, hand-held calculators:

> [The] technology allowed me more freedom.

> I used the calculator to ‘discover’ new principles, and then used them [with the students].

> The CAS technology has made me think more about how and what we teach; especially in terms of the emphasis we place on obtaining skills. Also teaching the topics holistically (especially Algebra and graphs overlapping together). This has impacted my teaching in non-CAS classes too.

Some teachers preferred to use demonstrations for students either using the emulator linked to a data projector, or an Interactive Whiteboard (IAW). One teacher said, “[Using an] emulator means the kids are not focused on the technology.” At least two schools had linked the CAS emulator with the IAW as described in Chapter 3. However, video studies by Zevenbergen and Lerman (2008) found that the IAW were often used for quick introductions, or for teacher directed learning rather than the more exploratory style advocated in the CAS pilot.

The need to have a way to keep pace with technology was touched on by some teachers. This was perhaps the most salient issue rather than concentrating on specific features of a specific technology. The one certainty is change, and this is at its most obvious in technological change. We believe that the issue is more one of exploring effective ways of using currently available technology to enhance teaching, and learning with understanding. One teacher commented on the effect on students of keeping up with technology when they said:

> Students, in an unconscious way, see technology is changing, and the school is keeping up with it. This gives a sense of excitement.

As in the 2005 pilot, teachers commented on the fact that, ultimately, technology is just one tool in the teachers’ arsenal.

Some of the reservations about the “black box” nature of technology that teachers made have also been made in the literature. It can indeed be used as a black box, though some like Buchberger (1990, cited in Cedillo & Kieran, 2003) describe educationally sound ways of using technology as a white box. The classroom itself can be likened to a black box, as pointed out by Black and Wiliam (1998). They state that:

> present [UK] policy seems to treat the classroom as a black box. Certain inputs from the outside are fed in or make demands—pupils, teachers [etc]. Some outputs follow, hopefully pupils who are more knowledgeable and competent …". (p. 1)

This *inputs–outputs* model of the classroom, lacking 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 any understanding of the mathematical concepts. The black box cannot be escaped by merely ignoring technology. What goes on inside the classroom is what matters regardless of whether technology is used or not. 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.

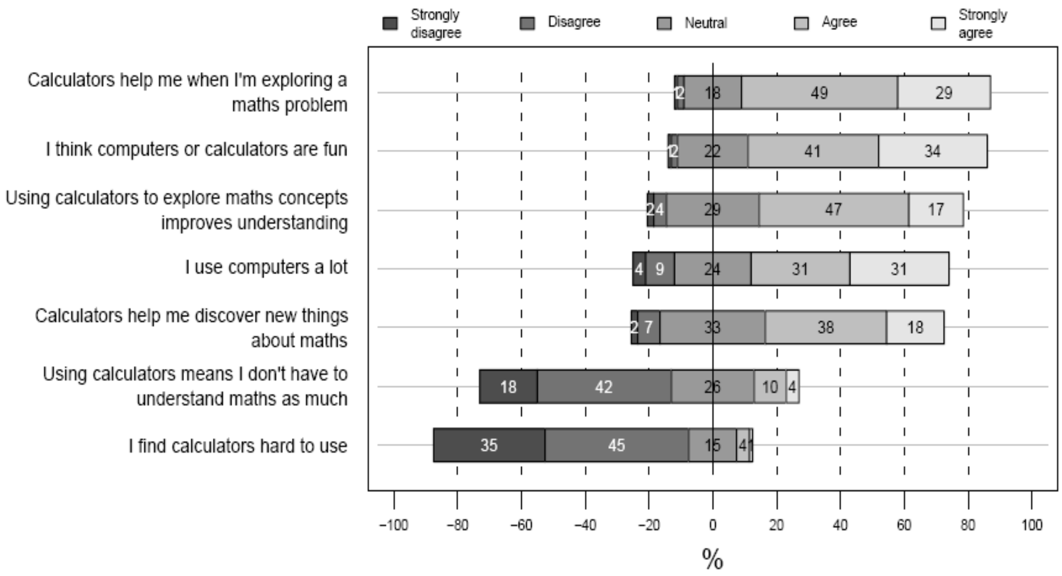
Student attitudes

General attitudes to technology

Responses to the student questionnaire, and to questions asked in the focus groups at the case study schools, were used to gauge student attitudes towards technology. The trends from the questions on technology follow, with selections of student comments added.

All Year 9 students (CAS and control) were asked the same seven questions about attitudes to technology prior to beginning lessons using CAS calculators. The pattern of the baseline results was very similar for both the 2006 and the 2007 cohorts, and for both the CAS and the control groups, with none being statistically significantly different, and so just the results from the 2006 Year 9 CAS class are shown in Figure 36.

Figure 36 **Students' baseline responses about technology (2006 Year 9 CAS)**



For all statements, students were supportive or highly supportive of technology, with between 55 percent and 80 percent reporting positively towards it (the last two statements show support by disagreement with the statement rather than agreement, as the first five do).

- Even though about 80 percent of students thought that calculators helped them when they were exploring a mathematics problem, only about 60 percent thought calculators helped improve mathematics understanding, and a similar percentage disagreed with the statement that they meant students didn't have to understand as much mathematics.
- Three-quarters of students thought computers or calculators were fun, but only just over 60 percent used computers a lot.
- The least supported statement was that calculators help students discover new things about mathematics, with only 56 percent support.

Changes in views of technology

Year 9 CAS students showed significantly greater changes in their attitudes than did the control class students. The control group showed no consistent and statistically significant changes. The CAS students showed a significant change in all but the question on whether they used calculators a lot. In all other cases, the CAS students' changes were towards viewing technology less favourably. We are not sure why this may be, but one possible reason was that this particular calculator was far harder to master than other calculators that junior students are likely to have encountered, and that many students could not easily transfer their PC skills across to them. It seems that the negative effects, whatever they are, have more than outweighed any novelty effect.

Table 34 **Change in attitude towards calculators or computers for the 2006 cohort**

Attitude to calculators or computers	Yr 9 2006 CAS	Yr 9 2006 Control	Yr 10 2007 CAS	Yr 10 2007 Control	Overall CAS	Overall Control
Calculators help with problems	**-0.19**	-0.02	-0.03	-0.03	**-0.22**	-0.06
Computers/calculators are fun	**-0.31**	0.00	-0.09	0.03	**-0.42**	0.01
Calculators help understanding	**-0.22**	0.03	-0.04	0.01	**-0.25**	0.04
I use calculators a lot	0.04	**-0.11**	0.02	**0.27**	0.07	0.18
Calculators help discovery	**-0.32**	0.07	-0.05	-0.10	**-0.36**	-0.04
Need less understanding of maths	**0.21**	**0.17**	**0.17**	0.04	**0.38**	**0.23**
Calculators are hard to use	**0.39**	0.09	0.01	**0.11**	**0.38**	**0.24**

Note: Bolded figures are indicative of significant differences of above 0.1 for one year, and 0.2 for two years.

As can be seen from Table 34, most of the significant changes in attitude occurred with Year 9 students. This was also the case for the 2007 cohort of Year 9 students, though the trends for these were not as strong. However, in Year 10, the students showed only a few changes in their opinions by the end of the year, indicating that their attitudes towards technology had stabilised. The changes were as follows:

- By the end of their first year in the project, the Year 9 CAS students overall were significantly less likely to state that calculators or computers helped their understanding, and were more likely to agree that calculators meant that they didn’t have to understand as much.
- They were less likely to agree that they helped them in their problem solving; or that they helped them discover new things in mathematics.
- Students were also less likely by the end of the year to see calculators as fun, and were far more likely to view calculators as hard to use. This is hardly surprising, as the students had had no prior contact with the CAS calculators, and they are much harder to use than scientific calculators.

The 2006 Year 9 control class students had no significant changes in attitude on any of the questions, except that they were more likely to agree that calculators mean you don’t have to understand as much. This was not replicated in the 2007 control classes, so may be of lesser significance overall.

While a decrease in students’ perceptions about technology was generally the case, there was a significant number of students who were well disposed towards technology after their involvement in the CAS pilot.

Even though the CAS students were less positive towards technology, this must be interpreted in light of the generally positive attitudes shown in the baseline data (Figure 36), and that CAS students were still largely positive by the end of Year 9, only somewhat less so.

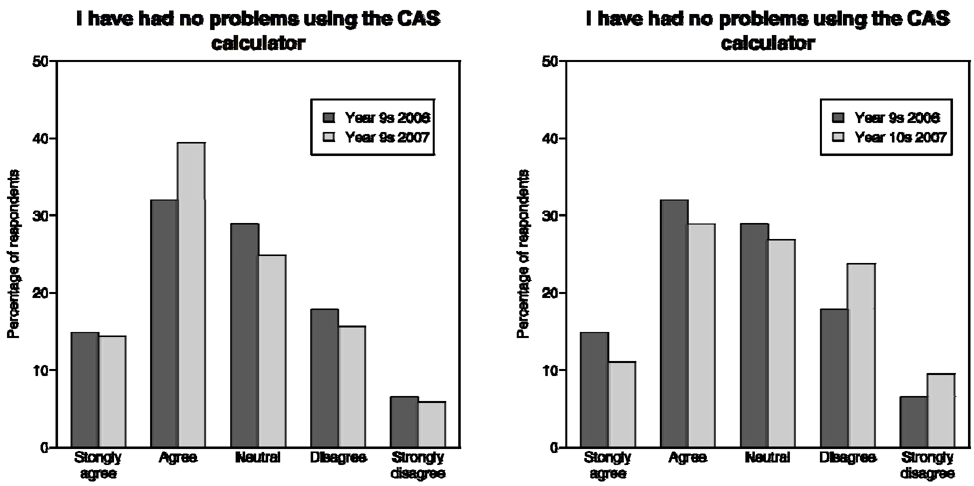
There were no meaningful trends between student ability and any of these questions about technology.

Attitudes to CAS calculators

All students who were part of the CAS pilot answered questions about their experiences using the CAS calculator. Graphs of these are included as well as a selection of student comments from the student focus groups at the case study schools. The responses to these showed a more positive attitude towards technology than the previous section implies. This is displayed on the two graphs in Figure 37. The left-hand one compares the two Year 9 cohorts, while the right-hand one compares the 2006 cohort as Year 9s in 2006 and the same students who were Year 10s in 2007.

Ease of use

Figure 37 **Students' views on whether they have had no problems using CAS calculators**



Both Year 9 cohorts and the Year 10 CAS students showed similar patterns, and this tended towards having relatively few problems using the CAS calculators. There were, however, statistically significant differences between the three cohorts. The 2007 Year 10 students were less likely to agree (that they had no problems) than the 2006 or the 2007 Year 9 students.[19]

The later two groups were barely significantly different[20] with slightly more of the 2006 group reporting problems. Just why more Year 10s reported problems is unclear, though students did comment that they were using them less in Year 10 than in Year 9.

Some comments from students follow:

> Really good calculator but [I need to] understand what comes next. Settings is an issue.

[19] Year 9 2006 vs Year 10 2007 Chi-squared = 19.11, 4 d.f., $p < 0.0001$
Year 9 2007 vs Year 10 2007 Chi-squared = 32.06, 4 d.f., $p = 0.0008$

[20] Chi-squared = 9.60, 4 d.f., $p = 0.0477$

> It was hard at first, then simple once I got to know it.
>
> Yes, but the CAS calc is slower for easy stuff.
>
> Trying to learn [how to do] graphs was hard at first.
>
> [I] sometimes forget [how to do it on the CAS] and get the wrong answers.
>
> Easy, but [I] don't know how to find everything.
>
> [It is] hard to use for algebra because you have to remember lots of menus.
>
> [I] know how to use it, but some applets cause me problems.

Some of the learning activities for students were based on applets made available by one of the PD providers. While these were educationally sound, teachers and students needed to learn how to "drive" these applets, which was not always trivial. Some students found this a hurdle. It may perhaps be more useful to provide PD to help teachers produce their own applets, and for them to share these with each other.

Our classroom observations indicated that there can still be barriers to learning and using the CAS calculators. On numbers of occasions we have observed the same student using both the CAS calculator and a scientific calculator. One student said, "I enjoy it for graphing but it is quicker on a scientific calculator." Students did not always find it easy to use the CAS for number operations. Another commented on the problems they had with the way the CAS represented its numerical results, because they had "[a] problem with dividing—it can't use fractions". Yet another commented that "the CAS calculator is slower for easy stuff". Numbers of students in many classes did not always have their CAS calculators with them, which sometimes led to classroom organisational issues for teachers.

This strongly contrasted with one Year 11 class where virtually all the students had brought their CAS calculators to class. Many of these students had intricately decorated their calculators in neat geometric patterns or had florid naming on them. This indicated a deep identification and personalisation of the calculator which is surely a desirable outcome.

This brings up the issue of the use of CAS calculators in other subject areas. It seems unreasonable for students to have to master multiple technologies. A teacher reflected that "Individual ownership of CAS implies they should be acceptable in other subjects."

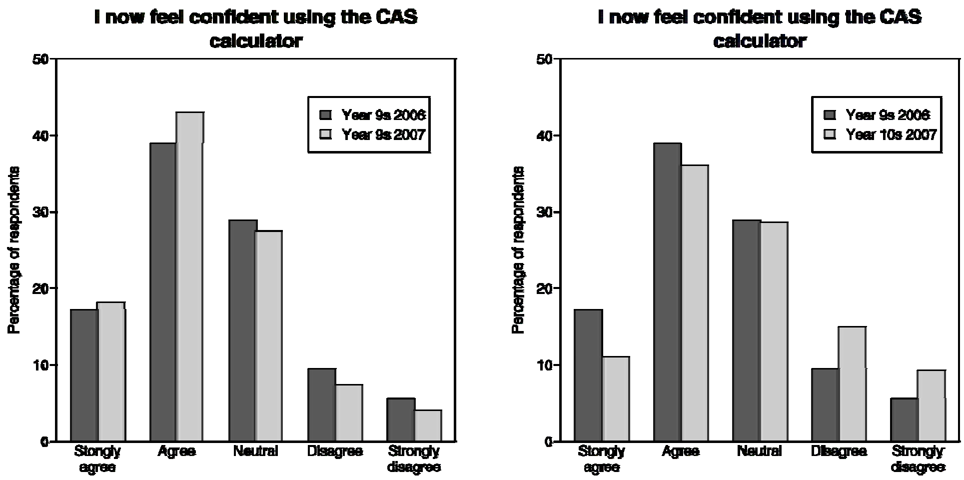
Confidence of use

Confidence in using the CAS calculator has grown, as shown in Figure 38. The 2006 and the 2007 Year 9 students followed similar patterns of current confidence. The 2007 Year 10 students felt significantly more confident than either of the Year 9 groups.[21]

---

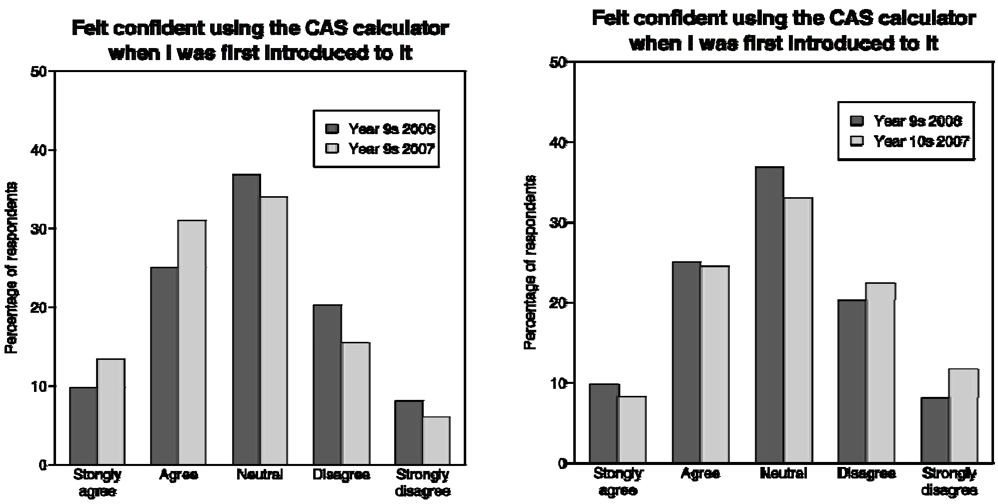
[21] Year 9 2006 vs Year 10 2007 Chi-squared = 47.40, 4 d.f., $p < 0.0001$
Year 9 2007 vs Year 10 2007 Chi-squared = 30.60, 4 d.f., $p < 0.0001$

Figure 38 **Students' current confidence in using the CAS calculators**



The 2007 Year 9 students had a small but significantly higher confidence when they started than the 2006 Year 9 students.[22] The Year 10 students of 2007 were only marginally different in their response from the one they made in 2006 as Year 9s.

Figure 39 **Students' initial confidence in using the CAS calculators**



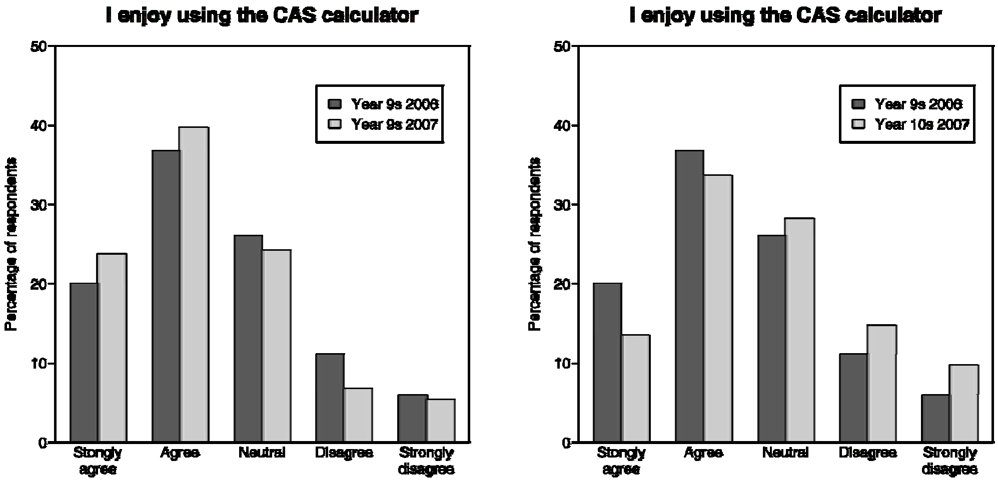
> I'm [only] kind of confident because we don't use them enough.
>
> The unknown is revealed—understand how to use them. Can use 'solve' to get the answer? Gets me an 'Excellent'. However, too many buttons—three 'Enter' buttons.
>
> [I'm] not overly confident but I'm still learning stuff.

[22] Chi-squared = 17.09,1 4 d.f., p = 0.0019

Enjoyment of use

Students generally enjoyed using the CAS calculator. The 2007 Year 9 students were significantly more likely to report that they enjoyed the CAS than the 2006 Year 9s.[23] The 2007 Year 10 students reported significantly less enjoyment using the CAS than they did when they were Year 9 students in 2006.[24] This latter effect is by far the stronger, showing that the novelty effect wears off for students over time.

Figure 40 **Students' enjoyment using the CAS calculators**



There were no meaningful trends between student ability and: problems they had using CAS; enjoyment of CAS calculators; or their confidence in using them.

Some final student comments about enjoying or disliking the CAS calculators follow:

> Yes [I like it], because there are more things you can do.
>
> [I] like technology and gadgets. If I get bored [there are] other games.
>
> Frustrated. It doesn't do what you tell it to do.
>
> I'd rather just do it myself.

Key points of Chapter 8

Teachers in the pilot supported the concept of using technology in the classroom. This was equally the case before and after the pilot project. The most common factors influencing them using technology were its widespread current and its prospective future use. Their support for technology was similar to those of their peers in a wider, random sample of nearly 500 mathematics teachers (as shown in Thomas et al., 2007).

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[23] Chi-squared = 11.294, 4 d.f., $p = 0.0235$

[24] Chi-squared = 25.150, 4 d.f., $p < 0.0001$

Teachers had a range of skills, skill levels, and levels of classroom usage in a number of different technologies. This study shows that upskilling teachers was effective at impacting uptake of technology, as the classroom use of technologies roughly mirrored levels of teacher expertise. Teachers showed substantial increases in their skill levels in, and their classroom use of CAS; and their skills and use of data projectors with calculators.

While teachers' assessment of actual usefulness of CAS was lower than their general expectations, a notable exception was its role in Algebra, where they saw that it impacted positively, and was most useful in this strand. Teachers had expected CAS to be of most use in Algebra, and of least use in Measurement. They did, however, use it in differing levels in all strands of mathematics. This is consistent with the findings in Chapters 5 and 6, which showed that teachers saw student achievement and attitudes being most strongly influenced in Algebra.

Technology has a number of affordances as well as constraints to its use. Each new technology has its own issues, but the wider question is how best to utilise the advantages and minimise the disadvantages of technology in a time of technological change.

- The most common affordances mentioned were that the CAS technology: allows exploration; enhances student motivation; enhances learning; aids some learning preferences; and allows better or different activities.
- Constraints included the cost and resourcing issues, but also technological problems such as: new operating systems; new versions of the calculator; and technical issues with current calculators were mentioned by teachers. Technical assistance such as that given to computers in schools was suggested as a way to remediate this.

At the start of the project, students were largely positive towards technology and its potential to influence their mathematical learning. There was, however, a wide range of opinions.

- Students tended to be confident in using the CAS calculators, with Year 10 students being more confident than Year 9 students. Some students, however, lacked confidence.
- Students typically enjoyed using CAS, though Year 10 students showed lower levels of enjoyment than Year 9 students. Again, some students did not enjoy using them at all.
- Students had relatively few problems using CAS, though there were some students who reported many problems. Year 10 CAS students reported more problems than the Year 9 students. This may well be because the CAS was used less in Year 10, and students could not always recall how to use it.
- Students' attitudes towards CAS typically became significantly less positive over the course of Year 9, whereas control class students stayed static in their views. Student views towards technology stayed largely static over the course of Year 10 for CAS and control class students. This is somewhat paradoxical given the generally positive attitudes towards CAS. There are a number of possible reasons for this. It may be that the CAS required a steep learning curve, and was not as intuitive as other calculators the students had encountered and this had influenced their views on technology in general, or that the strong focus on technology (which

was much higher than usual) had negatively affected attitudes. For others, it may have been because they had been encountering some frustration with the calculators.

9. Assessment of learning, for learning

One of the questions that this evaluation addresses is, “Do current forms of assessment need to change, and if so, in what ways?”

The teachers of the CAS classes and the students in the focus groups were asked their views on assessment issues. The pilot project in 2005, 2006, and 2007 looked at the junior secondary school (Year 9 and Year 10 students only), so that any effects of NCEA examinations on classroom practice would be kept to a minimum. By 2007, however, the 2005 cohort of Year 9 students took the Level 1 NCEA. In view of this, questions about summative assessment also need to address lower stakes school-based assessment, as well as high-stakes national assessment.

The following research question is addressed in this chapter:

- *Research question 8*: What are the appropriate ways to assess student learning when CAS technology is available?

Summary

Teachers reported that their approach to assessment had not changed as a result of the CAS pilot. They did, however, acknowledge that assessment questions (in particular high-stakes summative assessment questions) needed to change, to ensure that the questions fitted the exploratory, understanding-based teaching approach endorsed by the CAS pilot, and also to make sure that students were neither advantaged nor disadvantaged by having a CAS calculator in high-stakes NCEA assessments. 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.

Teachers were divided in their opinions of the draft NCEA assessment exemplars. Some thought that they were aimed at the more able students, while others saw them as being of comparable difficulty, but of a different style. Teachers agreed that it was imperative to get the draft material sooner, so they could adequately prepare their students for their Level 1 (and also Levels 2 and 3) NCEA assessments. Year 10 students were split as to whether they were confident or not at sitting the CAS-enabled NCEA exams. Many schools were planning to have just one of the two CAS pilot classes sitting the Level 1 NCEA exams in 2008. Some envisaged that both CAS classes would sit them, and others thought that neither class would.

During classroom observations, we observed a relatively high level of formative assessment. Students and teachers also reported that this type of assessment was taking place regularly in their classrooms. The introduction of the CAS had supported this, as it created a need for teachers to know where there students were at with both the CAS calculator and their mathematics understanding. Giving feedback on the two aspects was one of the reasons for the high frequency of formative practices we observed.

The following sections give the detailed findings.

Teacher views

Teachers' responses about assessment are largely based on their interviews. As can be seen in Table 35, the most common response from teachers to the follow-up question said "My approach to assessment has changed as a result of using CAS in the classroom" was neutral. While somewhat more teachers agreed with this statement than disagreed, this was not statistically significant. This is congruent with the findings in Chapter 4 on changes in teacher practices that relate to assessment. Figures 12 and 13 show that the initial frequency of practice was very similar to the frequency of practice after the CAS project. This was true in both teachers' CAS and non-CAS classes. In our 2005 study (Neill & Maguire, 2006b, pp. 63–4), teachers reported a significant drop in the levels of their formative assessment. This was no longer evident in the 2006–2007 study.

Table 35 **Teachers' response to changes in their approach to assessment**

Response	Number	Percentage
Strongly agree	3	4
Agree	23	30
Neutral	34	45
Disagree	11	14
Strongly disagree	5	7
TOTAL	**76**	**100**

Different questions needed

Only a few teachers made assessment-related comments on the questionnaire. The main theme was that the assessment questions needed to be different and needed to reflect and test student understanding. During their interviews, a number of teachers picked up this same point as they reflected upon assessment, or the draft material for Level 1 CAS-enabled assessment:

> We will have to change the way we assess. I have always tried to teach with understanding, therefore I wouldn't like exams [to be] too different. Both need deeper thinking [to be] revealed.

> Well done—[the draft NCEA questions are] technology neutral.

> We need to give questions in a different way; for example, "Given the graph, describe the tangent", or "Replace the co-efficient with a letter". This is the reverse of the usual question. Now this is the norm in the US.

The latter comment was made by a teacher who had been heavily involved in setting appropriate questions for technology-enabled examinations at the tertiary level. Utilising such expertise is crucial, as there are very few people in New Zealand with this expertise.

If there is to be one standard for all with a single exam, questions will need to be CAS-independent. This means that the questions should neither advantage nor disadvantage students who have, or do not have, a CAS calculator with them in the examination. Already, some questions have been drafted that are attempting to move in this direction. There is a body of literature that discusses CAS-resistant (or technology-resistant) questions. Many authors, including Brown (2001), Forbes (2001), Leigh-Lancaster and Stephens (2001), and Saunders (2003) have written on this subject. An implication of this is that students need to be prepared for the new style of NCEA assessment. Several teachers reflected upon this:

> Students need the skills for sitting the new style of question. Students need to be more clear about variables etc.

> There are quite stark differences in the goals we set for our students between the draft and current assessment. The draft is more holistic and requires changes in the way we teach subjects like algebra and graphs in particular.

> It did require a build up to practise that type of question.

Some of the teachers had developed their own school-based assessments that were CAS-independent. Teachers commented in a similar vein to the 2005 teachers, that it takes considerable time and expertise to develop these questions.

There are technical issues that need to be addressed as to the comparability of CAS-enabled and non-CAS-enabled exams. Using the longitudinal student achievement data from the pilot could be a direct way of comparing the two papers. Producing a CAS-independent paper would ideally involve testing the instrument with students of known ability, with some having access to CAS calculators, and some not.

The NCEA structure of achieved, merit, excellence may start to resolve some of these issues. To gain merit or excellence, students need to be able to demonstrate higher order thinking or deeper understanding with some explanation. Just a solution may be acceptable for achieved at Level 1 of NCEA, but this could well be a problem at Levels 2 and 3. Skill-based questions can be done very quickly. Students will just need to write down the answer. Students may, however, have to record how they got their answers, and not just "press a button". As one teacher said, "People will teach to the CAS-enabled task", while a student said that "you should have to show how you did it [not just push buttons]".

Difficulty of draft Level 1 NCEA material

Draft examination questions were made available in late 2006 by the New Zealand Qualifications Authority (NZQA), and more of these became available on its website in mid-2007. Many teachers in the pilot were not aware of this material. Several teachers who had seen the draft material commented on it. They seemed to be roughly equally divided into two different groups. One group saw the material as being of a comparable level of difficulty, while the other saw the material as being harder.

Comments from the former group included:

> [I] really liked [the] 2006 material. They are asking [questions where] the level of difficulty is comparable. The material is not different, but just a different approach.
>
> With CAS calculators the effect has been neutral in [our school] exams.
>
> [The recent ones] cover the standard adequately and the level of them is OK. Some of the ‘achieved’ questions seem almost trivial for better students. The 2006 material was also useful. [A] good base to develop questions from.
>
> Yeah, they’ll be just as good as other years. Some of the questions they will have been exposed to since Year 9 even if they haven’t seen them in exams.

Reservations included comments about the questions either being more at the merit level, or not being accessible to weaker students. This would have the effect of restricting the accessibility of the exams to students who could only realistically aim at the achieved level:

> Some questions looked interesting and exciting but harder. OK for merit questions but [not for] achieved.
>
> Testing understanding may lead to it being harder, at least to start with. Able students are OK. [I have] concerns about the weaker students and whether they would do better in the traditional NCEA.
>
> [They are] fine for students at that level of thinking. At this school, students are not at that level—even the top kids are struggling. (This school was not planning to do the CAS-enabled NCEA Level 1 exam in 2008.)

Another reservation was that writing questions that validly measure students’ understanding is not easy to do:

> Current measures of excellence don’t measure understanding.

Timeliness of NCEA material

Several teachers would have liked to have seen the draft material somewhat earlier. This was true not only at Level 1, but also at Levels 2 and 3:

> Still hard to pick Year 11 directions. A bit worrying that we don’t know L2 and L3 standards and the effect of the new curriculum. Six months before [the NCEA exams] is too short a time frame. Need longer term planning.

> Getting the exemplars late was an issue as [we] did not know what questions were going to look like so [it was] hard to give examples in class. [We] had to come up with [our] own questions.

> [There is] trepidation from both students and teachers. A lot of unknowns—[we] have only been able to look at one example of a CAS paper whereas [students and teachers] can view plenty of past exam papers for non-CAS exams.

Appropriateness for external examinations

Some teachers queried the place of calculators in external exams. Some suggested that they were better suited to internal assessments, some saw them as being clumsy to use in exams compared with scientific calculators, and others queried whether the CAS-enabled paper would be comparable to the other paper.

Of the 2005 pilot schools, two indicated that CAS students would be split amongst the Year 11 classes and would make individual choices about sitting the CAS-enabled examination. One school indicated that they had one CAS class that would sit the CAS-enabled paper, and the other would sit the traditional paper. The remaining three suggested that both classes would sit the CAS paper. This means that only about the equivalent of six to seven of the 12 classes that started the pilot would have sat the 2007 CAS-enabled paper.

Of the schools that had begun the project in 2006, the most common anticipated option for schools was to have just one CAS class who would sit that paper, with the other class being split up among other classes who would sit the non-CAS-enabled exam. Up to five schools were seriously considering having none of their students sitting the CAS-enabled exam. The reasons for this varied. For one school, it was reservations about the ability level of their students; for another it was class organisational issues; for another the 2006 cohort had too many disruptions but the 2007 cohort had a better chance of sitting it; and for one school, many of their more able CAS students were sitting Cambridge exams. The fifth school was undecided.

Cross-curricula or internal mathematics standards use of CAS

Another issue to be addressed is whether the CAS technology can be used in the assessment of other subjects: science, economics, and geography in particular. Allied to this are issues as to whether CAS can be used in mathematics internal standards that have not been a focus of the CAS PD; for example measurement, and statistics. Preferably, students should be able to use just the one calculator in the classroom, and in their low-stakes and high-stakes internal and external assessments. Having just the one calculator throughout the whole of a student's secondary schooling that can be used in all subjects would be the ideal.

Formative and summative assessment

There is a need to address both formative and summative assessment. The former aims to enable effective teaching and learning to take place, while the latter measures the learning that has actually occurred.

There is an increasing emphasis on the fundamental role that formative assessment plays in effective teaching and learning. Authors such as Black and Wiliam (1998), and Crooks (2001), plus many others, have written on this subject. Teachers gain from a formative approach to classroom assessment, as it helps them gain a more accurate picture of students' understandings and misunderstandings. This allows them to readjust their teaching to the needs of their particular students, and gives them pointers to their next steps in learning. Formative assessment that includes quality feedback to students enables them to refocus their learning on to areas that are relevant to their own needs, and allows specific goal setting. Our 2005 study (Neill & Maguire, 2006b, p. 65), noted:

> Summative assessment must not lose sight of the fact that it also influences teaching and learning. It helps define what happens in the classroom. This means that 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.

High-stakes assessment often acts as the driver of teaching and learning, and so it needs to reflect the values that educators wish to emphasise. Summative assessment should not run counter to formative assessment. While summative assessment retains a more output-based focus, whereas formative assessment is more process-based, the two should be part of the same continuum and should be assessing to the same underlying construct of mathematical knowledge, skills, and understandings. If exploration and understanding are to be the focuses of teaching and learning, then they should be reflected in high-stakes summative assessment.

The baseline questionnaire asked teachers to specify what formative and summative assessment strategies they employed. The responses of the 69 teachers who responded are summarised below.

Table 36 **Formative and summative assessment techniques reported by teachers**

Response	Formative		Summative	
	Frequency of responses	Percentage of teachers[1]	Frequency of responses	Percentage of teachers[1]
General formative techniques				
Observations	21	30%	1	1%
Discussions/questioning	27	39%	1	1%
Giving feedback	8	12%	0	0%
Peer or self-assessment	6	9%	1	1%
Informal student work				
Lesson starter questions	24	35%	1	1%
Games or competitions	2	3%	0	0%
Checking homework or classwork	20	29%	6	9%
Quizzes	13	19%	0	0%
Formative tests				
Pre-tests	11	16%	1	1%
Mid-topic tests	8	12%	2	3%
Formal (summative) testing				
Standardised tests	4	6%	5	7%
Topic tests	14	20%	56	81%
School wide tests or exams	2	3%	26	38%
Practise for summative assessment	5	7%	3	4%
National assessments	1	1%	1	1%
Projects, practical tasks, group presentations	4	6%	15	22%
TOTAL	**170**	**69**	**118**	**69**

[1] The percentages are of the 69 teachers. These sum to over 100% as teachers gave multiple responses.

Largely speaking, teachers could clearly distinguish between the two types of assessment, with the possible exceptions of topic tests and practise for summative assessments. Both of these probably lie in the summative domain. Standardised tests or projects etc. may fulfil either role.

The main formative techniques used were observations, discussions, or questioning. Rather fewer teachers mentioned the role of feedback, even though the literature sees its role as pivotal (for example, Crooks, 1988).

The strong influence of formative assessment was borne out by the classroom observations, where many of the hallmarks of formative assessment were observed to be occurring, especially the informal types of assessment. High levels of student–teacher interaction were observed. Teachers were roving the classroom, questioning students about their understanding, and giving them feedback on their learning. Teachers were also listening to students explaining ideas to each other, either in pairs, groups, or to the whole class. This again helped the teachers form views of the students' current skills and understanding.

By far the most commonly used summative technique was topic-based tests. Over 80 percent of teachers mentioned them, and school wide assessments or exams were the next most common. The only other common summative technique was the use of either projects, assignments, practical tasks, or group presentations.

Student views

Students in the Year 10 focus groups at seven of the eight case study schools were asked how confident they were about using the CAS calculators in the NCEA Level 1 exam that they would be sitting in 2008. The students responded on a continuum, and a number of open-ended responses were recorded. There was a large and reasonably even spread from those who were highly confident, through to those who were not confident at all. Twenty-four students were towards the confident end of the scale, three were in the middle, and 19 were towards the nonconfident end. There was thus a small but not statistically significant preponderance of those who were at the confident end of the scale. Students were largely confident at three of the schools, while at three other schools they were not confident. At the seventh school, they were reasonably evenly split as to their level of confidence. Comments from students follow:

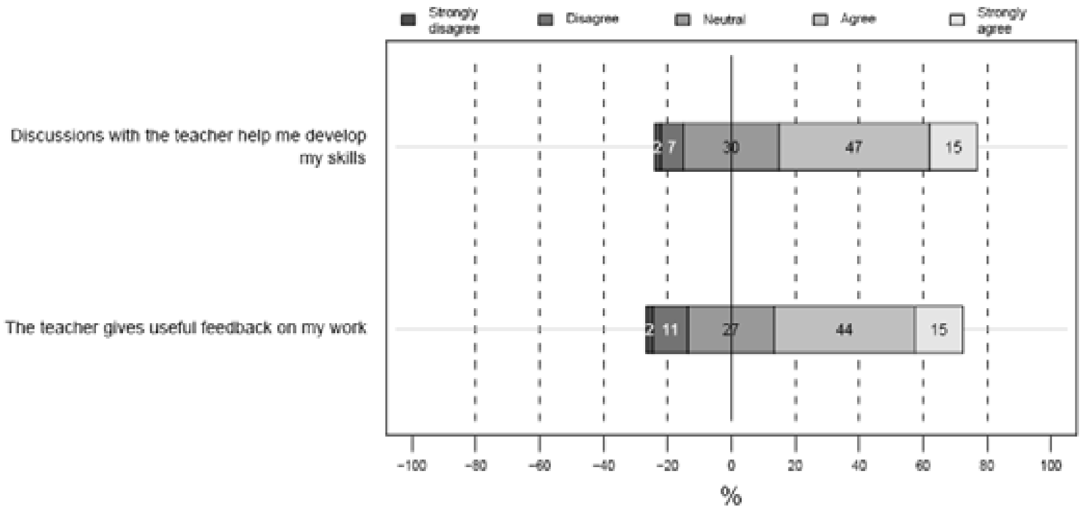
Table 37 **Student confidence at sitting NCEA Level 1 CAS-enabled paper**

Confident students	Neutral students	Nonconfident students
I like the CAS and know how to use it.	It's hard to use and [I] could do it by hand [more easily].	[I have] issues of remembering how to do an applet.
Yes. [I'm more confident] with CAS than without it.	It is time consuming [in the exam].	[It would be OK] if we learnt it lots and teachers did a lot of CAS.
I know how to use it and for which question.	It's confusing—get something muddled and [you] get the wrong answer.	[I] can work it out in head and confirm with calculator.
[It's] easier than normal calculators. [You can] use graphs to help you.	Because we are the first people to do this it is going to be hard.	
I'm fairly confident, but what if it goes wrong. Need some spare calculators available.	[I] don't know all the functions.	

Students were also asked two questions in the questionnaire about assessment issues, both of which come under the umbrella of formative assessment. The results for the 2006 and 2007 Year

9 students were very similar as were the responses from CAS and control classes, and so just the 2006 Year 9 CAS data are displayed below.

Figure 41 **Baseline responses to assessment questions (2006 Year 9 CAS)**

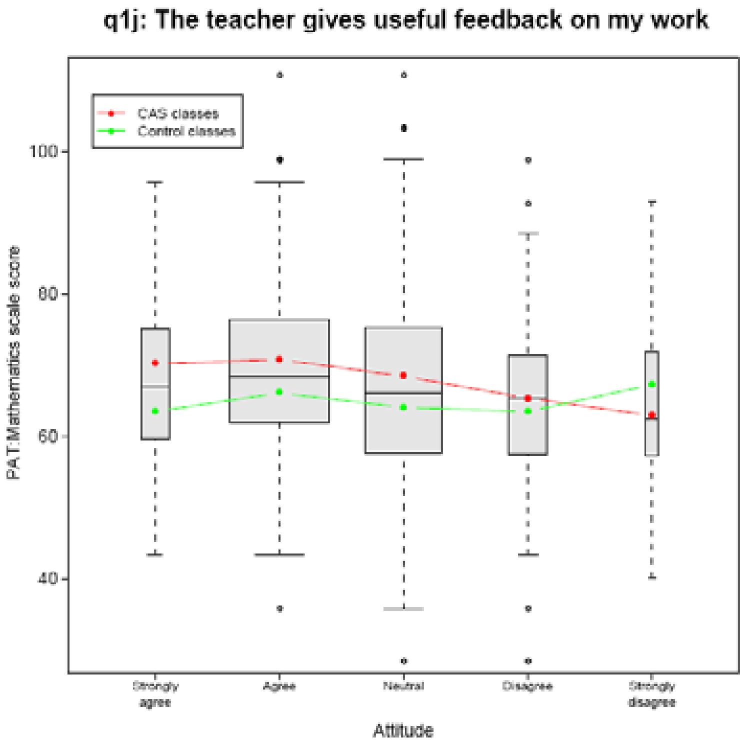


Overall, students reported positively that discussions with the teacher were helpful, and that they received feedback from the teacher, with about 60 percent agreeing or strongly agreeing with each statement, and only 10 percent disagreeing. Students were far more likely to report feedback than teachers, where only 12 percent mentioned it (see Table 36). CAS and control classes followed largely similar patterns. The only difference that was statistically significant was that CAS students were less likely to strongly agree, but more likely to agree that discussions with their teacher had been helpful than control students were. The total number of students who were in agreement (i.e. agree or strongly agree) was almost the same, which indicates that this statistical significance is of minimal effect.

Year 9 students in control classes were significantly less likely to agree or strongly agree with the two statements at the end of the year than they were at the beginning of the year, whereas the CAS classes stayed roughly the same. This indicates that formative assessment was more a feature of the CAS classes. However, in Year 10, there was a drop in feedback in the CAS classes.

There was no meaningful relationship between student ability and the two questions on assessment issues shown in Figure 41. The only exception was that the more able Year 10 CAS students were more likely to agree that they received useful feedback (and to a lesser extent saw discussions with the teacher as useful) than the weaker students. In neither case was there an effect in the control classrooms (see Figure 42). The 2007 cohort showed this same effect only for the discussions question, but not for feedback.

Figure 42 **Relationship between student ability and assessment practices—2007 Year 10 cohort**



Key points of Chapter 9

To support ongoing use of, and a full roll-out of CAS, this evaluation suggests a number of assessment issues. The following are aspects around NCEA that that could be considered:

- For the CAS pedagogical approach to become embedded, it would be ideal for assessment resources, including high-stakes assessments, to be congruent with, and encourage the use of, exploration to gain understanding in mathematics.
- A different style of question is more appropriate for summative assessment purposes, especially in the external NCEA examinations.
- A larger range of exemplars of assessment materials would be highly valuable to teachers, and these could be made available in a more timely way than at present.
- Some teachers were concerned that the draft assessment materials were too difficult for many students, while others saw them as of comparable difficulty, but of a different nature.
- Use of CAS in internal NCEA assessments, and in NCEA assessments in other subjects, needs consideration. It is demanding on students to have to be competent in more than one calculator.
- The CAS calculators were somewhat prone to malfunctioning, and it may be that spare ones being made available in external examinations may alleviate this concern.

After their involvement in the pilot, teachers often reported changes in their approach to assessment. In particular, there were numbers of issues around appropriate summative assessment practices. Some teachers had reservations about the appropriateness of CAS calculators in external assessments, though others were happy about this. Students were split on their level of confidence about sitting Level 1 NCEA CAS-enabled assessments.

Pilot schools had experimented with a number of styles of summative assessment for their school wide assessments. Topic tests were by far the most common summative assessment strategy used by CAS teachers. Some schools were producing CAS-independent questions for their internal examinations. Many schools in the pilot were opting for just one CAS class to sit the Level 1 NCEA in 2008, with the other class split between other Year 11 classes. The ability to choose to opt out or opt in to the CAS-enabled paper was an issue in many schools.

We observed high levels of formative assessment in CAS classrooms, even though teachers did not necessarily perceive this to be the case. It may be that their perception of formative assessment is overly formal. While they reported no increase in formative assessment, teachers mentioned a wide range of formative assessment strategies that they were using, and students reacted positively to these. Control class students reported a drop in the levels of formative assessment, but these stayed constant in CAS classes.

10. Into the future—sustaining the CAS initiative

In this chapter, we discuss a number of dimensions for sustainability of the project. The responses for this have all come from interviews with teachers who were involved with the pilot project.

This section addresses the research question:

- *Research question 5:* What issues will need to be addressed and what support will be needed to be given to teachers to enable the effective and sustained use of CAS technology?

Summary

To maximise the usefulness and uptake of the CAS approach, this study suggests some conditions need to be in place if a full roll-out is to take place. Parents, mathematics teachers, other subject teachers, and the wider mathematics community may need some convincing of the value of this approach. This suggests it would be helpful to have ongoing education of stakeholders. This education could communicate that the main driver for the project is a constructivist pedagogy that utilises the affordances that technology offers. Technology is not the driver, but neither can technological change be ignored.

Feedback from participants in the pilot indicates that teachers saw a need for ongoing PD, both for teachers who have been involved in the pilot and for those who have yet to experience CAS PD. To ensure any full roll-out is well managed, it would be of benefit to explore the most appropriate PD model. What has worked in the environment of a pilot may not necessarily be the most suitable. Using local skills would give relevance and credibility to the PD, though expecting teachers be the providers of PD on top of their other commitments was not seen as reasonable. Releasing and training local teachers as facilitators is one option worth exploring, in the same way that the model has been used successfully in the Numeracy Development Projects.

To support a full roll-out, teachers would also require quality classroom resources, and well-considered sequences of teaching units that support the pedagogical approach of CAS. Pilot teachers had difficulty finding time to produce these resources themselves. This points to the need for a system of developing and sharing quality resources.

The costs of the technology will be one barrier to uptake in many schools. Staff and student turnover is another hurdle that will remain until the CAS-based approach to mathematics education is in place in most schools.

The need for a coherent direction that utilises technology effectively as a tool for the teaching and learning of mathematics suggests that one generic device could be adopted. However, the question as to whether CAS calculators are the best way forward needs to be asked. This question may need to be regularly re-evaluated given the ongoing advances in technologies. Many of the pedagogical approaches used in the CAS pilot may well continue to be pertinent to the future use of technologies in mathematics classrooms.

The following sections give the detailed findings.

Wider acceptance and uptake

Without a wide acceptance of the CAS project and its values and teaching practices, uptake will be limited. The main issue here seems to be buy-in by parents and teachers, and this is the focus of the discussion that follows. There was, however, a handful of comments on the role of schools' leadership. One teacher stated that there "needs [to be] someone in school leadership promoting this pedagogical approach". The ongoing commitment and support of the Ministry of Education and New Zealand Qualifications Authority is also vital.

Teachers and educators

Some teachers in the pilot were asked how the wider education community would react to a wider roll-out of the CAS initiative. This included how they thought that other mathematics teachers, teachers in other subject areas, and the wider mathematics community would react to CAS use in schools.

Mathematics teachers

There was a mix of responses about how mathematics teachers who had not been actively involved in the pilot might react. Relatively more teachers aired reservations than in the 2005 pilot. Many positive comments were made, especially about their acceptance amongst other teachers in schools that were involved with the pilot:

> Here at school, those not involved have mixed feelings. They see the good, [but] have reservations. More widely [there are] reservations on pedagogy, organisation, and financial [issues] leading to negative views.
>
> Middle of the road—younger teachers [are] happier to try, older teachers are more reluctant.

There were, of course, reservations about teachers in schools that had not been part of the pilot, and these may be more pronounced than those who had been involved. Pilot teachers commented on the lack of knowledge about the project from others in the mathematics community. “The level of ignorance [about CAS] appals me”, “[There are] people out there who don’t know what they can do”, and “The negative reactions are from those who haven’t been exposed to the calculators. It is a valid fear” were some of the comments. Potential barriers included: time; costs; reservations on the pedagogy; teachers’ mathematics knowledge; and fears that technology limits understanding:

> Other teachers are not that keen or positive about CAS. Some [other schools] realise it’s going to happen so are getting on board.
>
> A real problem. Maths teachers are not strong [in maths], and this might make it worse. [They] need a good understanding of maths to use them with meaning.
>
> [There is a] fear that technology will replace thinking.
>
> Some will be resistant. Teachers are flexible but can put up barriers because of difficulties with time etc.

Other subject areas

Mixed reactions from teachers in other disciplines have been reported in the pilot schools. In some schools, the attitudes are very positive, though in others there are mixed or negative reactions as this quote shows:

> [Reactions are] positive in general. However, I tried to show a science teacher the potential of using the calculators with data logging but got negative feedback—[they were] not open to the possibilities.

The acceptance and use of the CAS calculator across other curriculum areas needs to be addressed, both from a teaching and from an assessment perspective.

Wider mathematics community

CAS teachers perceived that there were also issues of acceptance in the wider mathematics community. Their place in interschool competitions, and their acceptance at universities were areas of concern raised by teachers:

> CAS are banned in inter-school competitions. There is a perception that CAS will tell all the answers.
>
> Universities are not ready for CAS yet.
>
> There are still concerns about it at the tertiary level, but I think we have embraced it and are paving the way for the new technology.

Parents

Teachers of the 2006 and 2007 students made fewer comments about parental views than they did in the 2005 pilot, especially at Year 10 or Year 11. A teacher at one school reported that, "one parent asked for their child to be excused from the programme. There must be people who see them [calculators] as a dumbing down." On the other hand, some schools had reported no negative comments, and one student had even told their teacher that "My Dad really likes the calculator."

Some schools thought that cost would be a significant issue for parents. However, one school had offered CAS calculators to students at a discounted rate, and over 30 had bought them. This school was concerned, however, that these students got value for their money by having the calculators utilised in areas of their schooling other than mathematics.

As in the 2005 schools, many teachers had made CAS the major focus of their initial meet-the-teacher evening or parent interviews. One teacher reported that parents had asked, "Why are you using CAS because they are not using their brain?", and the teacher had then explained how it was being used for mathematical explorations.

Some schools had sent written information home to parents or included it in the school newsletters. One school shared that they had "[done] a page in the school website with photos and sent a letter home".

Students in the focus groups largely saw their parents as being neutral towards the CAS calculators, with many saying that their parents either "don't know" or "couldn't care". A few reported positive attitudes from their parents, while on the other hand, one stated that, "My parents don't like it because it means I'm not thinking."

Changing perceptions

In light of these comments, and the cautious, even negative, views on the CAS pilot, there is a need to educate people about the educative potential of the CAS approach.

Firstly, it needs to be made clear that the major driver in the programme is pedagogy, not technology. The major thrust of the pilot it to adopt a more investigative and constructivist approach to learning. This may itself be debated by some, but the separation between the roles of pedagogy and of technology is vital.

It is also important to put the record straight about the use of the terminology "CAS". The calculators in the pilot are essentially just the next generation of graphics calculators. One of their many features is CAS (Computer Algebraic Systems), but this is not the only one employed by teachers, even when teaching algebra. Indeed, the calculators have a spreadsheet and other capabilities, but calling them "Spreadsheet Calculators" would be a misnomer. "CAS", too, is a misnomer, and perhaps another descriptor of the initiative should be employed.

Technology will continue to change, and the project needs to be understood it the light of how teaching will need to adapt alongside technological change. We've moved though discourse, pencil and paper, logarithmic tables, slide rule, arithmetic and scientific calculators, to computers. "How could and should these impact upon teaching and learning?" is the question.

Ongoing support for teachers

This section covers a number of issues that teachers who were already in the CAS project saw as being vital to the impact and longevity of the initiative. Many of these related to resourcing that they themselves needed to maintain their momentum in this new style of teaching, but also saw that teachers who were new to the project would also need support. The primary need was around ongoing quality PD. Teachers commented on appropriate models for the full roll-out of the project. This section also looks at classroom and assessment resources, and the time teachers need to implement the programme.

To adopt the CAS approach, teachers need PD to help them to address change in two dimensions. The first dimension is pedagogy. This can be thought of as a spectrum running from a behavioural, transmission approach at one end, to an exploratory, constructivist approach at the other. The second dimension is technological nous. Prensky (2001) talks of digital natives and digital immigrants. Teachers largely are digital immigrants, teaching the digital natives—their students. Teachers who are towards the digital-native end of the spectrum, and have a constructivist approach to teaching, will adapt the fastest to the changes required by the CAS approach. Digital immigrants (or even digital Luddites) who tend toward the transmission method of teaching, will have the most difficulty changing. They may need to feel fully comfortable with the technology before they will make pedagogical changes. The PD needs to accommodate teachers at all stages of the plane defined by these two dimensions.

Professional development

The most common teacher comment was the central role that PD played, and needs to continue to play, in the ongoing project. First and foremost was the need for "massive PD", "lots of PD", or a "huge amount of PD—How else can I teach this?" to use the teachers' words:

> If there is not substantial PD it will become a 'push the buttons and get the answers' algorithmic approach.

Various different aspects or features of the PD that were mentioned by teachers were that:

- ongoing PD is needed;
- shorter but more frequent PD would be useful;
- just-in-time PD is more effective;
- the PD can't come on top of all the teachers' other commitments (a time issue); and

- there is a need for quality PD presenters.

One teacher commented that, "Non-pilot schools will be at a disadvantage. [I] wonder how it will work out in these schools. They will need lots of PD." Some suggestions for possible PD models were hinted at when a teacher commented:

> Make sure teachers are familiar enough with using the calculators. Students can be more 'on to it' [so teachers] need to keep up. It is a huge learning curve. [Teachers] need to have workshops, websites, email groups etc.

The other significant PD need related to how to use the CAS approach in the senior school and the associated PD that would be needed to support this. The PD given in the pilot was all at the junior mathematics level. Several teachers said that they would need specific PD aimed at Year 12, while a head of department (HOD) said that "PD is needed for this, e.g. [for] iterative methods, linear inequalities, confidence intervals etc."

PD models for full roll-out

As mentioned above, teachers queried whether they would be the ones responsible for future PD, and the extra time load this would put on them. One teacher commented that, "in 2008 the two experienced teachers will be leading PD sessions in the school on CAS". One HOD expressed reservations about the future training and support needs of teachers:

> [I have] grave concerns if CAS technology is going across the board in next 2–3 years. [The pilot has] selected teachers on their ability to change. Others will need more support. Where will this extra support come from?

An issue is whether participating in the CAS pilot is adequate preparation to become a provider of PD. The role of facilitator requires knowledge and experience of being an adult educator, which has differing skills to that of being a classroom teacher to young people. Higgins, Sherley, and Tait-McCutcheon (2007) used four categories of leadership content knowledge required for leading curriculum reform within a school. One of these is knowledge of teachers as learners. Harvey, Higgins, and Jackson (2006) outline some of the impacts upon teachers and facilitators of their involvement in the Secondary Numeracy Pilot Project. On the other hand, the national survey shows that teachers see other teachers as their best source of ideas for the classroom (Hipkins & Hogden, 2004). Local teachers who have successfully implemented CAS could be released and trained as facilitators, in much the same way that the highly successful NDPs have.

Teachers are reluctant to take on the role of facilitator, even within their own schools. As one teacher said, "I'd not be confident once I was the guru." This teacher, like others at this school, depended heavily on one teacher who was passionate and highly competent at implementing lessons using CAS. A teacher at another school remarked, "[We are] still learning ourselves so [we] don't feel confident about supporting and teaching others." This suggests that effective, experienced teachers need to be given training and time away from the classroom to become PD providers for the wider CAS roll-out.

The PD provider also needs passion, and a strong pedagogical base:

> PD model for full roll-out needs a person with the same passion as [named PD provider].

> The key is to have someone who is passionate about it.

Another common opinion was that having people who are immediately available to schools would be an advantage. This would also mean that they were knowledgeable about New Zealand mathematics education:

> I don't see [PD] as being 'outside NZ'. It needs to be NZ-based teachers who have gone through the PD [named two pilot project teachers]. It should be a paid role.

> [We] have to make use of the PD developed within each region, run by teachers, for teachers that encompasses the reality of the classroom. [I] would like to see the colleges of education and universities wake up to this.

These findings suggest that thought needs to be given to the most appropriate form of PD for the roll-out of the pilot to all schools. Four models were discussed in the report on the 2005 pilot (Neill & Maguire, 2006b, pp. 85–87). Briefly these were:

1. *The materials approach*. Providing quality teaching resources.
2. *The commercial model.* PD provided by presenters of each calculator company.
3. *The pair-of-peers approach.* Training two teachers per school.
4. *The (NZ) professional development model.* The model used in the Numeracy project.

The pilot model is a mix of models 2 and 3. Model 1 really only provides support material for the other models.

The pair-of-peers approach: Schools had mixed views on this. Many liked the idea of more than one teacher being involved in the PD each year for mutual support, planning, and potentially team teaching. Several teachers did question whether this was the best mode within the school, as having just some teachers involved made the school more vulnerable to teachers moving.

The (NZ) professional development model: There seems to be some support for a New Zealand-based model. Year 10 and Year 11 teachers interviewed were asked about the effect of other initiatives in the school, and were prompted for their views on the numeracy projects. Some teachers saw strong similarities between the CAS and the NDPs:

> [CAS and the NDPs] are identical. There is a misunderstanding that they are different. They will merge well.

> I believe [the NDPs and the CAS project] merge perfectly. Both are encouraging different approaches and multiple strategies. The underlying pedagogy is the same.

> The PD model for Numeracy would be great for CAS—superior to the calculator-company-[led PD].

Some saw some conflict between them, or had mixed feelings; for example:

> Numeracy got in the way, as has asTTLe. Hard to blend CAS and Numeracy.
>
> [We did] the Numeracy Project—two out of four terms at Year 9 level. [With] Numeracy [we] do not allow the use of calculators, so they aren't being used for half of the year.
>
> The explorative nature of CAS and Numeracy [is the same, but] there are still some contradictions and some overlaps. CAS emphasis is [more] on proof.

Having been exposed to both the CAS and the NDPs, it is our belief that the deep beliefs of both initiatives are closely aligned. Both believe in an exploratory, constructivist approach rather than a behavioural, transmission model of teaching. Both believe in high levels of collaboration and discussion between students, and that multiple strategies and representations are powerful in the mathematics classroom. Perhaps resolving the distinguishing issues, such as calculator use, etc., could allow one integrated approach rather than having two close cousins that exist in isolation from each other.

Professional support

Teachers suggested there should be networks of professional support set up between teachers, but also between them and other agencies. They mentioned local or regional Mathematics Associations, mathematics advisory teams such as Team Solutions, as well as individual mathematics advisers who were knowledgeable with the technology and appropriate pedagogical approaches to using it. Another suggestion was to use New Zealand teachers who had successfully implemented the approach in their own classrooms as advisers. One suggested identifying schools that were centres of excellence, but went on to point out that this would be "unfair on those schools that would have to give time for free". As suggested in the previous section, suitably experienced and effective teachers could be trained and used in this way in much the same way that the NDP has numeracy advisers.

Teacher resources

Several teachers commented on the ongoing need for resources, particularly teaching resources, including those that are needed to get started. One teacher suggested "matching up activities from workshops to the curriculum". Another suggested an "absolute need for a 'book of ideas'". "We need to have a consistent plan about what to teach with appropriate resources," said another teacher. Teachers saw that there was a need not just for a collection of resources and working ideas in isolation, but also a more detailed series of lesson plans that they could use if they wished. One of the PD providers in the pilot gave out such a plan, but was clear that teachers were free to use or adapt it to their own needs. It is important to recognise that teachers can make professional choices of what they use when given both resources, and structured unit plans. There are already a number of commercially available resources on the market, and it is therefore all the more important that resources that are consistent with the values of the CAS pilot are readily available.

Teachers also recognised the need for assessment resources and for exemplars of these to be available well in advance. One stated that they "had hoped to offer a CAS exam in mock exam period but did not get the material in time".

Several teachers suggested making the research accessible to teachers:

> People doing research could get the bare bones of what they found helped, e.g. specific advice on what works written in teacher friendly talk, e.g. a go-between the teaching and [the] research worlds.

Another commented that having a simple instruction book or sheet would have helped them "play around over the holidays [rather than] starting from scratch". Another stated:

> [I] would like online resources. [It] is good to have email contact with presenter but sometimes need something more immediate. An email update with good activities to try out or websites to look at would be helpful.

Time to implement the programme

Teachers commented on the significant time involvement required for their participation in the CAS pilot. This is not just because of the need to become conversant with the technology, and the need to be a trouble-shooter for it, but also the pedagogical sea change that is needed. As one teacher put it, "CAS challenges the way of teaching. [It takes] time for a teacher to work through this." One teacher commented how the time component of preparation may reduce as teachers continue with the approach. He said that "Last year I took a lot of time adapting and fitting resources, [but] less so this year." Another was not so confident when they said that they were "not able to find time to prepare a unit and [was] not willing to do it half cocked".

There were also queries about whether classroom teachers could really be expected to pick up the load of providing PD to others. Teachers suggested that the issue of time needs to be addressed, possibly by giving time allowances to those who are involved with the ongoing implementation, as well as to classroom teachers.

Barriers to sustainability

Other issues arise that may affect the ongoing viability of the CAS initiative. Other concerns that were raised by the teachers are outlined in the following sections.

Financial costs of technology

Many teachers expressed reservations at the cost of the technology, especially when the cost of purchasing calculators was either passed on to parents or picked up by the school. Even one school that had been proactive in running a hire scheme to make graphics calculators more accessible to students reported that it was "unrealistic for CAS to be in more wide use [because of] money". On top of this there was a significant need for replacement batteries. Schools also need to grapple with the financial outlay of having fixed data projectors in classrooms, and with the additional security problems associated with this.

Equity issues

Once all mathematics exams are fully CAS-enabled, schools and students will need a level playing field on which assessments can be made. This issue has already been addressed by creating CAS-neutral questions for the assessments. Other issues of equity will need to be addressed.

Experience indicates that having a graphics calculator in the current NCEA exams is advantageous. Teachers have picked up this thread and one stated, "To be fair to students, they would probably need a CAS. It gives students a better chance and time to answer excellence questions."

Teachers also need to be able to consistently support students who use the calculators, and with the understanding-based pedagogy:

> [You] need to have calculators available across all classes in a school to counter organisational issues where students get mixed up in new classes each year with teachers who are unfamiliar with the calculators.
>
> Needs each teacher to understand that students will need to understand the underlying maths.

Staff and student mobility

The issue of staff turnover (and of its twin of staff taking on other responsibilities that curtailed their level of involvement in the CAS pilot) impacted on several schools. In one of the 2005 schools, none of the CAS-trained teachers were still there at the beginning of 2007, and all but one of the 2005 schools had lost one or more of their CAS-trained teachers.

The turnover of staff is particularly acute if a key person leaves. One teacher commented, "If we lost [a specific teacher] it would have an impact." Two other salutary quotes from schools were:

> One teacher has been seconded, and another teacher is now Head of Department and no longer teaching CAS classes. That teacher has also been doing the Numeracy training. We are using teachers as best we can. A third teacher came half way through the project but [was] not up to speed. Another teacher is not interested at all.

> Teacher turnover is an issue. Two new Year 10 teachers have had no exposure to the calculators and are reluctant to use them. Meanwhile those with experience have taken on other duties and are not available to support current staff.

Another teacher was concerned at the "availability of mathematics teachers with good mathematics knowledge", and thought that this was particularly evident in exploring algebraic principles.

One teacher had moved from one CAS pilot school to another, and saw that teachers with CAS PD may well be in demand. "There is a problem of the desirability of CAS-trained teachers," said the school that had lost this teacher, while the new school admitted "CAS-trained teachers are being sought out". This affects sustainability within a school, especially when they lose CAS-trained teachers. It does have the potential to permeate the CAS philosophy more widely to other schools, but there may also be a dilution effect if the teacher moves to a school where no one else has expertise or interest in CAS. There was no evidence of teachers moving on to higher decile schools.

Schools need to have succession plans in place to cope with these issues, and even these would be stretched under some circumstances. One school said they had thought through this to some extent even though there would be an "issue of a key staff member moving. [We have] no real succession planning, but we have got most maths teachers involved." Another teacher thought that it "would be better to have the whole school involved so teacher turnover wasn't such an issue".

Students moving schools

Student mobility is also a related issue. A student may move from a CAS to a non-CAS school, or vice versa. This will be a very common occurrence until the vast majority of schools have been involved in the project:

> Movement of students between schools [is an issue]. Until every class is a CAS class this is a problem.

CAS in the senior school

An issue is the way that classes are formed in the senior school—"The Ministry will [want] them used in senior school. They assume the classes would be kept together in Yr 12 and 13." Our feedback from schools indicated that classes were not being kept together even at Year 11, where often there was only one CAS class. By Years 12 and 13 this will be an even bigger issue, where classes will often have a mix of students with only some having been in a CAS class:

> [We will have] one CAS-enabled class in [2008], the other class won't have the option. [Students] need the choice to opt out, but some may not be able to opt in.

> Year 12 timetabling issues are huge. The chances of a full class are slim.

> [It is] still hard to pick Year 11 directions. A bit worrying that we don't know L2 and L3 standards and the effect of the new curriculum. Six months before [the NCEA exams] is too short a time frame. Need longer term planning.

Future research

Ongoing tracking of students

Given the longitudinal nature of the CAS pilot project, information about students and teachers in the 2006 cohort should continue to be collected in subsequent years, for research and evaluation purposes. This is the cohort on which the most information is available. They had their attitudes and achievement measured at three time points: the beginning of Year 9; the end of Year 9; and the end of Year 10. Their 2008 NCEA Level 1 results could be collected and analysed, giving a fourth point in the time series. Having prior measures of students' mathematics ability would provide a more direct way to compare the CAS and non-CAS-enabled assessments than using students' results in other NCEA assessments.

If the 2007 cohort were to continue to be monitored, then their attitude and achievement data would need to be collected at the end of 2008. This would give the same amount of data as for the 2006 cohort of Year 9 students if their 2009 NCEA Level 1 results were also collected. This would bring the added benefit of being able to compare two cohorts of students, as well as increasing the sample size of students taking Level 2 and Level 3 assessments. Some teachers thought that the true benefits of CAS would become most apparent then.

Key points of Chapter 10

If CAS and its associated pedagogical values are to take hold in the longer term, a variety of conditions are important to be addressed.

This study suggests it would be helpful to convince a range of stakeholders of its merit if it is to gain traction within mathematics education:

- Mathematics teachers who have not been involved with the pilot may need to see that teaching using exploration and discovery can enhance understanding, and could be shown how technology such as the CAS calculators can assist in this.
- Professional leadership and support at the system level are important ingredients.
- School leadership that is supportive of the values and practice of the CAS pedagogical approach within their school or department will improve the uptake within an individual school.
- Communication with parents and caregivers about the potential advantages of CAS technology as a tool for learning is desirable.

Teachers in the pilot commented about the extra workload of implementing CAS. They suggested there could be some recognition of this, and also some ongoing support for teachers. This was particularly so in resource provision and ongoing PD. If there is to be a full roll-out of the project, we would suggest careful thought be given to other possible PD and support models:

- Effective and sustainable PD models help the initiative to have longevity. Utilising local people who have local classroom experience of using the CAS approach, and have had "training in teaching teachers" would be a good use of available assets. Consideration of using the PD expertise and values of the NDPs could supply useful synergies.
- A greater number of quality teaching resources, and teaching units, that model CAS use across all the areas of mathematics have been identified by teachers as something they would value.
- Access to local people who can give advice on day-to-day implementation issues would help teachers.

There are a number of other barriers to the longer term sustainability of CAS use:

- Cost constraints will be an issue both at an individual as well as at the school level. This has strong potential to cause equity issues unless adequate funding models are available.
- Teacher and student mobility will be an issue until all schools have been exposed to CAS pedagogy.

The need of having a coherent direction that utilises technology effectively as a tool for the teaching and learning of mathematics indicates that one generic device should be adopted. However, the question as to whether CAS calculators are the best way forward needs to be asked. The most appropriate technology to use may be regularly re-evaluated given the advances and new technologies becoming available. Many of the pedagogical approaches used in the CAS pilot may well, however, continue to be pertinent to the future use of technologies in mathematics classrooms.

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Appendix A: Teacher baseline questionnaire

TEACHER QUESTIONNAIRE

CAS Pilot Project
2006 Baseline

This Questionnaire is part of the research being done by NZCER about the CAS Pilot Project. Please complete it and return it in the prepaid envelope.

Your name will not be used in any research reports. Your information will be treated as confidential and you have the right to withdraw your information from the research at any time.

Background information

Code [ ]

Date: ____/____/____

School: __________________________________

Position in school: ________________________

Subject(s) taught: ________________________

Year Levels at which you have taught mathematics (tick as many as apply)

Primary O **Y9** O **Y10** O **Y11**O **Y12** O **Y13** O

Years in this school: _________

Years as a teacher: __________

Years as a mathematics teacher: __________

Brand and Model of CAS calculator used: ____________________________

Personal and classroom use of ICT in mathematics

1) Please indicate by ticking the circle in the column that best describes your **personal** skill level and your **classroom** use of the listed technology.

	Personal skills			Classroom use		
	NEVER USED	BASIC SKILLS	SKILLED	NEVER	RARELY	ROUTINELY
Scientific calculators	O	O	O	O	O	O
Graphics calculators	O	O	O	O	O	O
PC based software (e.g. in a computer lab)	O	O	O	O	O	O
CAS calculators	O	O	O	O	O	O
Data projector with calculator	O	O	O	O	O	O
Databases	O	O	O	O	O	O
PowerPoint	O	O	O	O	O	O
Internet	O	O	O	O	O	O
Other (Please specify)	O	O	O	O	O	O

1) *"Technology in the classroom is essential for teaching and learning mathematics in the 21st century"*

Please tick the circle that best describes your position with respect to the statement above.

O	O	O	O	O
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Please explain your choice:

____

____

____

____

Professional Development, Teaching, Learning and Assessment

1) What are you expecting to learn at your professional development workshops?

____

____

____

____

2) Here are some statements describing different approaches to teaching mathematics.

Please circle the one which best describes your approach:

(**A**) I ensure students have mastery of the rules and procedures of mathematics.

(**B**) I focus on the learner's personal construction of mathematical ideas.

(**C**) I emphasise understanding of mathematical concepts.

(**D**) Other (Please describe)

____

Comment (optional):

____

____

3) What formative assessment do you use in the classroom (assessment intended to promote further improvement of student attainment, often classroom-based)?

____

____

____

____

4) What summative assessment do you use in the classroom (summarising student achievement at a particular time)?

____

____

____

____

5) Give an overall rating of Year 9 students' relative **ability** in these areas of mathematics:

	VERY HIGH	HIGH	AVERAGE	LOW	VERY LOW
Number	O	O	O	O	O
Algebra	O	O	O	O	O
Geometry	O	O	O	O	O
Measurement	O	O	O	O	O
Statistics	O	O	O	O	O

6) Give an overall rating of Year 9 students' relative **attitudes** n these areas of mathematics:

	VERY POSITIVE	POSITIVE	NEUTRAL	NEGATIVE	VERY NEGATIVE
Number	O	O	O	O	O
Algebra	O	O	O	O	O
Geometry	O	O	O	O	O
Measurement	O	O	O	O	O
Statistics	O	O	O	O	O

7) Give an overall rating of how **useful** you expect CAS calculators to be for Year 9 students in these areas of mathematics:

	VERY USEFUL	USEFUL	SOME USE	LITTLE USE	NO USE
Number	O	O	O	O	O
Algebra	O	O	O	O	O
Geometry	O	O	O	O	O
Measurement	O	O	O	O	O
Statistics	O	O	O	O	O

Priorities and Practices

The statements down the left hand side of this table have been distilled from recent research on shifts in teaching and in the learning focus that could better align students' learning with their likely post-school needs in the twenty-first century. Please tick ONE box in each of the two columns (Q1, Q2). N.B. Table layout amended to fit this report.

Q8. What priority do you think should be given to each of these practices?				
Very high	High	Medium	Low	Very Low

Q9. How often do these practices happen in your Year 9 classes?				
All/most of the time	Often	Medium	Occasionally	Hardly ever /never

1.	Providing stimulus materials that challenge students' ideas and that encourage discussion, speculation, and ongoing exploration.
2.	Using strategies (such as co-operative learning, and strategic selection of groups), to establish an atmosphere of co-operation and collaboration.
3.	Encouraging students to make their own decisions in planning and carrying out investigations.
4.	Focussing on the learner's personal construction of mathematical ideas.
5.	Allowing time for discussions to arise naturally and be followed in class.
6.	Including frequent open-ended investigations, short-term open explorations, or tasks that have an open-ended aspect.
7.	Ensuring higher order tasks involving the generation, application, analysis and synthesis of ideas are well represented.
8.	Encouraging students to actively clarify their own ideas, and to think about their learning processes (e.g. by using concept mapping, exploration of alternative strategies etc.)
9.	Setting a variety of types of tasks during each unit.
10.	Involving students in decision making about what should be assessed, how assessment should be carried out, and what the next steps are.
11.	Using a variety of methods to assess student understandings, at various points in a unit, (e.g. open ended questioning, checklists, project work, problems, practical reports).
12.	Ensuring assessment incorporates a range of levels and/or types of thinking.
13.	Probing student understandings and perspectives early in a learning sequence to help plan subsequent lessons.
14.	Ensuring students have ongoing feedback, which indicates their strengths and weaknesses and their next learning steps.
15.	Discussing and developing an understanding of language conventions in mathematics.
16.	Using learning technologies to support quality learning behaviours such as exploration, conjecture, or collaboration (e.g. spreadsheets, internet, graphics calculators).
17.	Creating a classroom environment where ICT is an integral component.
18.	Being a guide, facilitator and co-learner with students using ICT in the classroom.
19.	Providing opportunities for students to engage in activities enhanced by ICT which are essentially self-evaluating, co-operative and collaborative.
20.	Exploring different attitudes, values and perspectives that students bring to their mathematics learning.

Appendix B: Teacher follow-up questionnaire

TEACHER QUESTIONNAIRE

CAS Pilot Project

2006 – followup

This Questionnaire is part of the research being done by NZCER about the CAS Pilot Project. Please complete it and return it in the prepaid envelope.

Your name will not be used in any research reports. Your information will be treated as confidential and you have the right to withdraw your information from the research at any time.

The questionnaire is largely asking you to fill in responses. There is room for comments if you wish to make them.

Background information

Code [ ]

Date: ____/____/____

School: ________________________________

Name: ________________________________

Personal and classroom use of ICT in mathematics

1) Please indicate by shading the circle in the column that best describes your **personal** skill level and your **classroom** use of the listed technology.

	Personal skills			Classroom use		
	NEVER USED	BASIC SKILLS	SKILLED	NEVER	RARELY	ROUTINELY
Scientific calculators	O	O	O	O	O	O
Graphics calculators	O	O	O	O	O	O
PC based software (e.g. in a computer lab)	O	O	O	O	O	O
CAS calculators	O	O	O	O	O	O
Data projector with calculator	O	O	O	O	O	O
Databases	O	O	O	O	O	O
PowerPoint	O	O	O	O	O	O
Internet	O	O	O	O	O	O
Other (Please specify	O	O	O	O	O	O

2) Please shade the circle that best describes your position with respect to the statement below.

Technology in the classroom is essential for teaching and learning mathematics in the 21st century.

O	O	O	O	O
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Comments:

____

____

Professional Development, Teaching, Learning and Assessment

Please shade the circle that best describes your position with respect to the following statements (short comments may be made in the spaces provided).

3) The professional development gave me the skills I needed to confidently use the CAS calculator with my class.

O	O	O	O	O
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Comments:

____

____

4) The professional development gave me quality teaching strategies to use with my class.

O	O	O	O	O
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Comments:

____

____

5) The professional development gave me quality resources to use with my class.

O	O	O	O	O
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Comments:

____

____

6) I have changed my style of teaching with my CAS pilot class.

O	O	O	O	O
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Comments:

____

____

7) I have changed the way I teach **other** mathematics classes since using CAS.

O	O	O	O	O
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Comments:

____

____

8) Students' attitudes are more positive in my CAS class than in other equivalent classes.

O	O	O	O	O
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Comments: ____

____

9) Students' understanding has improved more in my CAS class than in other equivalent classes.

O	O	O	O	O
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Comments:

____

____

10) Students' mathematical skills have improved more in my CAS class than in other equivalent classes.

O	O	O	O	O
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Comments: ____

____

11) My approach to assessment has changed as a result of using CAS in the classroom.

O	O	O	O	O
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Comments:

____

____

12) Here are some statements describing different approaches to teaching mathematics.

(Please circle the one which best describes your approach).

(**A**) I ensure students have mastery of the rules and procedures of mathematics.

(**B**) I focus on the learner's personal construction of mathematical ideas.

(**C**) I emphasise understanding of mathematical concepts.

(D) Other (Please describe) ____

13) Give an overall rating of your CAS students' relative ability in these areas of mathematics.

(Shade in one circle per line)

	VERY HIGH	HIGH	AVERAGE	LOW	VERY LOW
Number	O	O	O	O	O
Algebra	O	O	O	O	O
Geometry	O	O	O	O	O
Measurement	O	O	O	O	O
Statistics	O	O	O	O	O

Comments: ____

____

14) Give an overall rating of your CAS students' relative attitudes in these areas of mathematics:

(Shade in one circle per line)

	Very Positive	Positive	Neutral	Negative	Very Negative
`	O	O	O	O	O
Algebra	O	O	O	O	O
Geometry	O	O	O	O	O
Measurement	O	O	O	O	O
Statistics	O	O	O	O	O

Comments: ____

____

15) How much have you used the CAS calculators in each of these areas of mathematics?
(Shade in <u>one</u> circle per line)

	All the time	Most of the time	Sometimes	Occasionally	Never
Number	O	O	O	O	O
Algebra	O	O	O	O	O
Geometry	O	O	O	O	O
Measurement	O	O	O	O	O
Statistics	O	O	O	O	O

Comments: ____

____

16) Give an overall rating of how useful your students have found the lessons involving CAS calculators in each of these areas of mathematics:
(Shade in <u>one</u> circle per line)

	Very Useful	Useful	some use	Little Use	No Use	CAS not used
Number	O	O	O	O	O	O
Algebra	O	O	O	O	O	O
Geometry	O	O	O	O	O	O
Measurement	O	O	O	O	O	O
Statistics	O	O	O	O	O	O

Comments: ____

____

Priorities and Practices

The statements down the left hand side of this table have been distilled from recent research on shifts in teaching and in the learning focus that could better align students' learning with their likely post-school needs in the twenty-first century. Please tick ONE box in each of the two columns (Q17, Q18). N.B. Table layout amended to fit this report

Q17. How often do these practices happen in your classes when you are using CAS?				
All/most of the time	Often	Medium	Occasionally	Hardly ever/ never

Q18. How often do these practices happen in your classes when you <u>are not</u> using CAS?				
All/most of the time	Often	Medium	Occasionally	Hardly ever/never

1. Providing stimulus materials that challenge students' ideas and that encourage discussion, speculation, and ongoing exploration.
2. Using strategies (such as co-operative learning, and strategic selection of groups), to establish an atmosphere of co-operation and collaboration.
3. Encouraging students to make their own decisions in planning and carrying out investigations.
4. Focussing on the learner's personal construction of mathematical ideas.
5. Allowing time for discussions to arise naturally and be followed in class.
6. Including frequent open-ended investigations, short-term open explorations, or tasks that have an open-ended aspect.
7. Ensuring higher order tasks involving the generation, application, analysis and synthesis of ideas are well represented.
8. Encouraging students to actively clarify their own ideas, and to think about their learning processes (e.g. by using concept mapping, exploration of alternative strategies etc.)
9. Setting a variety of types of tasks during each unit.
10. Involving students in decision making about what should be assessed, how assessment should be carried out, and what the next steps are.
11. Using a variety of methods to assess student understandings, at various points in a unit, (e.g. open ended questioning, checklists, project work, problems, practical reports).
12. Ensuring assessment incorporates a range of levels and/or types of thinking.
13. Probing student understandings and perspectives early in a learning sequence to help plan subsequent lessons.
14. Ensuring students have ongoing feedback, which indicates their strengths and weaknesses and their next learning steps.
15. Discussing and developing an understanding of language conventions in mathematics.
16. Using learning technologies to support quality learning behaviours such as exploration, conjecture, or collaboration (e.g. spreadsheets, internet, graphics calculators).
17. Creating a classroom environment where ICT is an integral component.
18. Being a guide, facilitator and co-learner with students using ICT in the classroom.
19. Providing opportunities for students to engage in activities enhanced by ICT which are essentially self-evaluating, co-operative and collaborative.
20. Exploring different attitudes, values and perspectives that students bring to their mathematics learning.

Appendix C: Teacher interviews

The interviews for the Year 9 teachers were the same as for the 2005 pilot and are in an appendix to that report (Neill & Maguire, 2006b). The interviews for the Year 10 and Year 11 teachers follow.

TEACHER INTERVIEW – Year 10 Teachers (2007)

CAS Pilot Project

Background Information

Codes ____________________

Date: ____/____/____ **Interviewer initials: ______**

Professional development

1 How helpful has the PD for Year 10 mathematics been compared with the Year 9 PD?

In algebra, and probability

2 How effective have the Year 9 teachers found the PD?

3 What ongoing support or professional development will you or your school need once the 2 year pilot period has finished?

Teaching and learning

4 What are the teaching/classroom issues for you in 2007 that are different from any issues in 2006?

5 How are you finding taking a Year 9 class for a second time? (If relevant)

6 What challenges or organisational issues have been associated with implementing CAS in your classroom now there are more classes involved with the project?

7 How is it having a pool of 4 rather than 2 teachers in the project?

Mentoring, planning (pairs or all 4)

8 How do you anticipate organising Year 11 students from the CAS project classes in 2008?

Student Learning

9 How do the students' attitudes towards <u>CAS</u> compare with their attitudes last year?

10 How do the students' attitudes towards <u>maths</u> compare with their attitudes last year?

11 How well are the CAS students performing compared with other Year 10 classes?

Better / Same / Worse **Do you have evidence to support this?**

Assessment

12 What types of assessments have you been performing with your Year 10 classes?

Formative / summative

13 What changes to the approach to or the types of assessment have you made compared with 2006?

14 What is your reaction to the draft assessment materials aimed at level 1 of NCEA?

15 How confident are students about sitting a CAS enabled Level 1 NCEA paper?

Future

16 What support will teachers need to be given to enable the *sustained* use of CAS?

17 What effect are other school initiatives having on the CAS project?

Numeracy etc

18 How do you rate the level of acceptance of CAS calculator use by teachers in general?

For teaching, for high-stakes assessment?

19 What other issues will need to be addressed to enable the *sustained* use of CAS in all schools across the country?

20 Are there any other issues you would like to comment on, or other issues raised by our conversation?

TEACHER INTERVIEW – Year 11 Teachers (2007)

CAS Pilot Project

Background Information

Codes ____________________

Date: ____/____/____ **Interviewer initials: ______**

Professional development

1 What PD have you had this year?

2 What ongoing support or professional development will you or your school need once the pilot period has finished?

Teaching and learning

3 What are the teaching/classroom issues for you in 2007 that are different from any issues in 2006

and/or 2005?

4 Are you taking a class for a second time?

If yes, how are you finding that?

5a How are you organising the 2007 Year 11 students?

5b How do you anticipate organising Year 11 students from the CAS project classes in 2008?

5c How do you anticipate organising Year 12 students from the CAS project classes in 2008?

6a What staff changes have occurred since you started the CAS Pilot Project?

6b How have you dealt with these changes?

Student Learning

7 How do the students' attitudes towards CAS compare with their attitudes last year?

How do the students' attitudes towards maths compare with their attitudes last year?

8 How well are the CAS students performing compared with other Year 11 classes?

Better / Same / Worse **Do you have evidence to support this?**

Assessment

9 What types of assessments have you been performing with your Year 11 classes?

Formative / summative

10 How different are the types of assessments you are performing with your Year 11 CAS classes compared with other Year 11 classes?

11a What is your reaction to the assessment materials aimed at level 1 of NCEA?

11b How are you using the sample NCEA CAS questions?

12 What challenges or issues have you faced in preparing CAS students for NCEA?

13 How confident are students about sitting a CAS enabled Level 1 NCEA paper?

Future

15 What support (other than PD) will teachers need to be given to enable the *sustained* use of CAS?

16 What effect are other school initiatives having on the CAS project?

Numeracy etc

17 How do you rate the level of acceptance of CAS calculator use by teachers in general?

For teaching, for high-stakes assessment?

18 What other issues will need to be addressed to enable the *sustained* use of CAS in all schools across the country?

19 Are there any other issues you would like to comment on, or other issues raised by our conversation?

Appendix D: Student attitudes

All students answer answered Questions I to V, and only CAS students answered Question VI. At the beginning of the year, Year 9 CAS students only answered questions I to VI

CAS PILOT STUDY

STUDENT VIEWS OF MATHS

Year 10 CAS Pilot students

These questions are mainly about your experiences in maths at school. Your answers will help us understand how effective CAS calculators can be as a tool for learning maths.

These questions are not a test. There are no right or wrong answers. Some questions may seem personal and some are about things that not everybody does. You can choose whether or not to answer a particular question.

Please answer each question based on what *you* really think. No one from your home or school will see your answers. NZCER will keep them strictly confidential. We will at no stage individually identify you.

If you **do** answer any of the questions, this means that you are giving us permission to use your results in our research. If you **do not** wish to answer this questionnaire, just leave it blank and hand it in with all the other questionnaires.

To answer a question, use a **pencil** to mark the response that best matches your view.

I. Here are some questions that are about your maths classroom.

*Please fill in the circle that **best** matches your view.*

Maths is a class where:		*Strongly agree*	*agree*	*neutral*	*disagree*	*Strongly disagree*
A)	I learn things that are challenging	○	○	○	○	○
B)	I muck around	○	○	○	○	○
C)	I am happier than in any other subjects	○	○	○	○	○
D)	I don't enjoy what I am doing	○	○	○	○	○
E)	I get totally absorbed in my work	○	○	○	○	○
F)	Students help and support each other	○	○	○	○	○
G)	The teacher spends most of the time helping us learn	○	○	○	○	○
H)	***THE TEACHER SPENDS MOST OF THE TIME TELLING US WHAT TO DO***	○	○	○	○	○
I)	***WE DISCUSS DIFFERENT WAYS OF LOOKING AT THINGS/INTERPRETATIONS***	○	○	○	○	○
J)	The teacher gives useful feedback on my work that helps me see what I have to do next and how to do it	○	○	○	○	○
K)	I can count on the teacher for help when I need it	○	○	○	○	○
L)	The teacher is happy to explain things more than once	○	○	○	○	○
M)	We keep doing the same things without learning anything new	○	○	○	○	○
N)	***WE HAVE A LOT OF HANDS-ON/PRACTICAL ACTIVITIES***	○	○	○	○	○
O)	***I GET TIME TO THINK AND TALK ABOUT HOW I AM LEARNING***	○	○	○	○	○
P)	***DISCUSSIONS WITH THE TEACHER HELP ME DEVELOP MY SKILLS/UNDERSTANDING/IDEAS FURTHER***	○	○	○	○	○
Q)	***I GET TIME TO THINK ABOUT IDEAS AND PROBLEMS IN NEW WAYS***	○	○	○	○	○
R)	***I CAN TRY OUT NEW IDEAS/WAYS OF DOING THINGS***	○	○	○	○	○
S)	***I AM INTERESTED IN WHAT WE LEARN***	○	○	○	○	○
T)	***I DO A LOT OF EXAMPLES FROM TEXTBOOKS***	○	○	○	○	○
U)	***I USE AN EXERCISE BOOK A LOT TO WRITE THINGS DOWN***	○	○	○	○	○
V)	***I RELY ON OTHER STUDENTS FOR HELP***	○	○	○	○	○

II. Here are some questions that are about maths as a subject.

*Please fill in the circle that **best** applies to your view:*

	Maths is a subject where:	Strongly agree	agree	neutral	disagree	Strongly disagree
A)	I don't know how to do the work	○	○	○	○	○
B)	When I'm doing something, I think about whether I understand what I'm doing	○	○	○	○	○
C)	I can get away with not doing much work	○	○	○	○	○
D)	I can get help from home if I want to	○	○	○	○	○
E)	I plan to drop it as soon as I can	○	○	○	○	○
F)	I gain knowledge that will be useful for my future	○	○	○	○	○
G)	I see connections with other things outside school	○	○	○	○	○
H)	*I DO WELL*	○	○	○	○	○
I)	I'm confident I can master what is being taught	○	○	○	○	○
J)	*I FEEL NERVOUS*	○	○	○	○	○

III. Here are three descriptions of the way some teachers teach mathematics.

Fill in the one circle that** best **describes your teacher.

1 ○ **My teacher makes sure I can recall all the rules of mathematics.**

2 ○ **My teacher lets me explore ideas and work out the rules of mathematics for myself.**

3 ○ **My teacher makes sure I understand all the ideas behind the rules of mathematics.**

IV. Here are five descriptions of some maths lessons.

*Fill in the circle that **best** matches how often each of these happen in your maths class.*

	What happens in my maths classes	*Always*	*Often*	*Sometimes*	*Seldom*	*Never*
A)	The teacher shows us how to do the work and then we do lots of examples.	○	○	○	○	○
B)	The teacher shows us how to do some things, which we do for a short time. Then they show us some more things, which we then do. We repeat this cycle a number of times.	○	○	○	○	○
C)	I can choose to work at my own pace either by myself or with others.	○	○	○	○	○
D)	The teacher leads discussions with the whole class where we explore ideas.	○	○	○	○	○
E)	Students work together in small groups exploring mathematical ideas.	○	○	○	○	○

If you do different things than these in your maths class, please describe a typical lesson.

____

____

V. The next questions ask about calculators or computers.

*Please fill in the circle that **best** applies to your view:*

	Use of calculators or computers	*Strongly agree*	*agree*	*neutral*	*disagree*	*Strongly disagree*
A)	Using calculators to explore mathematical concepts improves my understanding.	◯	◯	◯	◯	◯
B)	*I FIND CALCULATORS HARD TO USE.*	◯	◯	◯	◯	◯
C)	*I USE COMPUTERS A LOT (E.G. AT HOME, AT SCHOOL ETC.)*	◯	◯	◯	◯	◯
D)	*USING CALCULATORS MEANS I DON'T HAVE TO UNDERSTAND MATHS AS MUCH.*	◯	◯	◯	◯	◯
E)	*I THINK COMPUTERS OR CALCULATORS ARE FUN.*	◯	◯	◯	◯	◯
F)	*CALCULATORS HELP ME WHEN I AM EXPLORING A MATHS PROBLEM THAT I DON'T KNOW HOW TO SOLVE.*	◯	◯	◯	◯	◯
G)	*CALCULATORS HELP ME DISCOVER NEW THINGS ABOUT MATHS.*	◯	◯	◯	◯	◯

	VI. My experience of using the CAS calculator	*totally agree*	*agree*	*neutral*	*disagree*	*totally disagree*
A)	I have had no problems using the CAS calculator	◯	◯	◯	◯	◯
B)	*I ENJOY USING THE CAS CALCULATOR*	◯	◯	◯	◯	◯
C)	*LESSONS USING THE CAS CALCULATOR ARE JUST LIKE OTHER MATHS LESSONS*	◯	◯	◯	◯	◯
D)	*USING THE CAS CALCULATOR HAS HELPED ME UNDERSTAND ALGEBRA BETTER (DISAGREE MEANS YOU DO NOT UNDERSTAND AS WELL)*	◯	◯	◯	◯	◯
E)	*USING THE CAS CALCULATOR HAS HELPED ME UNDERSTAND GEOMETRY BETTER (DISAGREE MEANS YOU DO NOT UNDERSTAND AS WELL)*	◯	◯	◯	◯	◯
F)	*I FEEL MORE POSITIVE TOWARDS MATHS SINCE USING THE CAS CALCULATOR (DISAGREE MEANS YOU NOW FEEL LESS POSITIVE)*	◯	◯	◯	◯	◯
G)	*I NOW FEEL CONFIDENT USING THE CAS CALCULATOR*	◯	◯	◯	◯	◯
H)	*I FELT CONFIDENT ABOUT USING THE CAS CALCULATOR WHEN I WAS FIRST INTRODUCED TO IT.*	◯	◯	◯	◯	◯

Appendix E: Lesson observations

CAS Pilot Project 2006–7

LESSON OBSERVATION SCHEDULE

Teacher Code: ______ **Date: ____________**

Lesson Background *Discuss with teacher (if applicable)*

- **What is the curriculum objective or learning intention for this lesson?**
- **How does this lesson relate to previous lessons?**

Classroom Layout

Brief description and/or sketch of classroom (noting position of teacher's desk, grouping of student's desks, position of ICT equipment etc)

In-class observations

Record the style of teaching or type of activity taking place during the lesson, noting times for changes of style. Record start and finish times of lesson.

Codes for teaching style: lecture (L), Whole Class Teaching (WCT), Group teaching (GT), Group work (GW), Individual Work (I), Pair Work (P), Administration (A), Students explaining (S)

Time	Activity	Description
0		
5		
10		
15		
20		
25		
30		
35		
40		
45		
50		

Other Notes / Comments

Appendix F: Class-by-class box plots

Students' progress in achievement by class

Appendix Figures 43–45 show box plots of growth in achievement for all CAS and control classes in the study. The first two figures show growth in the two Year 9 cohorts (2006 and 2007), while the third shows changes for the Year 10 students in 2007. The control classes have a darker shading. Schools are denoted by letters of the alphabet, and classes are numbered within schools. The first group of schools in the graphs were using Type A calculators, the second group used Type B, and the final group used Type C. Clearly, some schools and some classes made more significant progress than others.

Figure 43 **Improvement in patm scores by school, and class—2006 Year 9 cohort**

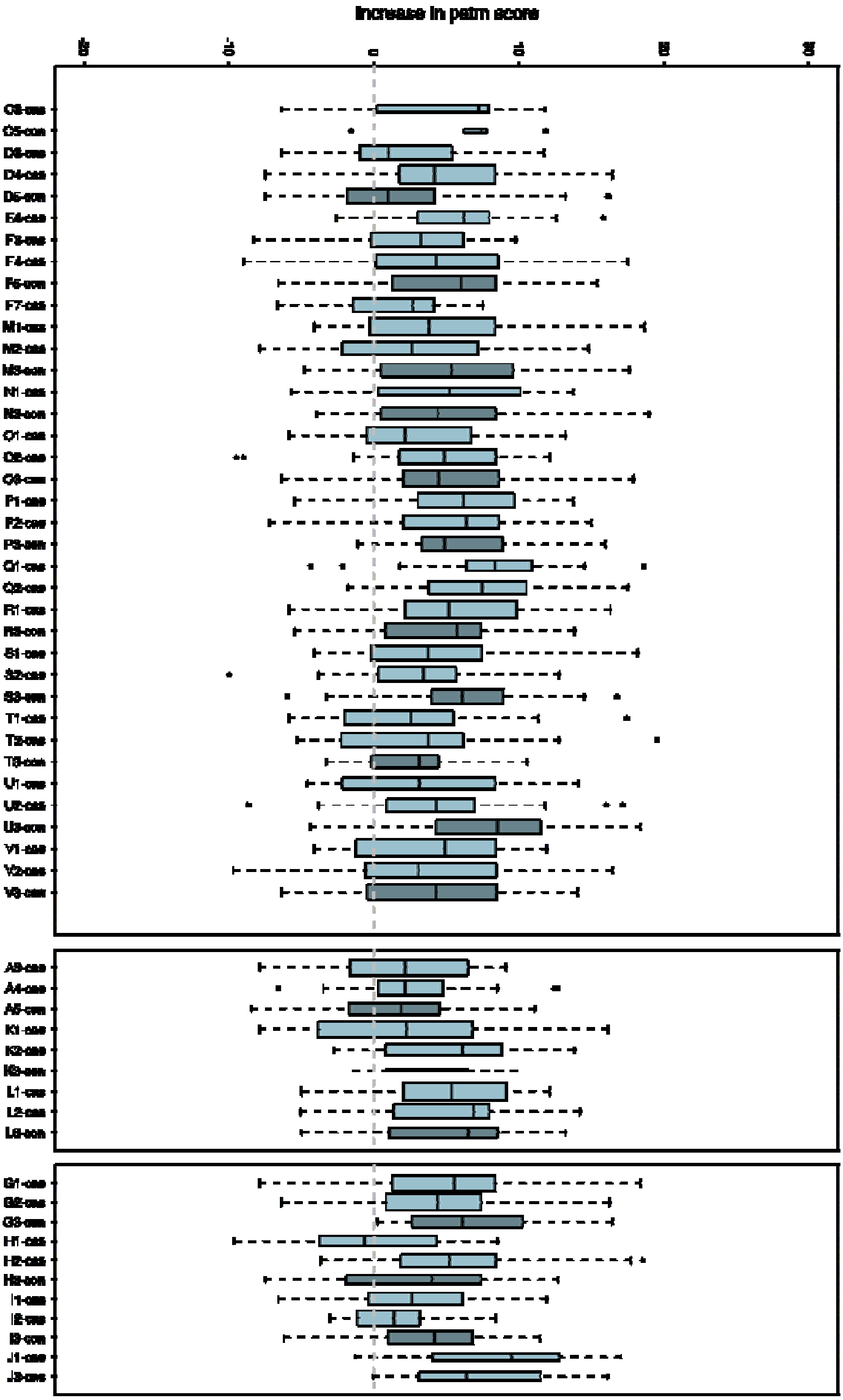

Figure 44 **Improvement in patm scores by school, and class—2007 Year 9 cohort**

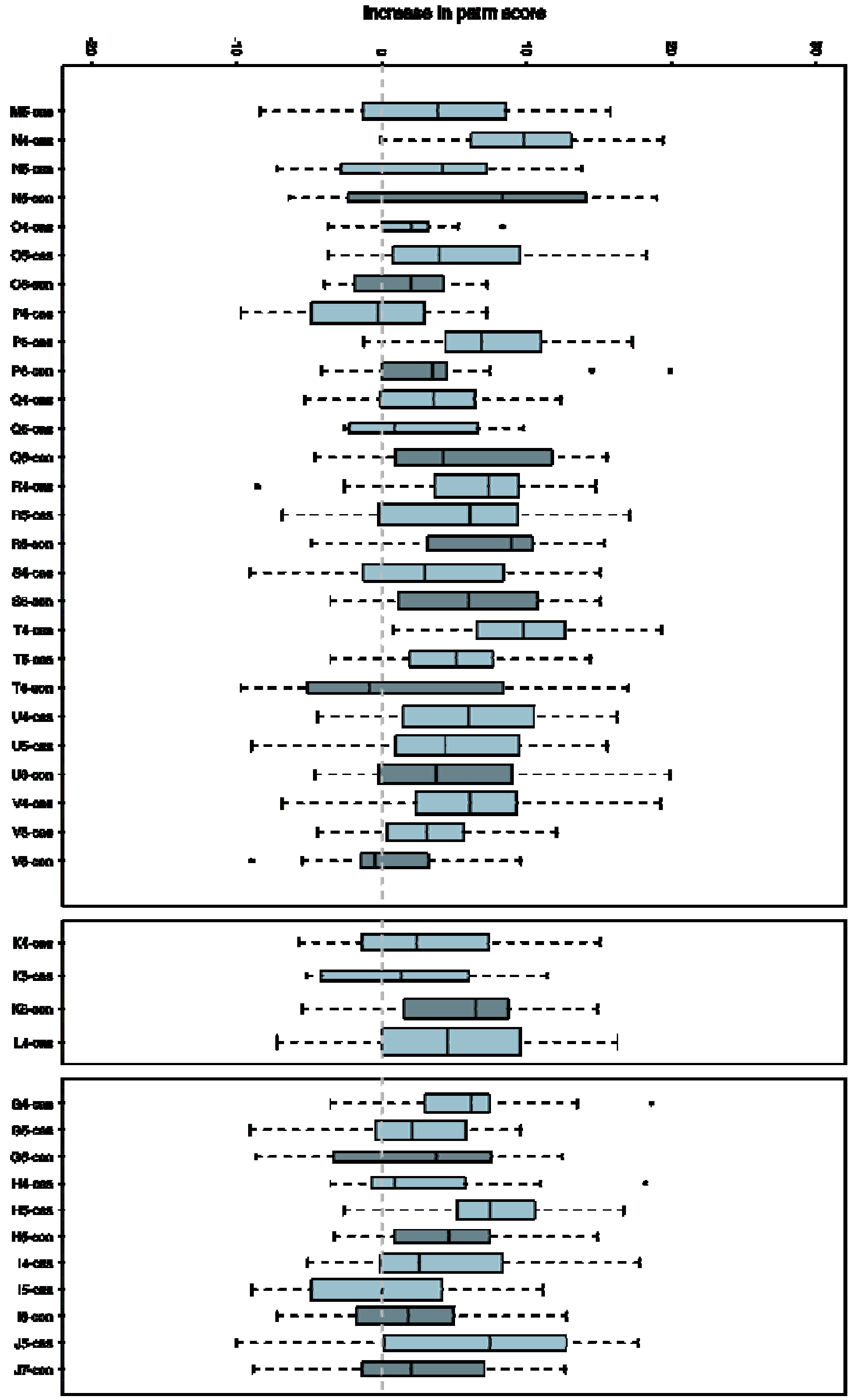

Figure 45 **Improvement in patm scores by school, and class—2007 Year 10 cohort**