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An Evaluation of the CAS Pilot Project

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

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NEW ZEALAND COUNCIL FOR EDUCATIONAL RESEARCH

TE RŪNANGA O AOTEAROA MŌ TE RANGAHAU I TE MĀTAURANGA

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Executive summary

If one word were to be used to sum up the CAS Pilot Project, it would be the word "pedagogy".

Using CAS is all about promoting a well-founded pedagogy of teaching and learning that can be supported and enhanced with technology. The teachers in the pilot were supported in achieving this by quality professional development, and classroom resources. They were striving to perform assessments of learning in ways that support and value the pedagogy of exploration, discovery, and understanding.

Pedagogy

The dominant aspect of this project was changing pedagogy to a more exploratory, discovery-based approach that enhances understanding, rather than a rules and algorithmic approach. An exploratory approach is the intent of the current mathematics curriculum, but has not always been the focus in the classroom. This pedagogy is not dependent upon technology, but good technology use in the pilot was enhancing it.

The teachers in the CAS pilot were all firmly in support of this pedagogical approach. They were either believers before the pilot began, or were won over by their participation in the project. The teachers and students reported changes to a more student-led, interactive, exploratory, collaborative, discussion-based style of teaching and learning. Teachers and students agreed that the focus was constructivist, with an emphasis on understanding rather than having a focus on rules and procedures. The students largely saw these lessons as different from other mathematics lessons.

Teachers were implementing the pedagogy of exploration in a variety of ways including: group work with a focus on peer learning and teaching; students working at their own pace; interactive discussions between the teacher and the class; or short cycles of teacher instruction followed by student work.

Teachers found that the pilot project was time consuming for them. Because this type of pedagogy was less familiar they needed to attend to a number of organisational and planning issues. They needed to spend time familiarising themselves with the CAS, refining resources, and making new resources or assessment instruments.

Learning

There was a consensus amongst the teachers that the understanding of students of all ability levels had increased, without a negative impact upon their more traditional manipulative skills. This is very much in line with discussions in the research literature. While the evidence from the pilot was largely subjective, teachers who had performed common assessments in their school did not see the CAS students doing less well in algorithmic questions than non-CAS students. One teacher taught several lessons using the traditional pencil-and-paper approach part way through his algebra unit. He found the students covered this work in a far shorter time than in previous years, when his students had not been exposed to the exploratory style of teaching. The pace of lessons for high ability students may need to be faster.

Students had mixed views on whether their mathematics understanding was higher. Many thought it was. A significant minority believed that their understanding was worse. Often this was because the lessons did not emphasise traditional skills. These students were often the more able ones, who had experienced success in a predominantly algorithmic approach to mathematics. Students generally enjoyed using the CAS and were confident about using it.

Professional development

Professional development (PD) was characterised by the providers modelling a pedagogical approach that teachers could use in their classrooms—that of using exploration and discovery to enhance understanding. Teachers experienced the PD in much the same way as their students experience mathematics lessons. Much of the guidance about how to use the technology was done on a "just in time" basis, so that teachers would not be swamped with technological details, but could see and explore the mathematical issues involved. A major benefit of the PD sessions was the interaction and sharing between the teachers in the pilot.

The initial training familiarised the teachers with the technology. Most of them were satisfied with this, but some felt the PD could become more focused by using only examples from junior high school mathematics, and having written guides for verbal instructions so teachers could replicate the learning sequences that were demonstrated.

The PD also provided teachers with frameworks for teaching units. These resources were intended to include sound pedagogy, a coherent and linked sequence of teaching, and complete instructions both on the mathematical ideas and instructions needed to operate the CAS in the prescribed manner. Largely the provided resources met these criteria, but part of the ongoing project is to refine the resources to better meet teacher needs and expectations. Teachers often saw a need to refine or adapt the resources to their own classrooms.

The PD provided to teachers in the pilot was of a very high standard. PD for the wider mathematics teaching fraternity needs to adopt an excellent, sustainable model. Facilitation of PD is a professional skill that differs from classroom teaching and requires trained facilitators with time to perform this task. Schools also need leadership commitment to the pedagogy. Using the PD expertise and values of the Numeracy Project should be considered.

Assessment

Assessment, both formative and summative, needs to reflect the values of exploration and understanding that define the pedagogical thrust of the CAS pilot. This poses challenges for traditional assessment practices.

Teachers were performing high levels of formative assessment in all their classrooms, but they did not always recognise this, usually because they were not employing many formal assessments.

Schools were still debating and experimenting with a variety of school-based summative assessments. New forms of summative assessment that reflect the nature of, and the values behind, the teaching in the CAS pilot are needed. Some of these may need to be "CAS-resistant", which means that students who do not have a CAS in the assessment are not disadvantaged. Teachers need models of assessment styles that will be used in the high-stakes NCEA assessments in time to prepare their students for them. The role of CAS in assessments of other subjects needs to be clarified. More time and resources will be needed to develop appropriate assessment material.

Technology

The teachers and the PD providers saw the technology as one tool for learning, not the driver of learning. The teachers were largely positive about the technology. They could see that it allowed more authentic contexts to be used, and a more problem-solving approach to be taken. Students generally enjoyed the technology, but most of them encountered specific problems concerning its use. Some of them could not always see the mathematical reasons for what they were doing on the CAS.

Care will need to be taken that the technology is used in an illuminating "white box" way (aiding in the construction of meaning for mathematical concepts), rather than in a "black box" way (press these buttons to get the answer). An appropriate pedagogical approach and assessment consistent with exploratory learning to enhance understanding will be needed to support this.

The price of the technology could be a barrier for many.

Future issues

For the project to become sustainable, both parents/caregivers and mathematics teachers need to come on board with, and understand the values of, this pedagogical approach. The schools were employing a range of effective strategies to communicate with parents or caregivers, and this will need to continue. Communication within the mathematical education community is also needed.

School leadership needs to be supportive of the values and practice of the CAS pedagogical approach within their school or department. System-wide leadership is needed as well, in policy, communication, and assessment issues.

More classroom resources across all the areas of the curriculum are needed.

1. Introduction

This research is an evaluation of the 2005 CAS[1] Pilot Project. The project aims to improve the teaching and learning of mathematics through the use of CAS technology in classrooms. Indicators of effectiveness that have been monitored include changes in teacher practice, changes in student attitudes towards mathematics, and changes in student learning. Other areas that have been evaluated include the professional development provided, the impact of CAS technology on assessment, attitudes towards technology, and issues of sustainability for the CAS initiative.

Research questions

Several questions formed the basis of the research reported here:

1. Have changes in teachers' roles and practices occurred in the CAS pilot school mathematics classes, and if so what are they?
2. At this stage what indications of changes in teacher practice are there?
3. Has the learning environment of these mathematics classes been affected, positively or negatively, and if so in what ways?
4. What are the professional development needs that have arisen in the pilot?
5. What issues will need to be addressed and what support will need to be given to teachers to enable the effective and sustained use of CAS technology? What wider implications does this have for the school, community, and the Ministry of Education?
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? What is the specific evidence of this?

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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.

8. What are the implications for assessment of student learning as a result of using the CAS technology? Do current forms of assessment need to change, and if so in what ways?

Background to the project

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

Some other countries are using CAS technology in the teaching of mathematics. Reports from teachers and from research suggest that the use of this technology can improve students' conceptual understanding of mathematics. It was decided to initiate a pilot project in 2005 that would look at ways of improving the teaching and learning of mathematics using the CAS technology in New Zealand schools. This pilot project has had its focus at the junior secondary school level, so that any effects of NCEA examinations in New Zealand schools on classroom practice would be kept to a minimum.

Two Year 9 classes in six schools around New Zealand were involved in the 2005 pilot. This will continue into 2006 with 16 new schools (32 Year 9 classes) taking part. In 2006, the six schools from the 2005 pilot will continue to use CAS technology with their 2005 Year 9 students, who will be in Year 10, as well as involving two new Year 9 classes in the project.

2. Methodology

An important aim of this research was to capture the stories of students, teachers, and professional development providers in the CAS Pilot Project, so that elements of effective practice could be identified and replicated. The information is therefore largely of a qualitative nature, based upon case studies in each of the pilot schools. Some quantitative data, in the form of short questionnaires, was gathered. Asking common questions has allowed triangulation between the teachers, students, and professional development providers.

The case study schools

An advertisement in the 2 August *New Zealand Education Gazette* (Ministry of Education, 2004b) invited schools to take part in the CAS Pilot Project. Six schools were selected from the 28 that responded. Four of the schools are in the North Island and two are in the South Island. While there is a range of decile ratings among the schools selected, they are predominantly in the high range. The schools are all state schools located in urban areas, with four being in major population centres and two in smaller, provincial centres. All but one are co-educational. The schools range in size from 770 to 2250 students.

Table 1 ***Case study schools***

School	*Decile*	*Size*	*Type*	*Student body*
School A	3	940	State	Co-educational
School B	6	970	State	Co-educational
School C	8	1230	State	Co-educational
School D	10	2250	State	Co-educational
School E	9	770	State	Single sex
School F	9	1200	State	Co-educational

Two mathematics teachers from each school took part in the study. There was a lead teacher, who was generally the person who had initiated their school's involvement in the project, and a second staff member joined them. All 12 teachers were mathematics teachers, although five had taught other subjects. On average, they had been teachers for about 12 years, teaching mathematics for a little less than 10 of those years.

The teachers took part in professional development workshops early in 2005 and then introduced CAS technology into their Year 9 mathematics classes. Two of the schools received training in the use of the Texas Instruments TI V200 while the remaining four schools used the Casio Classpad 300.

The design of the data gathering instruments

In order to capture a variety of perspectives about the use of CAS technology in the classroom, a wide range of instruments was developed. A questionnaire was sent to all 12 teachers prior to a school visit, during which an individual 50-minute interview was conducted with each of the teachers in the CAS pilot. The teacher questionnaire is in Appendix A, and the interview schedule is in Appendix C. During each school visit we also held a discussion with a group of students and observed one or two mathematics lessons. The student focus group schedule is in Appendix D, and the lesson observation schedule is in Appendix G. In addition, the two professional development providers and the professional leader responsible for the professional development were interviewed. These interview schedules are in Appendices E and F. Three professional development workshops were also attended.

It was not possible to establish baseline data from either the teachers or the students because the research part of the project got underway after the teachers had already been using CAS in their classrooms. We therefore had to rely on teachers' own perceptions of changes they had made or experienced. Similarly, we were unable to gather baseline achievement data for the 2005 student group, and changes in student learning and achievement have been gathered anecdotally.

We drew on several related NZCER studies: Bolstad (2002); Bolstad (2005); Boyd, Bolstad, Cameron, Ferral, Hipkins, McDowell, and Waiti (2005); Hipkins and Neill (in press); and Conner, Hipkins, and Neill (in press) for our instrument design.

The design of the teacher questionnaire

We wanted to get a picture of the changes teachers had made since using CAS in their classrooms. Without the benefit of baseline data, this was achieved through a self-reflective questionnaire that was based on the experiences of Hipkins and Neill (in press) and Hipkins, et al. (in press) in measuring changes teachers had made before and after the implementation of NCEA (see Appendix A). In their Shifting Balances reports, these authors drew on the work of the Victorian Science in Schools (SIS) Project (see, for example, Tytler, 2003) to develop a set of descriptors which allowed teachers to reflect on the small, but significant, changes that might have occurred in their classrooms. These descriptors formed the basis of our questionnaire, and are shown in Table 2. Fourteen of our 20 descriptors came directly from one or both of the Shifting Balances projects, with three having minor modifications made to them (descriptors 3, 16, and 20). Two descriptors from the original list in the SIS research (see Tytler, 2003) were added to reflect the more co-operative, discussion-based teaching we anticipated might be occurring in the CAS pilot classes (descriptors 2 and 5). A further descriptor that reflected a change in the way teachers might approach the teaching of mathematics was added (descriptor 4). Three new descriptors were developed to reflect both the technology being used and the collaborative nature of the teaching (descriptors 17, 18, and 19). The descriptors can also be arranged into four distinct groupings or themes, as shown in Table 3. These themes have been colour-coded, so that trends on the graphs that summarise the questionnaire findings can be more easily interpreted.

Table 2 ***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.

Table 3 ***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

Teachers were asked to assign a *priority* to each practice on the self-reflective questionnaire using a 5-point scale: very high, high, medium, low, very low. The purpose of this was to find out what the teachers considered was important for the teaching of mathematics as well as their views about teaching and learning. Perceptions of actual changes were measured by using two scales. One recorded teachers' perceptions of how often they carried out each of the practices pre-CAS, while the second captured how often they did these things now. A 5-point Likert-scale was used for both of these rather than the 7-point or 9-point scales used in Shifting Balances (Hipkins, et al., in press). The points used were: all/most of the time, often, medium, occasionally, hardly ever/never.

We felt that it was important for teachers to have time to consider their responses rather than making on-the-spot judgements. Accordingly the self-reflective questionnaires were sent out prior to our school visits along with the additional interview questions we intended to ask. Analysis of the self-reflective questionnaire is mainly covered in Section 3.

The questionnaire also included questions about specific ICT that teachers might use in the classroom. This was developed to generate a picture of the level of skill the teachers had in various areas of technology and how often they used them in the classroom. Analysis of this part of the questionnaire is reported on in Section 8 on Technology in the classroom.

2006 teacher self-reflective questionnaire

An extended version of the 2005 questionnaire was developed and sent out to all teachers participating in the 2006 project, excluding those who had taken part in the 2005 pilot (see Appendix B). This gives baseline data for these new teachers. Analysis of this data is beyond the scope of this evaluation of the 2005 pilot, but will be used in subsequent research or evaluations.

The ICT skills/use questions and the descriptor list from the 2005 questionnaire have been kept intact. Additional questions have been added to gather baseline data on the teachers' attitudes towards technology, expectations of the professional development workshops, approaches to teaching and assessment, and the mathematical ability and attitudes of Year 9 students at their school.

The interview schedules

We wanted to gather information across a broad range of topics and themes from the teachers, the professional development providers, and the professional development leader. Our interview schedules for all of them have been divided into seven sections: Background to the Project; Professional Development and Teacher Support; Technology (incorporated into Background for the professional development interviews); Teaching and Learning; Student Learning; Assessment; and Future Issues. The interview schedules are included as Appendices C, E, and F.

By exploring what teachers and professional development providers considered were the key aims of the project we hoped to discover whether the main goal of the pilot project (to improve teaching and learning in mathematics) was being taken on board by those involved.

We were interested in the views that teachers and professional development providers held about technology use in the classroom. We speculated that these views would impact on how effectively the technology was used in the classroom to promote learning. Lachambre and Abboud-Blanchard (1996, cited in Monaghan, 2001) refer to four aspects of CAS-related in-service training. They are "technical (operating a CAS), scientific (what a CAS can and cannot do), cultural (the experiences, influences, prejudices and predilections of teachers) and professional (relating to attitudes and classroom practices)" (p. 463). For the purposes of our interviews, we condensed these four areas to two—technical aspects and cultural/professional aspects—seeking to discover whether learning "how to" use CAS would hinder the teaching and learning of mathematics itself. We explored this with teachers, both in terms of their own professional development and their implementation of CAS in the classroom.

The issue of whether the use of CAS technology in the classroom would impact on teachers' roles and practices is fundamental to the aims of this pilot project. Kendal and Stacey (2002) reported that two teachers adapted their practice to teaching with CAS, where "…their teaching practices (and the changes they made) were influenced by their beliefs about learning and purpose for teaching, their content knowledge, pedagogical content knowledge, and knowledge of institutional constraints" (p. 96). To ascertain the pedagogical approach each of our teachers held before and after using CAS in the classroom, we used Kuhn and Ball's model (1986, cited in Kendal & Stacey, 2002). This described four broad types of teaching practices: "Learner-focused, Content-focused with an emphasis on conceptual understanding, Content-focused with an emphasis on performance, and Classroom-focused" (p. 197). Drawing also on Kendal, Stacey, and Pierce (2005), who discuss the experiences of three teachers using CAS, we wrote three statements to describe these different teaching practices:

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.

We then asked each teacher to select which one of these three descriptions best fitted their teaching practice prior to the introduction of CAS, and the one that best fitted now. We also asked teachers to note any changes they had made to how they taught their CAS classes, compared to previous years or other classes. Combined with the information from the teacher questionnaire, we envisaged this would paint a rich picture of the underlying beliefs and pedagogy practised by the teachers.

In our initial teacher interview schedule we included two questions relating to general views on the teaching of mathematics and, in particular, algebra. These were omitted after the first two interviews had been conducted, as they were broader than the scope of this study.

The other important aspect of this pilot project has been to measure the impact of the use of CAS technology on student learning. Heid (2003) noted that after using CAS "…students' mathematical development seemed to proceed more rapidly" (p. 40), while Heid and Edwards (2001) found that weaker students were able "to examine algebraic expressions from a more conceptual point of view…" (p. 131). Noguera (2001) also commented that "[students'] cognitive development in algebra improved during the six-week period [of a summer programme]" (p. 263). Without the benefit of baseline data, we included questions that asked teachers to compare the learning of their current CAS classes with other Year 9 mathematics classes, with respect to their depth of understanding and the speed at which concepts were grasped.

Also of interest was the impact of the CAS technology on lower, average, and higher ability students. Both Kutzler (2003) and Cedillo and Kieran (2003) commented that lower achieving students seemed to benefit most from using CAS. "Students who are mathematically challenged—a group for which change is most urgent—seem to benefit from the use of compensation tools" (Kutzler, 2003, p. 57). We sought to establish whether the teachers in our study had had similar experiences.

A crucial factor in student learning is attitude towards the subject. We asked teachers to comment on changes to student attitudes towards mathematics, or differences in attitudes between their CAS class and other Year 9 classes. Cedillo and Kieran (2003) and Noguera (2001) both noticed changes in student attitude after a period of time using CAS technology. "By the end of the six weeks all of the students agreed that they had experienced a positive change in their attitudes towards mathematics" (Noguera, 2001, p. 263).

Questions relating to assessment and future issues were developed directly from the overall research questions.

Teachers were invited to bring relevant planning documents and examples of student work to the interviews. The intention was to discuss how these demonstrated evidence of learning in ways not previously formally assessed. In the event, teachers were unable to provide us with anything that fitted this description. In several schools, teachers shared with us their experiences of using different types of summative assessments with their students and this is discussed further in Section 7 on Assessment. One factor that may have prevented teachers from presenting us with student work was that a lot of the tasks were completed on the CAS and very little written evidence was available. This issue of pen-and-paper versus CAS is further explored in Sections 4, 5, and 7 on Teaching, Learning, and Assessment.

We were able to collect some worksheets and class materials during our observations and interviews. These were often modelled on the materials teachers received during their professional development workshops and teachers related that they had shared these materials amongst themselves. Some had adapted the worksheets to meet the specific needs of their students or the teaching style they were using.

The student focus groups

During each school visit we met with a group of between five and eight students. In five of the schools these students were drawn from both of the CAS classes, while in one school logistical issues resulted in them coming from one class only. We had a roughly equal mix of boys and girls in the groups from the co-educational schools.

The broad themes for our discussion centred on Using CAS, Teachers and Teaching, Student Learning, and Advice. As we had done in the teacher interviews, we drew from related NZCER studies for our questions—Bolstad (2005), Neill (2005a), and Neill (2005b)—as well as attitudinal surveys in Mayes (1995), Noguera (2001), and Driver (2001).

Pierce and Stacey (2002) developed a framework that divided Effective Use of CAS into two aspects: "the students' ability to handle the *technical* aspect of their CAS and the *personal* aspects, encompassing their attitudes and manner of use of CAS" (p. 576). This framework dovetailed well into our research, which aimed to discover whether the technical aspects of CAS impacted on mathematical learning and which also wished to explore student attitudes towards CAS in the classroom. Our questions therefore covered both of these areas. The student focus group interview schedule is in Appendix D.

In order to encourage discussion and debate amongst the student group, we developed a set of statements that students rated on a scale from "strongly disagree" to "strongly agree". Each student was given a card with a letter between A and H on it. For each statement, the students placed their lettered card on a scale laid out in front of them. To reduce the influence of peer pressure, we asked students to initially record their response on an individual sheet before placing their lettered card on the large version of the scale. This also enabled us to capture the responses as hard data.

When exploring issues surrounding teachers and teaching we rewrote the three teacher descriptions used in the teacher interview and asked students to select which one best described their teacher. In this way we could compare students' perceptions with their teacher's perceptions of their style of teaching.

Observations

At half of the schools we were able to observe both of the CAS classes in action, while in the other three schools we sat in on one class only. In one case, a trainee teacher was conducting the class.

We initially developed an observation schedule that was designed to try to capture teacher-student and student-student interactions (see Appendix G). However, we found that these interactions were occurring so frequently, and in so many places in the classroom, that it was virtually impossible to capture them all. We did record a number of these interactions. We found that the most useful part of our original schedule was a timeline of the type of teaching and learning we observed. Using this, we were able to record, at approximately 5-minute intervals, what was actually happening in the classroom. As part of this, we made specific notes about the types of teacher-student and student-student interactions that we observed. We also noted how both teachers and students used CAS during the lessons. In this way we captured information about the technical aspects of teaching and learning with CAS that we could compare with its effectiveness in promoting learning.

We had an open schedule for our observations at the professional development workshops. At these, it was our intention to observe the process by which the teachers learned about the CAS technology and to take note of any issues that arose as part of this. We attended both the introductory Texas Instruments and Casio workshops for the 2006 teachers and a Casio debriefing session for the 2005 pilot teachers.

3. 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 that were mailed to them ahead of the individual interviews (see Appendix A for a copy of the questionnaire). Teachers' perceptions of the value that should be attached to the various classroom practices identified on the self-reflective questionnaire are compared with their perceptions of actual changes in classroom practice. The section begins with a short discussion of the collation and analysis of the teachers' responses.

All 12 teachers from the six pilot schools responded to the questionnaire. When considering the patterns reported, it should be noted that findings based on such a small sample cannot be generalised to all teachers of these subjects. Statistics such as average scores and variances are susceptible to being affected by just one or two respondents. For this reason, most of the analysis is done on ranked scores and the statistical tests done are non-parametric. Such tests are robust, and make no assumptions about normality.

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. The average scores were then ranked from 1 for the practice rated as the highest priority to 20 for the practice rated the lowest priority. The same process was followed to rank teachers' perceptions of the frequency of each practice before and after the CAS Pilot Project. The results are summarised in Table 4.

The teachers' responses

Table 4 shows the average score for the priorities (S_p) assigned to each descriptor, and then ranks these (R_p) from 1 to 20 (highest ranking to lowest ranking). Next it gives the average score for the perceived frequency of practice pre-CAS (S_b), and also ranks these (R_b). It then gives the average scores (S_a) and ranks (R_a) for the perceived frequencies of practice post-CAS. The final column gives the difference in average frequency between current practice and pre-CAS practice (S_a–S_b). This provides a means of quantitatively reporting the actual changes the responding teachers perceive that they have made. Refer to Table 2 in Section 2 for details of these descriptors.

Table 4 ***Teachers' perceptions of priorities and changes in practices***

Descriptor	*Average priority (S_p)*	*Priority rank (R_p)*	*Av. Pre-CAS (S_b)*	*Pre-CAS rank (R_b)*	*Av. Post-CAS (S_a)*	*Post-CAS rank (R_a)*	*Change (S_a–S_b)*
1	4.67	1=	3.25	8	4.00	5=	0.75**
2	4.00	10=	3.18	9=	3.67	10=	0.49
3	3.67	18	2.67	17	3.00	19	0.33
4	3.83	16	3.09	12	3.46	13	0.37
5	4.00	10=	3.36	7	3.27	17=	-0.09
6	3.91	15	2.54	18	3.36	15	0.82**
7	3.80	17	2.70	16	3.30	16	0.60
8	4.18	7=	2.90	15	3.40	14	0.50
9	4.27	6=	3.64	5	4.27	3	0.63
10	2.54	20	1.82	20	2.00	20	0.18
11	4.18	7=	3.54	6	4.00	5=	0.46
12	4.33	5=	3.81	3	4.18	4	0.37
13	4.67	1=	4.08	1	3.67	10=	-0.41
14	4.58	3	3.75	4	4.00	5=	0.25
15	4.50	4	4.00	2	4.42	2	0.42*
16	4.17	9	3.17	11	4.58	1	1.41**
17	3.92	13=	3.08	13	4.00	5=	0.92*
18	3.92	13=	2.92	14	4.00	5=	1.08**
19	4.00	10=	2.25	19	3.58	12	1.33**
20	3.64	19	3.18	9=	3.27	17=	0.09

* Significant at the 5% level

** Significant at the 1% level

In the discussion that follows, some of the results in Table 4 will be analysed by the themes of assessment, rich tasks, teaching and learning, and technology. These themes are displayed in Table 3, also in Section 2.

Changes in frequencies of teaching practice pre- and post-CAS

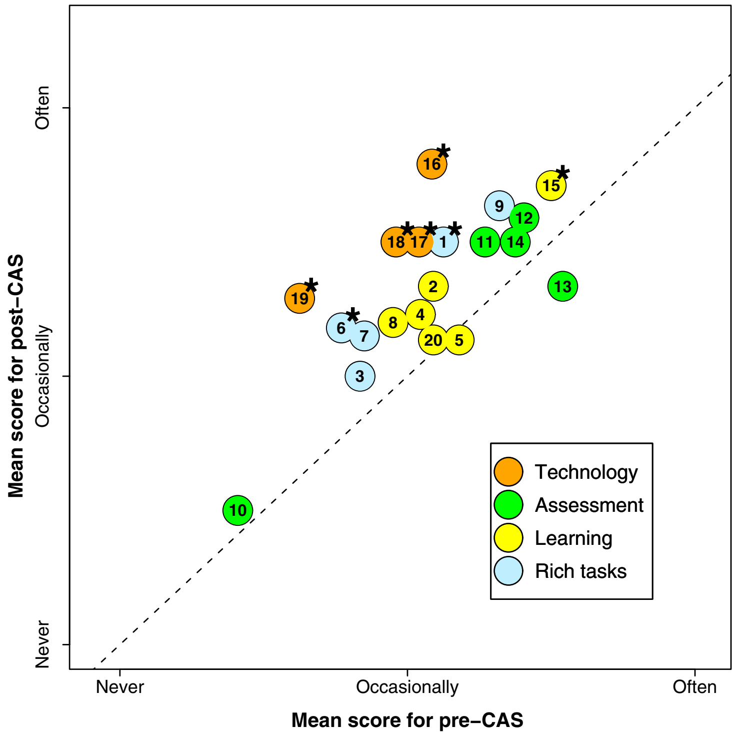
Overall the responses show a modest increase in teachers' practice for the majority of the 20 descriptors. For seven of them the change was statistically significant. Figure 1 compares teachers' perceptions of the frequency of their practices before the CAS pilot and the perceptions of their frequency 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 (these are also shown as the column labelled "S_a–S_b" in Table 4).

Only one of the 20 practices was scored as being less common now than prior to the pilot. This was descriptor 13 on formative assessment. This was seen as slightly less frequent since the pilot began. However, the discussion of formative assessment in Section 7 suggests that this was not actually the case.

While the majority of practices showed an increased frequency since the pilot started, this was statistically significant for seven of the practices (using the Wilcoxon signed-rank test for matched pairs, Wackerly, Mendenhall, & Schaeffer, 1996). To reach significance, teachers needed to be in almost complete agreement on the direction of the change of levels of practice.

As might be expected, the group that falls furthest above the line are the items about technology (coloured orange), with all four being performed significantly more often since the CAS pilot began. Rich tasks have increased by the next greatest in frequency, with two of them increasing significantly. These are shaded in blue. Issues related to teaching and learning styles (shaded yellow) had a slight increase, with only one increasing significantly. The assessment issues (shaded green) were about as common before and after the CAS pilot began.

Figure 1 ***CAS pilot teachers' perceptions of changes in practice***



* Statistically significant shift in practice

Figure 2 ***A comparison of CAS pilot teachers' rankings for priorities and current practice***

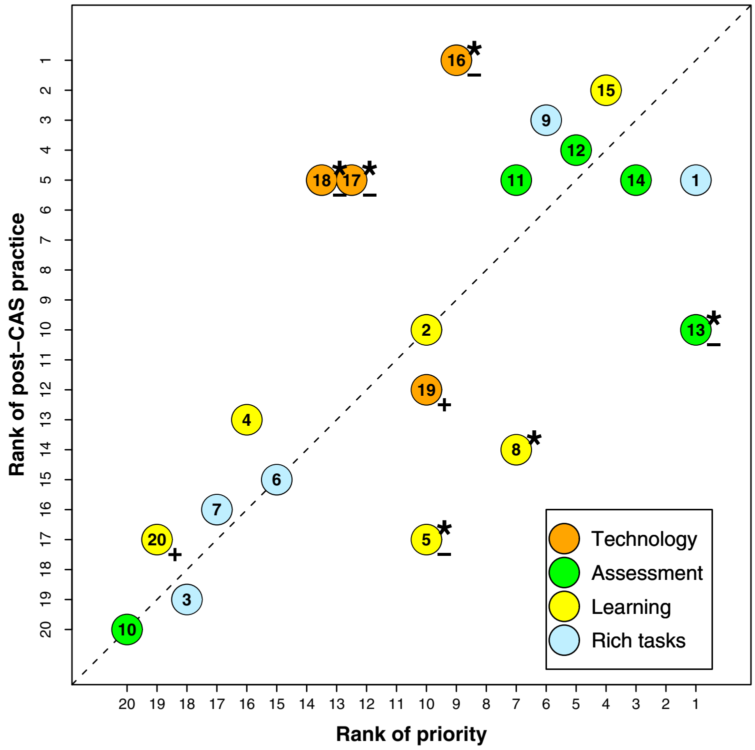
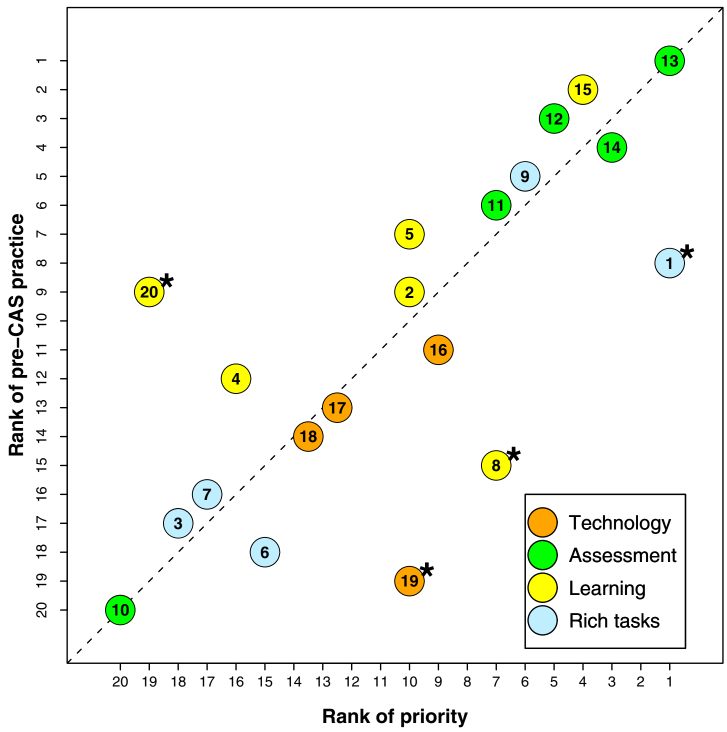


Figure 3 ***A comparison of CAS pilot teachers' rankings for priorities and prior practice***



* Substantial difference from the diagonal line on the graph
\+ Substantially better fit between priority and current practice than priority and prior practice
\- Substantially worse fit between priority and current practice than priority and prior practice

Current priorities

The rankings of current priorities can be seen in either Table 4, or in Figures 2 or 3. 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 two on formative assessment (descriptors 13 and 14). However student involvement in decision making about assessment (descriptor 10) had the lowest priority. Questions relating to the theme of rich and varied tasks within the classroom (coloured blue) had two descriptors of higher priority, and two of lower priority. 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 fourth highest.

Comparing rankings of priority and current practice

The rankings assigned to current practice by these teachers can be read from Figure 2. The practices with the highest ranking on current practice are at the top of the graph, whilst the lowest ranking ones are towards the bottom of the graph. High priorities lie to the right of the graph and low ones to the left, and these combine with the rankings of practice to give an overall picture of the match between priority and practice. For example, descriptors 1 (providing stimulus materials) and 13 (formative assessment) are both seen as the top priorities, but descriptor 13 is practised less often than descriptor 1.

It is useful to look at the patterns within Figure 2. Small differences in ranking can be assigned to random fluctuation. These are shown by points close to the diagonal line. This means that the teachers think they do these things about as much as they feel they should do them. Points well above the line indicate practices where the descriptor has a substantially higher ranking for its current practice than its perceived priority indicates that it should—that is, these are things teachers think they do more often in practice than they would like. Points substantially below the line show classroom practices that teachers currently carry out less often now than they would prefer to. Substantial changes were defined as differences of five or more between the practice ranking and the priority ranking of a descriptor.

Six descriptors differed by five or more ranking points. Descriptors 16, 17, and 18 (which all relate to technology) are well above the line, indicating that these aspects are practised relatively more than the teachers' priorities indicate they should. Conversely, descriptors 5 (time for discussions), 8 (metacognition), and 13 (formative assessments) are being practised less than their priority suggests that they should.

Shifts in the priority/practice match

Further comparisons can also be made by comparing the current practice and priority graph (Figure 2), with the pre-CAS practice and priority graph (Figure 3). This explores whether the match between priority and current practice is better than the match between priority and practice pre-CAS. On the whole, the points on Figure 3 lie a little closer to the line than they do in Figure 2, with only four descriptors lying well away from the diagonal line (descriptors 1, 8, 19, and 20). This means that overall there was a slightly better match between priority and practice prior to CAS than there is now.

To see if an individual descriptor better matches teachers' priorities now than prior to the CAS pilot, compare the vertical distance from the diagonal line to that descriptor in both Figure 2 and Figure 3. If this distance is now substantially smaller, there is a better match between priority and practice now (these are marked on the graph by a subscripted +). If it has increased in the CAS pilot, then there is a poorer match between priority and practice (these are marked on the graph by a subscripted -).

Current practice for the rich tasks (shaded blue), and the assessment tasks (shaded green) were all close to the assigned priority that teachers gave them. Observe how assessment tasks cluster at the top right in both Figure 2 and Figure 3. This indicates they are of high priority, and rank highly on current practice. The exception is for descriptor 13 (formative assessment), which has a worse match than it had prior to the CAS project. However, as previously indicated, this may be related to teachers' perceptions of what constitutes formative assessment. Our lesson observations indicate that, in reality, the match may well be better than the teachers suppose.

For the use of technology, descriptors 16 to 18 (using technology to support exploration and collaboration, integrating ICT into the classroom, and being a guide, facilitator, and co-learner of ICT) each closely matched priorities before the pilot, but in the pilot they are more common in practice than their priority indicates they should be. The technology descriptor 19 (ICT activities that are co-operative) now has a better match between priority and practice than previously. This is no surprise, as the pilot has a strong technology focus.

Two learning descriptors had changes in the practice–priority fit. Allowing time for discussions (descriptor 5) now is more lowly ranked in practice than its priority indicates it should be, whereas prior to the pilot, this was reported as being a little higher in practice than its priority. As indicated in Section 5, it may well be that discussions are taking a different form in the CAS pilot. Exploring attitudes (descriptor 20), which has a low priority, has a better fit since the CAS pilot began than it did previously, where it was far more common in practice than its low priority suggests that it should have been. Perhaps this may be that there was less need to discuss attitudes or to motivate students in the pilot.

There will be further discussion of relevant aspects of the classroom practice descriptors in the sections that follow.

Key points of Section 3

- The biggest changes in practice were in the technology practices. Teachers reported significantly more frequent use of all four of these in the CAS pilot.
- Providing rich activities had seen the next biggest increase in practice during the pilot.
- The emphasis on mathematical language had increased during the pilot.
- Teachers perceived there was a worse match between priority and practice for both formative assessment and classroom discussions. In each case this was more likely to be a misconception than the reality, as both practices were strong features of the classrooms we observed.

4. It is all about the pedagogy: Teaching issues

A new paradigm

Teachers, professional development providers, and the literature are all in agreement; it is all about how the CAS is used in teaching that makes the difference. The professional development coordinator went as far as saying that "The technology (CAS) is an excuse to impact pedagogy where teachers have not taken on the philosophy of the curriculum." *Mathematics in the New Zealand Curriculum* (Ministry of Education, 1992) gives approaches to teaching and learning that emphasise good problem-solving skills in real-life situations, often on open-ended questions that are amenable to a range of different mathematical techniques. Students are encouraged to "search the information for clues, and to make connections to the various pieces of mathematical and other knowledge and skills which they have learned" (p. 11). This more exploratory approach is an essential ingredient of the teaching styles encouraged by the CAS Pilot Project. As mentioned in the introduction, *Mathematics in the New Zealand Curriculum* also endorses the use of technology in mathematics. The technology, however, is intended to be the servant of the pedagogy.

The two providers who facilitated the professional development training days were promoting a new way of teaching and learning mathematics based on these principles. One of them stated:

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

The other provider saw this same need for a paradigm shift in mathematics education when he said:

> There is a need for change. Without this there is no future. [The CAS presents] dynamic learning opportunities.

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

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

So has teaching changed?

In this evaluation several different lenses focused on this question. Teachers were asked to reflect upon changes in their classroom practice. Each teacher was asked in an interview if and how teaching had changed, and what predominant style of teaching took place in their classrooms. Focus groups of students answered similar questions. This was supplemented with classroom observations. Comparisons are also made with the responses to the self-reflective questionnaires. From this triangulation (or "quadrangulation", if such a word exists) common themes occurred. These themes are discussed below, and are followed by some stories of classroom observations.

Teachers' and students' responses

Nine of the 12 teachers reported making changes to their teaching with their CAS pilot classes. The remaining three reported that their teaching remained largely the same. They identified that teaching and learning was more student-led, more interactive, more exploratory, involved more discussion and questioning, there was more collaboration between students, and less use of books. This is consistent with the self-reflective questionnaire results, which showed there had been a shift in teacher practices. Many of the issues that teachers had identified as areas where they had made changes were also commented on by students. Although a range of issues was touched on, several themes received wider attention from both the teachers and the students. These were backed up by lesson observations.

More student-led

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

> [After the teacher explains it] people who want to go further can.
>
> I have time to work it out for myself.
>
> We work out how to get the answer.

Each of these indicates a student focus. From the classroom observations it was also clear that the journey from teacher-led to student-led learning had begun. This balance differed from one teacher to the next, and was also being enacted in different ways. From the teacher questionnaire, both descriptors 3 (students making their own decisions in investigations) and 4 (personal construction of ideas) explored this issue. Both showed a modest increase in the frequency of these practices during the CAS pilot compared with prior practice (see Figure 1). It is interesting that neither was seen as a particularly high priority. This may carry implications for ongoing professional development.

More interactive

A teacher from one school changed his teaching, to "let the students see me solving the problem 'live' without [me doing] any preparation". This allowed the students to observe and respond to the teacher's problem-solving strategies. One student shared that "The teacher does it with us now. With the book he acted like he's right, [but] he learns CAS like us." High levels of teacher-student interaction were seen in all of the lessons, with these being initiated by both teachers and students. These episodes addressed mathematical issues as well as details of how to use the CAS technology. All the teachers were roving the class for substantial parts of the lesson. A student noted, "There is more walking around [by the teacher]." This highly interactive approach seemed to be more frequent in the observed lessons than is generally the case in secondary mathematics classrooms, although there are no baseline data to substantiate this claim. Interactions between student and student were high, either in pairs or in group work. This was seen in the lesson observations as well as being commented on by teachers. The teacher-student interactions were also more egalitarian. Students were regularly observed sharing ideas with the teacher or the whole class on different or better ways to do things. The freshness of the CAS technology, and students' innate feel for it, appeared to facilitate this. One student observed that there was better communication between teacher and student now.

More exploration

Both teachers and students reflected that the approach involved far more activity, exploration, and self-discovery with far less emphasis on a rules-based approach to algebra or geometry. A teacher described letting the students tussle with a problem by themselves for longer before offering help. A student in a focus group remarked that they had to find the mathematical rules for themselves rather than being shown or told them. “[We] explore to find out the formula,” said another. All the observed classes had a strong activity-based approach, with a focus on the explorations that were provided in the professional development. These employed multiple methods of problem solving and multiple representations of mathematical concepts. The teacher questionnaire also showed that rich tasks were now a more common feature than before the CAS pilot began. In particular, descriptor 1 (providing stimulus materials that encourage discussion, speculation, and ongoing exploration) and descriptor 6 (including frequent open-ended investigations) were significantly more frequently performed in the CAS pilot than they were previously (see the blue points in Figure 1). Prior to the CAS pilot, teachers were not providing stimulus materials as often as they would have liked to, but this had improved during the pilot. The questionnaire also showed that teachers felt that the balance between their priorities and their practice for these rich, more exploratory tasks matched both pre- and post-CAS. This can be seen by comparing Figures 2 and 3, where all the blue points are close to the diagonal lines except descriptor 1 in Figure 3.

More discussion and questioning

Several teachers commented on this. “We are getting more mathematical discussions now”, was one observation, while another teacher commented that they were employing a different style of questioning, with more open-ended questions and more time for students to contemplate and debate issues. “[There is] more student debating of mathematics”, was one teacher observation. One student observed that there was more discussion now, and another said that they had to do more explaining of ideas, while a third said “[The teacher] asks questions like ‘How does it work?’.” In three of the observed classes this very active form of questioning was employed. There was extensive questioning from these teachers, with students replying and justifying their responses. Teachers’ responses in the questionnaire showed a significantly higher level of use of stimulus material that encourages discussion (descriptor 1), and this practice now more closely fits its high priority level than before the CAS pilot. On the other hand teachers reported the same level of class time spent in discussion (descriptor 5) both before and after the CAS pilot began. In fact, they now see a worse match between their priority for this and the relatively low ranking of it occurring in practice. Much of this is probably due to the increased discussions in the one-on-one or group interactions, with relatively less whole class discussion, which was only a strong feature in two of the nine observed lessons.

The opportunity for an approach that involved more discussion and questioning led one teacher to observe, “Discussion on all units has been great. [It has] helped students generate ideas for themselves.” Another teacher saw how “students were taking greater responsibility for learning”. A third noted how his class discussions had gone even further than this. He shared how they had “got into discussions of metacognition, discussions of how we learn”. The implication of the more student-led, discussion-based approach is that students become more aware of their learning. This is somewhat at odds with the teachers’ perception that descriptor 8 from the questionnaire (encouraging students to actively clarify their own ideas and assumptions, and to think about their learning processes) was relatively higher on teachers' priority than it was being practised both before and after CAS (see Figure 1). It may well be that teachers are not aware of the extent of increases in metacognition.

More collaboration

A strong focus on either group work or working together in pairs aided this exploratory style. Most teachers reported they were already using group work, but some reported an increase in this, or in the frequency of peers helping each other to learn. One teacher stated, "There is a completely different feeling in the class. There is much more peer learning and helping each other." One student said, "When you teach others you learn it more." Several students also commented that they shared ideas more now. One said that there was more sharing of answers as well. In all the observed lessons many students were helping and explaining things to each other. Teachers reported a modest increase in the frequency of collaboration post-CAS (see descriptors 2 and 19 in Figure 1, which are about co-operation and collaboration). Both have increased in frequency, especially descriptor 19. In our lesson observations we saw high levels of co-operative and collaborative work, indicating that these practices may have shifted more than the self-reflective questionnaire suggested.

Less use of textbooks and exercise books

In most classes there was little or no use of textbooks, and only limited use of exercise books. Students in particular had commented on this. "We [used to do] lots of book work and write lots of stuff," said one. A change from textbook-led to teacher-led practice was also commented on by students, with one saying "Without [CAS] we just read the notes but now he explains more" while another observed that previously lots of the explanations were from the book, "Now they are from the teacher." One teacher was contemplating not using a text at all. In one class students were being taught how to record their work on the CAS machine itself, while a student using the other brand of calculator had discovered and was using this facility for himself. The observations also confirm the lower level of exercise book use and the complete lack of textbook use in any of the nine lessons we observed.

Other changes

One teacher shared how they were a "happier teacher [now]. [I am] able to do things differently, not learning to pass pre- or post-tests or exams. Students are gaining a passion for maths. [I am] less pressured for completion of units." Another had found that "Initially CAS inhibited my style of teaching. It wasn't my material so I was uncomfortable with it. As I got more familiar with the material I became more comfortable."

Other changes in teaching practice included:

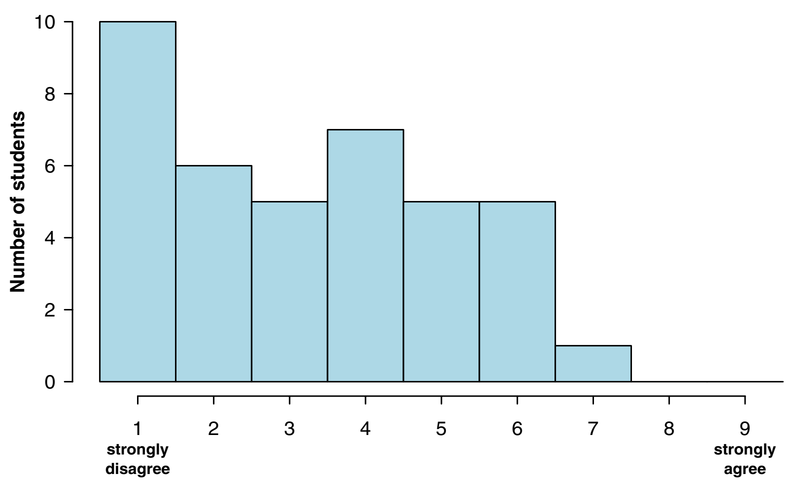
- less focus on finishing the syllabus. This was not seen as a problem, as integrating mathematical ideas and getting through work more quickly had allowed coverage to occur;
- more authentic problems and contexts could be used;
- focusing more on why students were doing things;
- stronger emphasis on mathematical understandings rather than skills; a move from mechanical, skill-based maths to conceptual maths; and
- discussing and developing an understanding of language conventions in mathematics (descriptor 15 in the teacher questionnaire) had an increased frequency during the CAS pilot compared with pre-CAS.

Students' awareness of the changes to teaching

Students were asked for their responses to the statement "Lessons using the CAS calculator are just like any other mathematics lesson." They were asked to place their response on a continuum from strongly disagree to strongly agree, and their responses were coded into nine equally spaced bands. These are shown in Figure 4. Students saw clear differences between the lessons in the pilot and other lessons. No student strongly agreed, and only 6 of the 39 students agreed with the statement compared with 28 who disagreed.

The reasons they gave for these differences were largely the same as those outlined in the previous section, but a few other points were mentioned. One comment was that the lessons were not so repetitive. At counterpoint to this, another student said the lessons proceeded more slowly. The use of the OHP or data projector was commented on, as was the need to have daily explanations on how to use the calculator. One student saw that it was "sort of (the same). It's like we've got used to CAS so that it's just part of maths."

Figure 4 ***Student response to "CAS lessons are just like other maths lessons"***



Perceptions of teaching style

An Australian study of CAS followed the practice of three teachers over a period of time (Kendal et al. 2005). The teaching practices of the three teachers in the study were summarised as follows in our interview schedules:

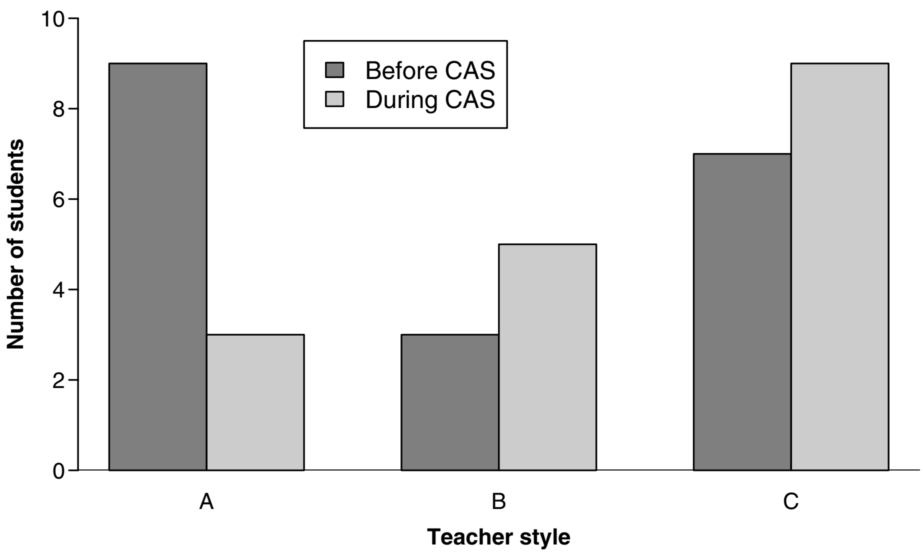
A: I ensure students have mastery of the rules and procedures of algebra.

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

C: I emphasise understanding of algebraic concepts.

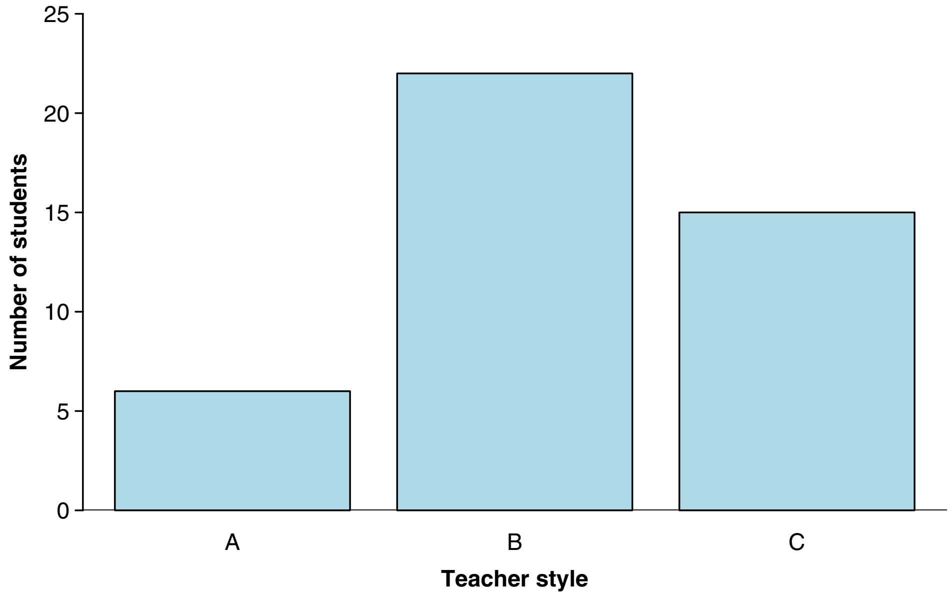
Teachers were asked which of the three different teaching styles most reflected their practice prior to the CAS pilot, and which style typified their practice during the pilot. Figure 5 shows the teachers' perceptions of their own teaching style pre- and post-CAS. Teachers were allowed to select a combination of styles if they wished, so there are more than 12 responses both pre- and post-CAS. The graph shows a definite movement away from a rules and procedural style of teaching towards an exploratory and constructivist approach or an understanding-based style. Teachers primarily see their style as leaning most heavily towards teaching for understanding.

Figure 5 ***Teachers' perception of their teaching style pre-CAS and post-CAS***



The students in the focus groups were also asked for their perceptions of their teacher's style. These responses are shown in Figure 6. Students saw their teachers as predominantly following an exploratory, constructivist approach to their teaching. Indeed in one school, a teacher who rated themselves as a mix of styles A and C both before and after the CAS pilot began, was seen by all of his students as clearly employing style B.

Figure 6 ***Students' perception of their teacher's styles***



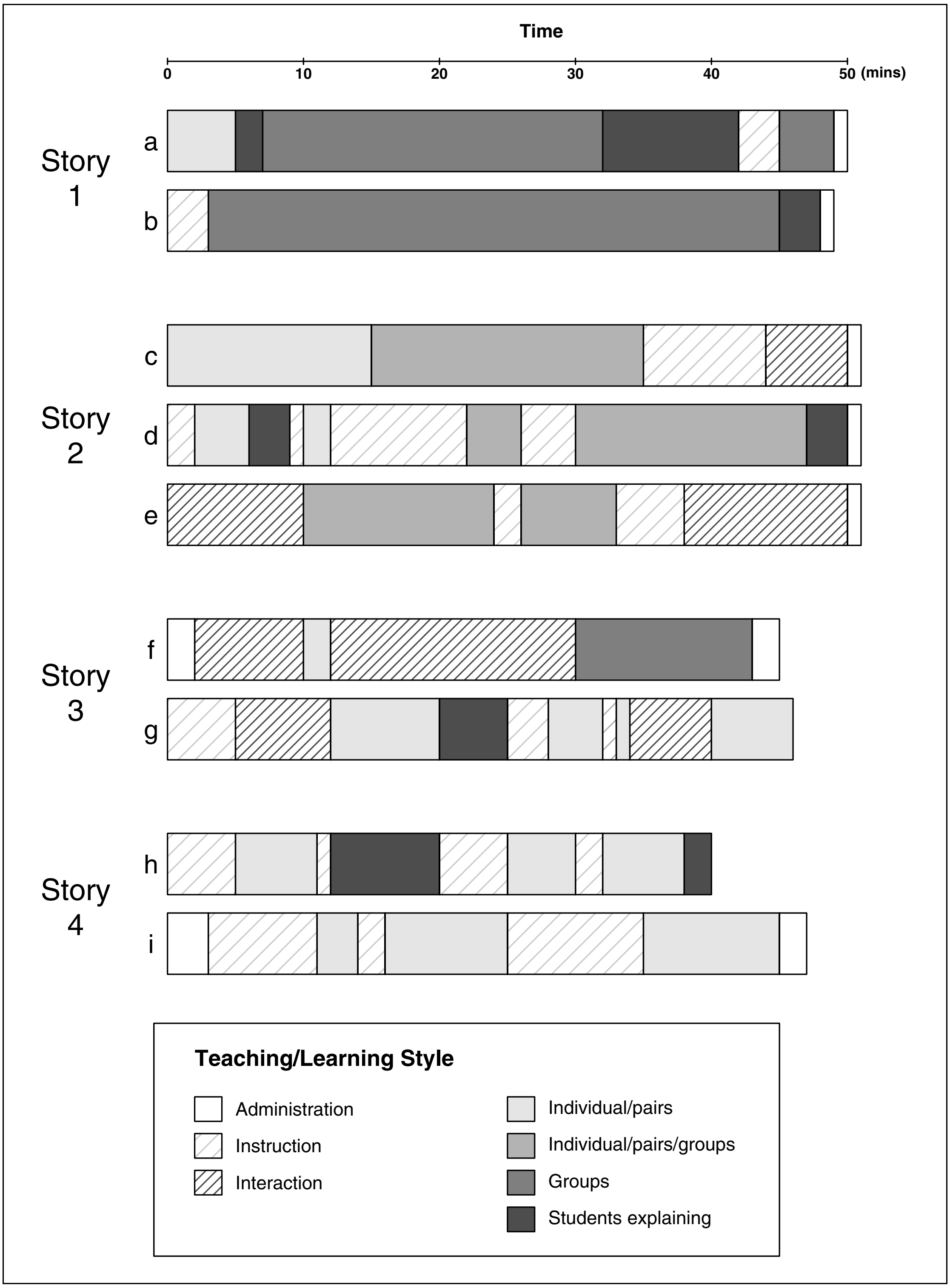
Stories of teaching

Many of the changes in teaching discussed in the interviews and focus groups were also seen in the lesson observations. Altogether, nine classes were observed from the six pilot schools. Of the nine classes, three were top stream classes while the remaining six were made up of students of mixed ability. Four of the classrooms had traditional seating, with pairs of desks arranged in rows facing the front. The other five classes were arranged in groups in various different ways. The desk arrangements obviously help shape the patterns of interactions, with the traditionally organised seating leading to pair work rather than group work.

Many lessons incorporated a structured way of students explaining their ideas to other students. Sometimes this was done in groups, or to the whole class. In one instance it was done between pairs of students.

The different styles of teaching in the observed lessons have been categorised into several distinct teaching methods. In some of the classes, the teaching was a mix of more than one method, while other classes primarily followed one pattern. These patterns are displayed in Figure 7. The stories that follow describe four quite different teaching approaches. These are arranged from most heavily student-led to those with a more teacher-led approach.

Figure 7 ***Observed style of teaching in lesson observations***



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

Story One: Expert groups exploration

This is a description of a specific teaching strategy within the overall interactive pedagogical approach. The major emphasis in this approach was using expert groups that each performed an exploration that helped them 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 both classes in School C, and took up the majority of each of the lessons observed. They are represented by bars a and b in Figure 7.

Students moved from their original desk groups into these 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 the 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 class 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 thorough enough grasp of the geometrical property to be able to return to his or her original desk group and describe the geometry to them. Each desk group member had to describe the mathematical property they had discovered in their expert group. The other group members then had to complete a cloze task relating to the geometry property that had just been shown to them by the student. In this way each student found out about all the explorations without necessarily having to complete them all.

The school that was using this approach had also been using the Te Kotahitanga project (Bishop, Berryman, Tiakiwai, & Richardson, 2003). One teacher commented that this programme had dovetailed very neatly with the CAS project. They also said that they would be disappointed if teaching involving CAS technology was teacher-led rather than exploratory.

Story Two: "Independent" work

This was typified by students performing explorations at their own pace, and in their own way. Three of the observed lessons used this independent approach, but in each case it involved less than half the class time. The classes that used this approach are represented by bars c, d, and e in Figure 7.

Students could choose to work individually, in pairs, or as a group. At times we observed mathematical interactions between groups in quite different parts of the classroom. During the independent explorations the teachers roved and interacted with the students, asking and answering questions. The amount of off-task behaviours in each of these times was the highest observed. One student even commented, "Sometimes I pretend to do work but play games instead." In one lesson a student offered to do the work for a number of students outside class time so that a non-mathematical discussion could be continued in the class.

In these situations there were also some incongruities between stated beliefs on teaching, and what appeared to be valued by the teacher. In one instance a student spent the entire lesson copying down the geometrical propositions into her book. In another, a group abandoned the exploration of the propositions, and merely relied on one student who already knew the mathematical properties involved. Even the student in this group who had started an exploration abandoned it and copied down all the properties into his exercise book. Unfortunately, this group was praised by the teacher as having made the most progress. In both of these instances knowing the mathematical rules appeared to be more highly valued than exploration and self-discovery.

Each of the three classes that employed this approach was a high streamed one. This is a possible explanation for the higher level of off-task behaviours observed. These students may need to move at a faster pace than unstreamed classes. This would be an extra challenge for teachers who would need to have prepared more advanced investigations for the students to move on to, and to have more advanced CAS skills. Alternatively the streaming of classes may need to be revisited. The strongly student-led approach is certainly a viable alternative, but needs to be carefully managed and structured, and perhaps may need to be led by a teacher with a strong personality.

Story Three: Teacher-led interactive discussions

The emphasis of this teaching approach was a dialogue between the teacher and the whole class. This approach was seen in three of the lessons we observed, and was the major focus in one of them. The classes that primarily used this approach are represented by bars f and g in Figure 7. The class represented by bar e also used strong elements of this approach.

While this method was teacher-centred, students were constantly responding to challenges from the teacher to do 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). The one teacher who used this as a major teaching strategy insisted the students turn their CAS face down when he wished them to do things mentally, with pen and paper, or to listen while he talked to the class. Students performed short, sharp explorations either singly or in pairs, and then shared at the whole class level. High levels of student engagement were evident in each of the classes when this methodology was employed. Two of these teachers were already experienced and comfortable with hand-held technology, and all three were able to give quality verbal instructions on how to operate the CAS to perform the required investigation. In one of the classes propositions were set up and actively debated. In another, students discussed possible wrong answers for a mathematical task, and the likely misconception that would lead to this error. Discussion was lively, and students were willing to defend their ideas even when they were in the minority.

Story Four: Teacher-led instruction

This approach most closely resembles the traditional method of teacher instruction followed by students performing tasks. This was observed in three lessons. Bars h and i in Figure 7 represent the two classes that predominantly used this approach. Bar h describes a class that was being taken by a pre-service teacher, rather than the regular classroom teacher who was involved in the pilot. The classes represented by bars d and g also employed strong elements of this approach. Each classroom using this approach had the traditional seating layout of pairs of desks arranged in rows all facing forward.

The lessons began with the teacher demonstrating to the whole class either a mathematical issue or how to use the CAS to perform an exploration. This was followed by a time where the students performed what the teacher had just been demonstrating. As they did so, the teacher roved asking or answering questions and checking that the students were on track. Generally the period of whole class teaching was short, as was the time when students performed the task. This pattern was then repeated several times during the lesson. Students were, however, engaging in explorations rather than doing large numbers of pencil-and-paper examples. These explorations distinguished this method from the traditional approach of a teacher lecture for the first part of the lesson followed by an extended period of independent work.

There is obviously no one correct way to teach. It depends on many factors such as teachers' experience and comfort with different approaches, their own personality and style, expectations within the school, and the individual dynamics of a particular class of students. On the very limited basis of a single lesson observation, we felt that the approaches in Story One and Story Three were the most challenging for students, and had the highest levels of on-task behaviours.

Learning the CAS technology

The teachers generally felt that only a small percentage of their time was spent on showing the students how to use the CAS, with the main focus on mathematical learning. Several did report that they initially focused on how to use the technology, but that this quickly changed to a focus on mathematics. One of these teachers said that the students picked it up fast, while another commented that the technical skills "spread like a bushfire for the first two weeks". Several commented that the emphasis on technical skills was relatively low as they taught just a small amount at a time, with a focus on what was particularly relevant to the specific learning objective they were addressing. Some schools reported that they had handed the CAS calculators out prior to any formal instruction and let the students play with them. These students seemed to quickly and independently work out how to use some of the calculator's technology before the pilot lessons began. Students freely shared their findings with each other and also offered alternative (and often better) ways of using them to their teachers. One teacher warned that you need to be careful with this, as sometimes students' methods had flaws in them, or obscured the mathematical ideas. Several classes had used the CAS in number, prior to their use in algebra or geometry, and this also seemed an effective strategy to familiarise students with the calculators. In all but one school the students were able to take the calculators home and, again, this allowed students to explore them and discover how better to operate them.

Traditional and exploratory uses of CAS

The literature debates whether students should learn the traditional pencil-and-paper algorithms first or whether learning should start with exploration of concepts. Monaghan (2001) states, “Most algebra teachers (I include myself) view [manual] techniques as very important” (p. 464). On the other hand, both Cedillo and Kieran (2003), and Heid (2003) point to studies which indicated that students have higher success rates if learning begins with conceptual understanding and by-hand skills follow. Both approaches could also be done concurrently, each feeding off the other. Kutzler (2003) sees this complementary nature when he comments, “Phases of experimentation should complete or supplement the traditional teaching methods rather than be a substitute for these methods” (p. 61). He also cautions that “We should not banish calculators and computers simply because some students use them improperly” (p. 55).

In this evaluation, the balance between traditional pencil-and-paper teaching methods and CAS-based methods differed between schools and between strands. Especially in geometry, teaching and learning started with the CAS, which was often followed by some form of recording. Some teachers reported that in algebra they started with a teaching sequence using the CAS, while others started with traditional methods. The teachers reported a greater need to link the two approaches together in algebra. In most cases this was related to a perception that it is necessary to have manual skills in manipulating and solving equations, but in some cases it came from parent pressure. Parents often saw the pencil-and-paper algorithmic approach as “proper algebra”. Teachers often checked if students could perform algebraic manipulations using manual methods. They reported that they were largely satisfied the students had acquired those skills, even when there had been little emphasis on them in class.

After receiving some negative feedback from students and parents related to the exploratory approach that was being used in the CAS pilot, one teacher took a series of three lessons that looked at the traditional approach to algorithms part way through the algebra unit. The teacher found that the students acquired these skills in three lessons rather than the two weeks or more it usually took. Other schools also reported that their students in the CAS pilot who were using the exploratory approach were doing at least as well on pencil-and-paper skills as students from other classes who were being taught by the traditional approach.

Students' advice to teachers

Each focus group of students was asked to give advice to teachers who were about to start using CAS calculators in their maths classes. These suggestions have been distilled into several different categories.

Slow down!

This was the most dominant theme, with most focus groups commenting on it:

> Go slower with some things. [Students] can get confused.
>
> Stay on the same topic for a week or so.
>
> Don't rush students.
>
> Make sure everyone has got it [before moving on].
>
> Make sure students understand.

These latter two imply some form of assessment, almost certainly of an informal, formative nature.

Another aspect of this was that teachers needed to spend time with students who missed a lesson to make sure that they caught up. One focus group suggested this could include making sure that they got the necessary data files, or that they got instruction worksheets.

Keep it simple!

This was another dominant theme:

> [You] need to really explain it [well].
>
> Make the language simple.
>
> [Give] step-by-step instructions.
>
> Explain 'why?' not just the CAS instructions.

This last student wanted more complete explanation about the underlying mathematics of what they were performing on the CAS.

Keep it up!

Several comments from the students were very encouraging. "Don't get discouraged," one said, while another said, "Keep doing it. At first I fought against it. [You] need to keep going." This student was clearly coming to understand the value of the CAS pilot approach. "It's hard to teach at first," a third student shared, but went on to be most pragmatic saying, "The students will help [with how to use the CAS calculator]."

General tips

Students had other ideas for effective pedagogy. “Walk around,” one said, while another reflected that teachers should “make students do it themselves”. Maybe this last point is debatable (i.e. the value of individual work versus group work or discussion) but certainly students need to understand it for themselves. “Get discussions [going]”, emphasised the interactive nature of teaching in this student’s mind. On a similar vein was “listen to students”. Another piece of advice was to “learn how to use [the CAS] first”. Certainly the teacher needs some knowledge of CAS, but co-construction of knowledge between teacher and students (and student to student) should not be discounted.

Organisational issues

Teachers and students reported a significant number of organisational and logistical issues that need to be addressed for the smooth running of lessons using CAS calculators. These are reported here, together with some of the ideas of what the 2005 pilot schools may do differently next year, or suggestions for new teachers or new schools. All these suggestions are in the words of those who made them.

Teaching issues

> Teachers need to work through all activities in a unit first before presenting material—knowing where things are going and being more selective. It is easier to match to students’ needs when you are more familiar with material.
>
> Repeat Year 9 material to get confidence in the material and fine-tune what has to happen.
>
> Look at a two-year maths programme so we can work at a more appropriate pace.
>
> Be more selective in material used. Look at the teaching schemes and the assessments schemes and materials.
>
> Students get excited (over-excited) when they see mathematics as active rather than passive.

Professional development issues

> Need to bring other teachers on board but non-maths specialist teachers are struggling.
>
> Meet with the new teachers.
>
> Spread ideas to the whole department. Have regular meetings to plan.
>
> Make other departments aware of what CAS can do and what kids will be able to do with them, e.g. data handling.

Equipment issues

Schools should get data projectors, wireless mouse, rechargeable batteries, and rechargeable USB. Each teacher needs their own data projector. The need to book and set up the data projector is a barrier.

Batteries run out.

Kids forget to bring their calculators to class.

The logistics of collecting calculators in at the end of each lesson is an issue.

Resolve whether the students take them home, which has clear advantages. The ownership of calculators and subsequent insurance issues is a worry.

Teaching in more than one different room is logistically difficult.

Distributing programs from CAS to CAS was a problem [for some but not for others].

Styluses break or get lost.

Time issues

Time is needed to plan, understand, and be confident in CAS use. This is harder than with the bookwork approach.

Having time to reflect and analyse what has gone well and what has gone not so well in a lesson is important.

It is hard to find time to create lessons or new resources.

Students corrupt programs and reloading them is time consuming.

Key points of Section 4

- Changing pedagogy to a more exploratory, discovery-based approach, rather than a rules and algorithmic-dominated approach, is the most important aspect of the project.
- CAS technology was being used as an effective tool to assist this approach.
- CAS technology was being used to enhance understanding, and not as a black box that merely spits out answers.
- Teaching in the pilot classes has moved away from a traditional approach to a more student-led, interactive, exploratory, collaborative, discussion-based style.
- Some tensions existed between the traditional approach and the exploratory approach, though there was evidence that the CAS approach was not disadvantaging the students.
- Levels of teacher-student, and student-student interaction were high.
- Some classes have moved further from the traditional model than others.
- Teachers had workload issues associated with involvement in the pilot.
- A number of organisational and planning issues needed to be addressed.

5. It is not like other maths: Learning issues

This section of the evaluation addresses two separate issues around student learning. Firstly, what is the evidence that mathematics learning has been affected as a result of the CAS pilot scheme? While this has not been measured directly, teachers in the pilot have made informed judgements that are reported here. Secondly, what are students' current attitudes to mathematics, and how have these changed as a result of the pilot? Both teachers and students were questioned about changes in attitudes that they had seen as a result of the pilot. A third issue (has the learning environment been affected, and in what ways?) is subsumed into these two dimensions. A final part follows, where students give advice to future students who may join the CAS Pilot Project.

Student learning

One common concern is that the introduction of CAS will have a negative effect upon students' ability to manipulate or solve algebraic expressions or equations using traditional analytic methods. Numbers of research studies have demonstrated that students who used CAS did just as well as other students who were not using CAS, when computational or procedural skills were tested. Heid, Blume, Hollebrands, and Piez (2002) 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. Some authors have also suggested that the rate of student progress is faster as the result of using the CAS to scaffold students' understanding (Heid, 2003).

Teachers were asked whether they thought students were learning at a deeper level or at a faster pace, and to give anecdotal evidence of any such improvements. They were also asked if the CAS pilot was particularly suitable for students of different ability levels. Students were also asked what effects the pilot was having on their learning.

Deeper understanding

Teachers' views on students' understanding

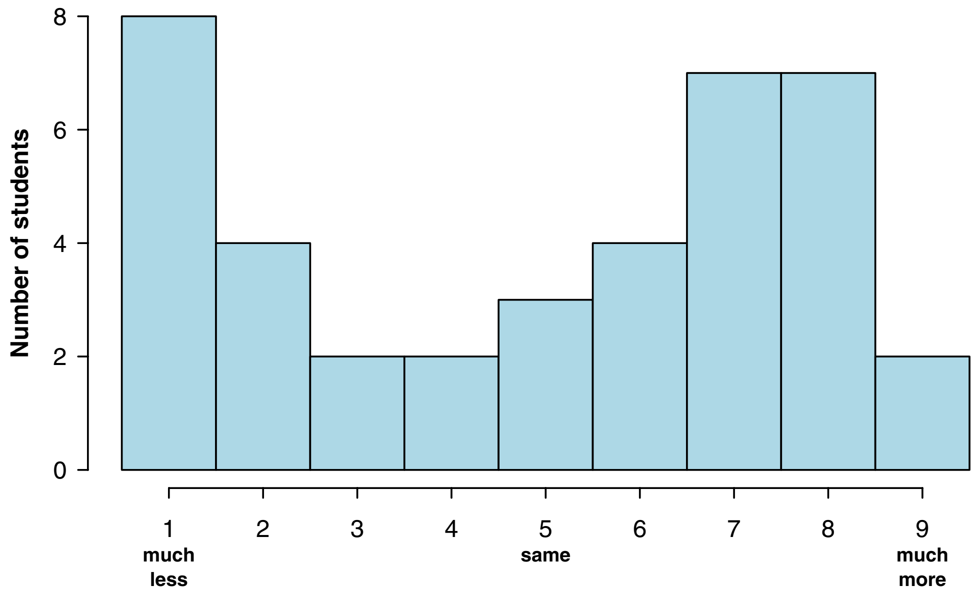
Over half the teachers believed that the CAS pilot had led to students having a deeper understanding of mathematical concepts. One teacher suggested that the learning might be broader as well as deeper, while another commented that they were going further in their mathematics. “They are actually thinking now,” said another. The remaining teachers were still unsure, apart from one who thought that the learning would be of the same depth. This teacher had been a little disappointed with the algebra unit in the pilot, and preferred the flowchart method they had used in previous years. None of the teachers saw the CAS pilot experience leading to understanding that was not as deep. While teachers found it hard to quantify the improved depth of learning, the more sophisticated questions the students were asking convinced one teacher that students’ understanding had improved. Further evidence of students’ positive progress will follow in Section 7 on assessment.

Three teachers identified a number of areas where they saw deeper learning. One teacher saw an improved understanding of the link between equations and graphs. Another commented on the clearer understanding of what algebraic symbols mean, and said that students grasped factorisation better. The third teacher said that their students had been exposed to the idea of mathematical modelling at a much earlier stage. Teachers also recognised that students could transfer from and to real situations more readily. This made their mathematics learning far more versatile and applicable to problem solving.

Students’ views on their understanding

Students in the focus groups were asked whether using the CAS calculators had helped them understand maths better. The distribution of student responses is shown in Figure 8. This is clearly bimodal; with a significant group stating their understanding was worse since the CAS pilot, and a similarly sized group viewing it positively. The pattern of responses also differed markedly between schools. In one school the responses were relatively positive. By contrast, in another school the students uniformly reported that the CAS pilot was having negative or strongly negative effects on their learning. This school was single sex, and all the students were of high ability. In two schools there was bimodality evident, with some students seeing improvements, and others believing they now had less mathematical understanding. The two remaining schools had a small range of responses all of which were relatively close to average.

Figure 8 ***Students' views on their mathematical understanding in the CAS pilot***



A number of issues seem to be affecting students' perception of whether their understanding had got better, got worse, or was about the same.

Positive influences

- Many of the students mentioned specific areas of mathematics that they felt more comfortable with since the CAS project. These included aspects of both algebra and geometry.
- The fact that learning with a CAS calculator was more hands on was seen positively.
- The pilot has helped students engage with mathematics. "I tended to get disinterested in mathematics. CAS has made me do work so I understand it more."
- Students said it helped them remember mathematical ideas more easily.
- Some students have realised that they can perform some of the mathematics without having to use the CAS.
- Some students appreciated learning new things especially the CAS itself, but also mathematical ideas.
- One student had found that proving of propositions and the phrasing of arguments about mathematical issues was helpful to them.
- Some students liked not having to record so much in their exercise books.

Negative influences

- It was hard to catch up after missing out on a lesson, especially on how to operate the CAS.
- Some students found using the CAS confusing. It was easy to miss a step and to then lose track of what to do next.

- Students were concerned that they would become too reliant on the calculator. “It didn’t necessarily [help my understanding] because CAS just did it all.”
- Some students were worried that it may have a negative effect on their future, especially if they had to sit exams without it.
- One student who liked to write in their exercise book found that this was not happening often now. Another said that they “wished we had the [text] books”.
- Some students did not see it as real mathematics, and they wanted a return to more traditional mathematics.

Student reactions to the non-traditional approach of CAS

This last point may be pivotal in explaining the more negative view some students held, and their perception that their mathematical understanding was lower than it used to be. A number of comments of this type were made in the focus groups:

> It’s kind of weird. [We] need some old school stuff.
>
> What’s this [way of teaching] got to do with maths? The calculator gets in the way.
>
> Sometimes I can’t see the point.

Lagrange (1996, cited in Pierce & Stacey, 2002) said that in his experience, “not all students wanted to use CAS. They did not want to be relieved of pen and paper work and that many, in fact, enjoyed doing routine calculations” (p. 576). One student liked the fact that they were learning how to use the CAS calculator but thought they weren’t learning as much maths. It seems to be a case of either students or parents believing “It’s not real maths” or at least “It’s maths, but not as we know it!”

All the students in one focus group believed their mathematical understanding was worse. This was in a single sex school with only high-streamed students taking part in the CAS pilot. They also tended to have the least positive attitude towards the way they were encountering mathematics in the CAS project. Several of them recounted that they used to like maths and used to be more successful with it. This focus group reported some negative reactions from their parents, and this feedback had also reached the teachers. As a result of this, one of their teachers had taken a short series of lessons using the traditional pencil-and-paper algorithmic way of performing algebra. This came after a number of lessons using an exploratory approach to CAS. He found that the students in his class picked up these procedures at a much faster pace than previous streamed classes had done without the grounding in the exploration of concepts assisted by CAS. It seems that having a belief that only a pen-and-paper approach is “real mathematics” had a negative effect upon these students’ views of progress, and that these views were unrealistically pessimistic. This fits with the studies quoted by Heid (2003) who concludes, “Using a CAS before developing related by-hand skills seemed to help students learn concepts in greater depth than the traditional skills-before-concepts curricula” (p. 38). It also fits with the experience of Mayes (1995) who saw performance improve when an exploratory approach was used. At the school where the students all had a negative view towards their levels of mathematical understanding, one student saw light at the end of the tunnel, and she advised next year's students to "Wait! You'll understand it soon."

More than one teacher commented that having previous success at a more algorithmic style of mathematics sometimes predisposed a student to have negative views toward the unfamiliar teaching style of the CAS pilot. "The ones who succeeded with traditional maths see they are missing out," said one teacher, who went on to suggest that some of this may come from attitudes students had picked up at home. One bright student just wanted to have the rules, and again the teacher saw parental attitudes being reflected. One teacher remarked that Asian students were resistant to CAS usage. This may reflect the style of teaching they are used to, and that calculators are often not allowed in the examination systems of some Asian nations. It was certainly the case that negative attitudes to maths correlated with negative views on the increased level of understanding that students thought they had made.

Faster learning

Teachers' views

The majority of teachers were still unsure whether students were grasping concepts more quickly. Some felt that they would need to teach Year 9 a second time through to make an informed judgement on this, while some with streamed classes were unsure how fast progress might be in unstreamed classes. Four teachers had found that students had learnt substantially more quickly. "[I] get through so much more and much faster. [I've] done so much more with them." Another who had used data logging and taken a kinaesthetic approach also saw faster progress. A further two were tentatively leaning in that direction. None reported that the use of CAS calculators had led to slower learning.

Two teachers felt that the speed of learning differed from student to student. "Sometimes [the learning is] almost instantaneous while it takes quite a long time for others to get it. I don't move on until I am comfortable the class has got it." Sometimes it was seen as important to take it more slowly as students needed time to construct their own understanding and to think independently.

Students' views

There were only a few comments on the speed of learning, and these differed from student to student. While one reported that the "class moves much faster now than before, even though it is more complicated", another said, "[They] thought we were lab rats" (which they defined as being slow learners).

Impact on students of different abilities

Teachers were asked if the CAS project had a positive, neutral, or negative impact on student learning for students of lower, average, and higher mathematical ability. Their opinions are summarised in Table 5.

Table 5 ***Teachers' estimation of the impact on learning for different ability groups***

Impact	*Low*	*Average*	*High*
Positive	4	6	7
Neutral – Positive	1	2	1
Neutral	0	0	1
Neutral – Negative	1	0	1
Negative	0	0	0
Mix	3	1	0
Don't know or N/A	3	3	2
TOTAL	***12***	***12***	***12***

It seems from this table that teachers see a positive impact overall upon student learning as a result of the CAS Pilot Project. This was most pronounced for both high achieving and average students, but was not so marked with low achieving students.

- **High achieving students:** There was a consensus that the project was having a positive effect on this group, and was leading to accelerated learning and richer discussions. However, three teachers expressed reservations. One noted the resistance of the class towards the CAS calculator approach. Some high achievers were happy to rote learn rather than stretch their understanding. For some top ability students some aspects of learning may be ridiculously easy when they use the CAS. One teacher mentioned exponential functions as an example of this. Another teacher of a high-streamed class saw a need to "pace algebra differently. It wasn't moving fast enough for some."
- **Average students:** Most teachers thought that the pilot had a positive affect on these students, with only one reporting a mixed impact. Students showed more interest in mathematics, and were better able to generate solutions to problems.
- **Low achieving students:** Four teachers saw positive effects on these students. They were seen as fully engaged, more confident, and enabled to talk about mathematics. Use of CAS also ameliorates against the lower reading and writing skills that some of these students exhibit. On the other hand, reservations were voiced. One teacher saw that they were "doing OK at first, but then it became a bit much". Two teachers said that a lack of numeracy skills was still holding these students back. Some students were not as enthusiastic because they found it hard to use the CAS. One teacher commented, "Some of the higher thinking stuff is hard [for them] to follow." Lower ability students may see the technology as tricky to master. This school was reviewing what to do with these lower tier students. They said, "With three classes at Year 11,

the top and middle [students are] OK, [but we] may need to review the 3rd tier class." There is a benefit for these students in that CAS can provide a backstop for them, or a wheelchair (to use the walk-bike-car-wheelchair analogy in Kutzler, 2003). He sees the extra assistance the CAS can give in a positive light, helping less able students to have their learning assisted and supported by technology.

The school taking part in the Te Kotahitanga project concurrently with the CAS project commented that achievement for their Māori students in the CAS pilot was high.

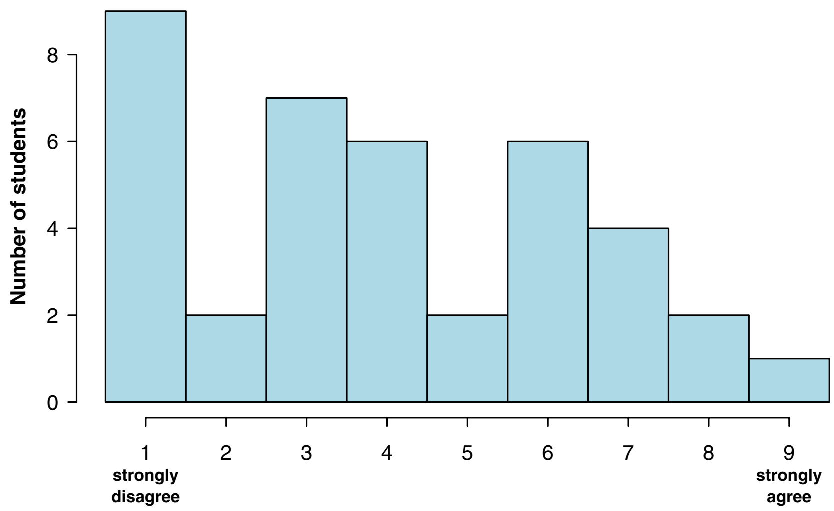
Barriers to student learning

Each of the student focus groups was asked what specific problems they had with learning how to use the CAS calculator, or learning mathematical concepts or skills. Very few comments were made by students about any specific problems they had had with the mathematical content. They were also asked what strategies they employed when they encountered a problem.

Issues with the CAS calculators

Students were asked to respond to the statement "I have had no problems using the CAS calculator". The majority disagreed with this statement, as can be seen by Figure 9. This indicates that most students had at least some specific problems using the CAS calculators. It is perhaps a little surprising that a number of students agreed quite strongly with the statement, which implies they had relatively few problems with the CAS calculator.

Figure 9 ***Student response to "I had no problems using the CAS calculator"***



What, then, were the problems that students had encountered? Remembering the sequence of operations (actual, or on soft keyboards, or drop down menus) that were necessary to perform different tasks was the primary difficulty encountered. The expanding range of CAS operations made remembering them a challenge. Missing just one small step in a sequence would prevent further progress on an investigation. Students sometimes found it hard to find the instruction(s) they needed to enter in the CAS. They often mentioned having to change default settings and not being able to remember how to do this. Batteries caused problems. When they ran out the CAS would freeze and would have to be reloaded. Several had accidentally deleted applications and had to reload them. One student commented that they knew what to do, but didn't know why they were doing it. They could not make the connections with the underlying mathematics.

Obtaining help

Almost all students said that the first person they would ask if they needed help was someone sitting next to them, or a friend. One qualified this by saying that it depended who you were sitting next to—"I go straight to the teacher because the person next to me finds it hard." Most often, the next port of call would be the teacher. One student lamented that you "can't get the teacher's attention". Another said, "If the person next to me doesn't get it, often lots of others haven't got it either." A teacher commented on the sea of hands that would accompany this situation. A few mentioned that they would ask a "go-to" person, "a specialist", or "someone who has finished or knows what they are doing". One was bold enough to say that they would follow the written instructions, but they didn't do that often. A few mentioned going home for help, especially from their fathers.

Other impacts on student learning

One teacher had noticed the way that students enjoyed getting along with each other. "The CAS calculators have enhanced their sharing. They look towards each other." Another teacher who had thought that computers may be better and faster, now saw how the hand-held calculators could be given to another person to share results. One had thought that their boys "were more into it than some of the girls. The boys play with it and use it a bit more than the girls." Another comment was that CAS gives "the freedom to explore. [It] gives students space to play." "It caters for different learning styles", was another observation. One teacher said that their class was more comfortable using other technology such as the internet. A final quote was:

> Students are generally thinking differently. They used to say 'just tell me how to do it' and now they want to understand how it works.

These all add to the picture of changes in student learning, and to the environment in which that learning occurs.

Student attitudes

Many authors have written about the relationship between student attitude and student learning. Cedillo and Kieran (2003) have suggested, "Our students' reactions and our classroom observations were evidence that the introduction of symbol-manipulating calculators in the classroom was a crucial factor in … their positive attitude towards mathematics” (p. 235). Noguera (2001) conducted a study of tenth grade students that included looking at attitudinal changes in students when learning algebra using CAS. She selected the students according to an attitudinal inventory. She observed, “All of the students agreed that they had experienced a positive change in their attitudes towards mathematics” (p. 257). Noguera also saw a significant improvement in the cognitive development of algebraic concepts experienced by the students.

Improved attitudes and improved performance do not always go hand in hand. In a study of university-level algebra students, Mayes (1995) compared one group who used an experimental approach similar to that used in the CAS pilot with a control group who were taught with a traditional approach. He found the experimental group performed significantly better than the control group on reasoning, visualisation, and problem solving while maintaining equivalent manipulation and computational skills. Their attitudes had, however, declined significantly.

In our evaluation, teachers were asked if they had observed attitudinal changes in their students. Students in the six focus groups were also asked a number of questions relating to their attitudes about CAS usage. The attitudes we explored were: how easy they found it to use CAS; how confident they felt using CAS; whether they enjoyed using CAS; and whether they now felt more positive about mathematics. One student had persistent problems getting the calculator to work, and her perceptions on all questions were coded as 1 (strongly disagree), except for her confidence at the beginning of the project, which she scored as 2 (disagree). Her experience was not shared by any other students and may well be due to some external factor beyond her control.

I found it easy to use the CAS calculator

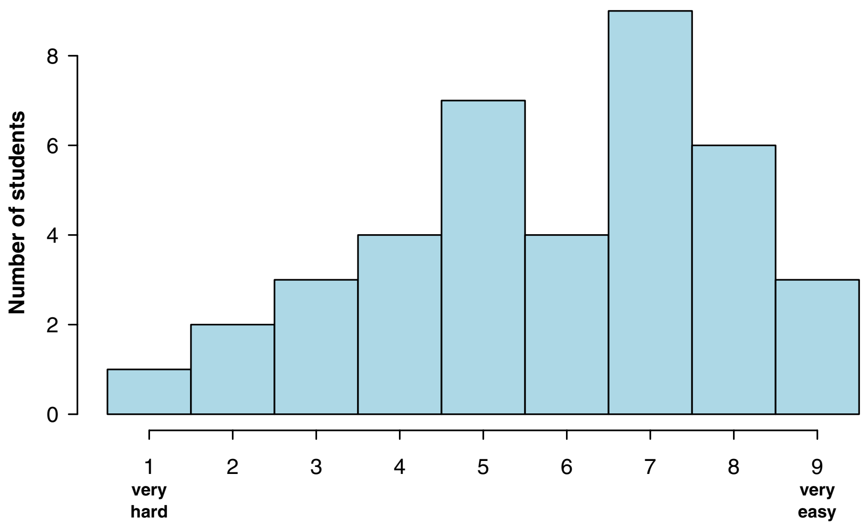
The results of this are displayed in Figure 10. This shows that there were more students who found learning how to use CAS to be easy than those who found it to be hard. Students in one school, however, rated this as relatively difficult compared with the other schools. This school was employing the most consistently exploratory approach to CAS (see Story One in Section 4). It is not clear why this style of teaching would have any influence on the ease of learning how to use the technology. Some students noted that some things were easy and some were hard. Some positive quotes from students include:

> Everyone found it easy.
>
> [It was] reasonably easy once I had picked it up.
>
> [It is] easier now because I know where the buttons are.

Other comments reflected that familiarity with the technology helps:

> I played with it and found out by myself [how to work it].
>
> [It is] like a computer with its menus.

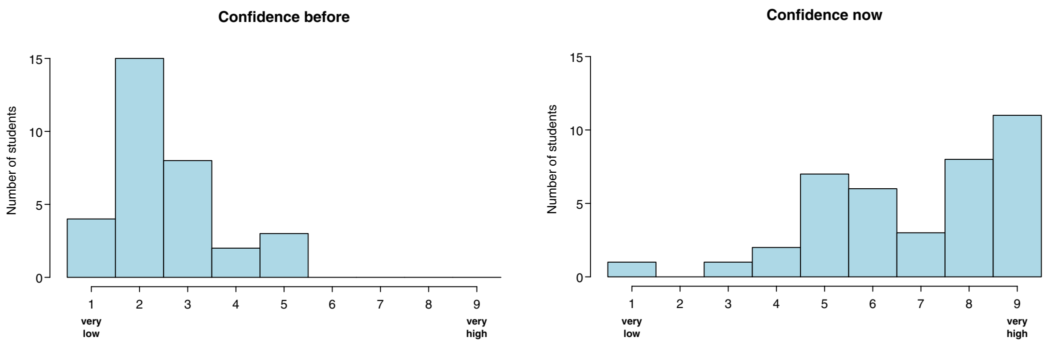
Figure 10 ***Ease of learning how to use the CAS calculator***



How confident are you at using the CAS?

Students were asked how confident they felt at using the CAS now, and how confident they felt at the beginning of the pilot lessons. These perceptions are displayed in Figure 11. It is clear that confidence is generally high now, but was relatively low at the beginning of the project. One shared, "I'm heaps more confident now. I [even] showed it to my father."

Figure 11 ***Student confidence in using the CAS calculator***



The students identified several factors that had helped them to grow in confidence. These included doing plenty of practice: "It's a lot easier for me now because we are doing the same thing over and over again." One said that playing with it a lot had helped. Being familiar with the calculator and knowing "where some basic buttons are" was also a help.

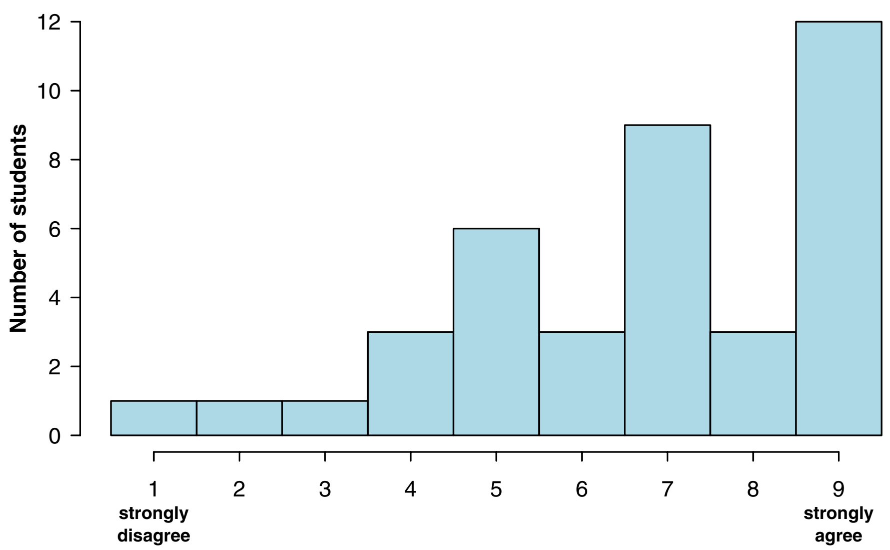
Some reservations were aired. Several students said that they were confident with some aspects of CAS but not others, especially new things. Remembering how some of the features worked was sometimes difficult. Some students also recognised that there was still a lot more that they needed to learn about the CAS calculator.

The student who had the very low confidence said she had all sorts of problems trying to get any sense out of her machine. “One moment the programs were there, then they weren’t”, and “[It] just isn’t working for me”, were two of her comments.

I enjoy using the CAS calculator

Many students agreed or strongly agreed with this statement. Several were relatively neutral, and just a few were negative because they had low confidence in their CAS skills. This included the student mentioned in the last section, who had real problems being able to use her technology. Figure 12 displays the results.

Figure 12 ***Student response to “I enjoy using the CAS calculator”***



There were many aspects of the CAS pilot that students had enjoyed. These included the animations and the games, or that the calculator was like a computer. A couple of students liked having less bookwork or writing. The ease of doing things, because the CAS is “doing it for you”, was also appreciated. One said, “You can have fun and learn at the same time.” Another student enjoyed the ability to work at his or her own pace. Other students simply saw it as “cool”.

The strongest reason for not enjoying the CAS was the complexity of instructions that had to be given to the machine. A “love-hate” relationship with the calculator was expressed by a small number of students:

> [There is] a big sequence [of steps] you have to remember.
>
> It’s too technical.

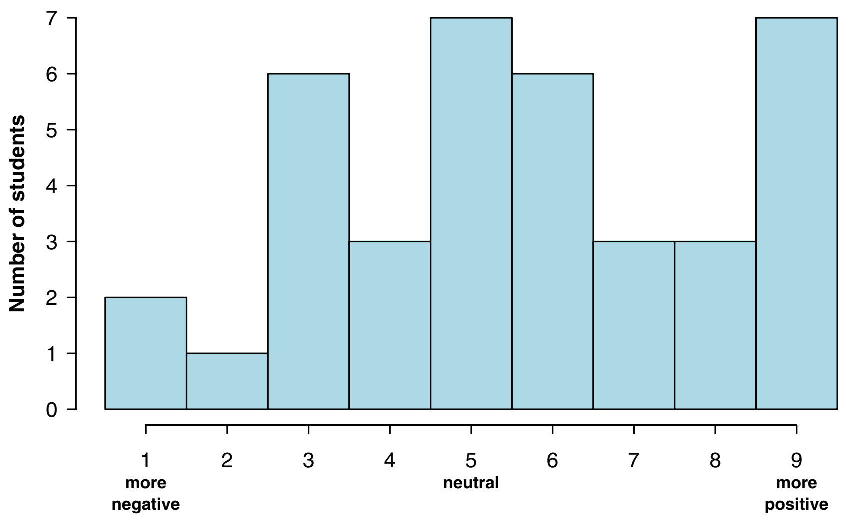
> [It] can be quite frustrating and I can get angry with it. It's quite complicated [and I say] 'Whew!' when finally I'm finished.

Several students said it was boring or that other students thought it was "uncool". One student quite openly stated that they preferred just being told the underlying maths than having to do the exploration. "Just tell us," she said.

I feel more positive towards maths

There was a real mix of views from students when this question was asked. Some students felt much more positive about maths, while others were less positive after the pilot than before it. Some saw it as a dumbing down of mathematics, or it not being real maths.

Figure 13 ***Positivity to maths since using the CAS calculator***



A number of students had commented that maths was no longer boring. Some students who felt more positive about maths attributed it to the novelty effect of the CAS calculator, and recognition of the new approach to learning:

> It's something new. We've done maths since primary school. This is completely different.
>
> It feels like I am not doing as much because I'm not writing it down, but I'm learning as much.
>
> I used to take maths off but now I don't.
>
> Before [I thought] maths didn't help you. Now maths is pretty cool.

However, some students shared why they felt less positive:

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

One student recognised that it was different from what she was used to but conceded, “it might get better”. Section 8 explores some of the influences on the negative attitudes some students display when using technology, while the previous section entitled “Student reactions to the non-traditional approach of CAS” explored students’ beliefs about what mathematics is.

Quite a number of students were neutral, and their attitudes can be best summed up in the words of one student who said, “Maths is still maths.”

Teachers’ views on student attitudes

About half the teachers said that students’ attitudes had changed for the better. “No one now says ‘I hate maths’”, was one comment. This teacher said students were more engaged and were enjoying the CAS experience. Others commented that they no longer heard students saying that they were bored. Several teachers said that the students were loving the project or that they were very enthusiastic and excited about it (apart from a few who were struggling with the technology). The positive effect caused by the novelty of having the CAS calculators was one factor they saw as contributing to this. There is some suggestion that student attitudes may vary from topic to topic. One teacher thought attitudes had improved, particularly in the algebra unit.

The other half of the teachers had seen a mixed pattern of attitudinal changes from their CAS students. Some students hated it and some loved it, some were frustrated, and some were fascinated. Teachers have observed that some students, especially bright ones, just want to be told the rules or do mathematics by the traditional, algorithmic approach. One teacher shared, “Sometimes students’ attitudes seem to [become more negative]. ‘We aren’t learning. We are playing not learning’.” This had led to some resistance towards CAS. At least two teachers commented that they believe some of these negative attitudes are coming from the homes of some students. One suggested that the students’ attitude might relate to their individual learning style.

Some teachers noted the students had better attitudes and less resistance to learning maths in their CAS class than in their other classes. “My other class, who are a lower ability group, hate maths” was one teacher’s reflection. Other students, especially senior ones, were seen by the teachers as being somewhat jealous that their younger counterparts had access to such sophisticated technology, or saw the CAS calculators as cool.

Student advice to other students

In the focus groups we asked the students what advice they would give to next year’s students. Most responses centred on what students needed to do in their learning, but some other advice was also given. Some of the students’ advice sounded a bit like the recommendations that adults constantly impress on children. While this advice seems platitudinous, it is perhaps pertinent in this particular context, as the CAS technology is so novel and new to students.

Listen, concentrate, read carefully

"Listen hard", was a common response. But more than this, the students urged their peers to listen and read very carefully. "Concentrate on every little bit", emphasises the depth of care these students thought was necessary. This is especially so with learning the steps needed to operate the CAS for a specific piece of mathematical learning.

Make sure you understand—ask for help

Because students need to keep up with both the technology and the maths, students emphasised that it was important for them to have understanding:

> Don't just skip [something] and pretend you know it.
>
> Understand what the CAS does.
>
> Do ask if you have a problem.

Catch up and keep up

Several students commented that it was not easy to understand what was going when they had missed a lesson. Keeping up in class was also seen as important:

> Don't miss a lesson.
>
> Catch up if you do miss a lesson.
>
> Get help from a friend.
>
> Even if you don't understand [in class], figure it out in your spare time.
>
> Figure it out first before maths.

As a counter-balance to this, one student warned that trying to rush ahead in class has dangers. "Don't go on ahead because it can backfire."

Hang in there

Some students had taken a while to come to terms with the technology and the new style of teaching. For those who were struggling came the advice:

> Wait, you'll understand it soon.
>
> Don't give up.
>
> It will get easier as you go.

And from the focus group that had reservations about the non-traditional approach of the CAS pilot came, "Give it a go!" Maybe they could see that the benefits of the new way of teaching would become apparent later.

Streetwise advice

Several gems of good sense came from the students. One warned "Don't show off with it too much outside the classroom." They explained that this might tempt someone else to take it. Another cautioned, "Don't download too many games." They had done this and there was not enough memory for the CAS to operate properly in class.

Key points of Section 5

- CAS pilot teachers reported students were learning with deeper understanding.
- The students seemed to have as many manipulative skills in algebra as non-CAS students.
- Many students saw positive benefits for their levels of understanding.
- Student confidence at using the CAS calculators had increased.
- Some students thought they understood less. Often this was because the lessons did not emphasise traditional skills. These students were often the more able ones, who had prior success in more traditionally taught mathematics.
- High-streamed classes may need a faster pace than non-streamed ones.
- Teachers saw the impact on learning for average students as positive.
- Some teachers said some low ability students were struggling.
- The CAS technology created barriers to learning for some students.
- Extensive use of peer learning was evident in all classes.
- Student attitudes were generally positive, except for a small group who did not see the CAS approach as "proper maths".

6. Professional development

The key driver in the CAS Pilot Project has been the provision of quality professional development (PD). The training sessions were run by PD providers. There was a different PD provider for each of the two brands of calculators. Each provider has had considerable experience as a teacher, and they have been working with various classroom technologies for a number of years. The overall PD programme has been coordinated by a teacher with extensive experience of classroom teaching and of providing professional development to teachers, and who has had a deep involvement with NCEA, and close links with the New Zealand Qualifications Authority.

The underpinning aims and philosophies of the PD professionals have provided much of the intellectual thrust for the project. These beliefs and aims have been major shapers of the professional development. Many of the teachers involved also had clear aims for the pilot, and could express philosophies surrounding the place of technology in the mathematics classroom. Before proceeding on to the actual professional development process, the aims of the PD professionals as well as those of the teachers will be explored. This will be followed by a description of the professional development process through the eyes of the presenters and then the teachers. Finally, some reflections on needs for future PD will be made.

Aims of the project

Facilitators' aims

In the words of the PD coordinator for the project "It is about teaching and learning mathematics." One of the PD providers teased this out further when he said:

> [It was about the] use of technology initially. As it has unfolded the aims have widened significantly. [It aims] to affect the way people present their maths concepts to kids through what context they choose and how to present these. How [do we] balance between algorithmic work and conceptual understanding and try and build a bridge between them?

The other PD provider looked at the flexibility the project gave teachers to be innovative because it was begun at Year 9. He said:

> There is not as much application in algebra areas in these junior years, [but] these teachers will be more open to exploration [now] because they don't have the overpowering threat … [of high stakes exams].

The PD coordinator said she believed that teachers become:

> ...more familiar with the tool, to be confident in using the tool in the classroom. That does not mean that they have all the answers but they must be willing to take the risks and to let the children at times be ahead of them in the learning of the tool, but that takes some level of confidence to get to that stage.

She said it was important to have coherent units of work and “well designed material that teachers can pick up and run with” because it provides a “linked sequence of learning for the teachers which you then want them to have the confidence to bring in their own activities, exploration, that sort of thing”.

Teachers’ aims

Teaching and learning dominated teachers’ stated aims, including the role of technology as a teaching and learning tool. Teachers aimed to improve their teaching by using exploration to enhance learning. The extensive exposure to the ideas of the PD presenters may well have had a formative effect upon these aims. All teachers made responses that indicated that the emphasis was on teaching that promoted learning and led to deeper understanding and higher thinking skills. One had the “hope, belief, and expectation, based on the Australian experience, that considered use of the CAS increases performance” and that it would “enhance students’ learning in mathematics by using technology to enhance understanding”. Ideas such as experiential teaching, self-teaching by exploring, and allowing students to establish links through using multiple representations of mathematical concepts were mentioned. One teacher saw a need to make teaching relevant to the twenty-first century.

Teachers also aimed to explore if and how technology affects the teaching and learning processes. Would teaching and learning be enhanced by improved access to ICT in the classroom by employing CAS technology? And what are the most appropriate ways to use CAS technology in the classroom?

Another group of aims was to determine the costs and benefits of using CAS, looking for any negative effects it may have, and ironing out any problems that might occur. For some teachers there was an expectation that the CAS pilot would lead to an increased accessibility to mathematics, and potentially more interest, which might result in a love of mathematics.

Only one teacher included addressing the assessment dimension as one of their aims for the project, and just one mentioned the PD dimension itself.

The professional development process

The professional development fell into three phases. First there was a 2-day introductory session, to familiarise teachers with the pilot project, and the CAS calculators. Next, there were two separate training sessions that looked at using CAS technology with appropriate pedagogy in algebra and then in geometry. Finally, there was a 1-day debriefing of the teachers' experiences of the way the 2005 CAS Pilot Project had gone. We observed one of these debriefing days and had some written feedback on the other. Quotes and recommendations from these days are incorporated in the part of this report to which they relate.

The introductory sessions

Each group of teachers in 2005 had a 2-day introductory session, the main aim of which was to familiarise the teachers with how to operate the CAS. This had been reduced to just one day for the 2006 teachers joining the pilot. The authors of this report observed these 2006 introductory days, which were held in late 2005. These sessions were held substantially before any of the other PD. This allowed teachers to explore and become familiar with the CAS calculators well before they began using them in class. This mirrored the practice in some schools, where students were able to take the calculators home before the pilot began and play with them. One school even used them in a number unit in the first term.

One of the PD presenters described the main aim for this introductory session as allowing the teachers to "walk out feeling that they could sit in a corner without any piece of paper or input and do [things using the CAS]". He had expressed some initial concern that there may not be sufficient support with technology for teachers. He went on to say that he was no longer as worried about doing less teaching on how to use the technology than some teachers thought he should be doing, because the units were fully documented with instructions on how to use the technology. There were no concerns raised about the levels of technical support by any of the teachers in these sessions. In fact they had felt that this aspect was about right.

The other presenter had these same aims for the introductory days. However, the teachers at one of the schools attending these sessions felt that they "needed to spend more time at the start on the technical operation of [the CAS]". One said that it had taken her considerable time to find information from the Web to help her learn how to use the CAS, and also commented, "Materials to help the process of learning about the calculator are needed. [It is] important to bring this material into the algebra unit. This removes a barrier." This presenter had adapted his style for the 2006 training to attempt to address these concerns, even though his preference was for a more exploratory style rather than this more functional approach. "Today had a lot of button pushing, which I abhor," he remarked, when reflecting on the 2006 introductory day. The material and resources for the 2006 sessions taken by this presenter were also being adapted to ensure there was a coherent, linked sequence of learning for the teachers so they could "pick [it] up and pretty much use [it] in the first instance in their teaching" in the words of the PD coordinator. She recognised that part of the 2005 pilot was "to make sure that the quality of the material is excellent before it goes out of our hands and so if material is being written and developed for the first year of the draft now then that is actually a trial of the material which has brought up some issues within the PD for some teachers".

Both presenters, even in these introductory sessions, modelled an exploratory style of teaching, where real problems were posed and the CAS was used to explore them. This reflected their belief that the project is about pedagogy rather than technology. One teacher commented on this in his interview, saying, “The initial emphasis was philosophical rather than technological. Technology is an assistant rather than a driver.” This style of presentation will be explored in the next section.

In these introductory sessions, many examples of peer tutoring were observed. Teachers were naturally working in their school groupings, and when one person missed something out, the other would assist them and show them what to do. This same behaviour was a major feature of interactions between students in the classrooms we observed.

One criticism some teachers made of these sessions was that the problems and examples being used were often “geared at senior students”, which they saw as a waste of time as the pilot was aimed at the junior level. This use of senior mathematics was evident in both of the 2006 introductory sessions. Most teachers were familiar with the mathematics involved, but it did present an obstacle for some of them.

Strand-based PD sessions

The introductory training was followed some time later by 2 days on the teaching and learning of algebra utilising the CAS. A separate day was then spent on the teaching and learning of geometry. Each session was led by a PD provider. Observation of these sessions by the authors of this report was not possible. We therefore present them through the eyes and the words of the PD providers and the teachers who attended them.

Style of presentation

Both presenters had styles that they described in very similar ways. Each of them had a strong belief that they should model in the training sessions what they thought should happen in the classroom. These extended quotes from each of the PD presenters show how they modelled appropriate pedagogy:

> It’s done [in the classroom] on a needs basis. I want it to be activity-based so that the focus remains essentially on the mathematics rather than on [the technology]. … I try and mimic what I do in the classroom. I don’t spend time in the classroom saying ‘This is how we are going to use this tool.’ I do an activity. … When you give kids a piece of software, they don’t read the instruction manual, they start playing and exploring. That’s how they like to learn. If we say to them ‘You have to do this, this, this and this before you are allowed to explore’, then the fun has been taken out of it. … [Last year, in 2005] I did a series of activities and the teachers were like ‘What if we want to do this [in our classrooms], and what if we want to do that?’

> The teachers are like kids and I model what I would do with children. We are fortunate that the materials are different enough to what they are accustomed to for teachers to act like children. They are totally learners. The difficulty for them is that they are learners in three

> ways. They are learners of the technology, learners because they are teachers and they have a new pedagogy thrust upon them, and for some of them they are learners just with the maths. None of the maths is new, but the way of thinking about it is new. You pose a question and all of a sudden they are a learner just like a kid. And then when they get the maths they have got to say ‘Wow, how would I present that?’ … What’s not in the teaching units is the philosophy [so I have to] impart [to] them that this is one way to approach the teaching and learning of maths. I am not going to lecture the theory to you. I am going to model it for you.

Both presenters modelled the integration of technology and pedagogy, with the emphasis on the latter. Both presenters said that they put teachers in the shoes of their students, and both emphasised an activity-based, exploratory, questioning, challenging approach to mathematics. One PD presenter said:

> [I] shock them mathematically. [It is] cool to pose a problem and suddenly they [the teachers] realise they don’t know everything. We all should know this. There is always a curve ball we can throw them. … This should remind them of what their kids do in front of them each day and remind them how they felt.

In these sessions, the major focus was on the pedagogy rather than learning how to use the CAS technology. The teachers judged that between 20 percent and 50 percent of the time was spent learning how to use the CAS, with the rest of the time spent on pedagogical issues. The teachers felt that the time spent on learning CAS was closer to 50 percent in the geometry session, but rather less for algebra. The PD presenters had though that this activity took just 10 percent to 20 percent of the time. “I’d be upset if it was any more than 15 percent,” said one. He explained the difference between his perception and teachers’ perceptions by noting:

> In geometry … the machine was in the hand for much of the time, the vast majority of time was thinking about what they just did, [and] what did it involve? So in that process almost no time was spent on getting an answer, [it was] all directed at processing how to deal with a problem.

Resources

The PD providers prepared teaching units that could be used by the teachers in their own classrooms during the CAS pilot. These were provided in hard copy or in an electronic form that could be loaded onto the CAS. The resources were whole teaching units, and had a number of distinguishing features.

- **Pedagogy:** The resources provided are based on a “theoretical approach to pedagogy, which is inherent in the way they are structured. Things appear early in a unit and come back in a circular way”, in the words of one of the presenters. The resources were based on a model of exploration and discovery.
- **Completeness:** The units were designed as replacement units of work. They have instructions for how to use the technology. “Teachers, if they wanted to, did not have to do anything at all apart from thinking about how they will implement the materials in the classroom,” one of the

PD providers said of his units. They could replace textbooks. Certainly we saw no textbook use in the lessons we observed, and students and teachers both commented that they were not being used.

- **Adaptable:** The materials can be adapted by teachers. Teachers had spent time thinking about how to present the material, and adapting it in various ways to their own classrooms.
- **Context-based:** Each unit was based in a context that was designed to be challenging for students. Some of the contexts were purely mathematical.

The teachers found that it took them considerable time to familiarise themselves with all aspects of these units, including both the mathematical and technical aspects of using the CAS calculators, and to adapt the units to the particular needs of their own classrooms.

Ongoing support for teachers

Both PD presenters had made themselves available by email. Each of them reported that there was only minimal use made of this option, which one said had shocked him as he had expected much more. "Given the positive nature of the feedback I can only assume the training we did worked," he said. He had emailed the teachers with ideas, but remarked that little support was being sought from him. The other provider commented that the strategy of having pairs of teachers who could work together gave effective peer support for the pilot teachers.

The PD coordinator noted "One of the calculator companies has given workshop days in Christchurch and Auckland, with large numbers of teachers attending these, and in Wellington where the response was minimal. Some of these teachers are actually now being invited to do some parallel training to the pilot." The other company took the PD approach of "asking the schools to approach them and then go in and help the school directly".

Teachers' perceptions of the professional development

Ten of the 12 teachers reported that the PD was helpful. Of the two who had replied that it was not, one had come into the CAS Pilot Project part way through, and had only had the PD in geometry. The other teacher needed a greater emphasis on how to use the CAS, would have liked "a written guide to support verbal instructions in all units", and had thought that the initial PD had been "set too high [mathematically]". They had, however, seen some other very positive aspects of the PD.

Several teachers reported that they felt more confident using the CAS, while others shared that "they could not do without the PD", "[I] gained professionally as a teacher", or that the PD was "invaluable". What, then, were the major benefits that the pilot school teachers said had come as a result of the PD, and what were areas that could have been improved upon?

Positive aspects of the PD

The benefits of the PD identified here have largely been gained through an analysis of the teachers' responses in their interviews. These are ordered according to the number of teachers that identified each issue. Some reflections from the PD professionals have also been added.

1. Getting together with teachers from other schools to share experiences and the pooling of resources were seen as key features of the PD. For many of the teachers this was one of the most significant parts of the PD. "The best thing in these sessions is the talking and interaction and sending [each other] emails," enthused one teacher.

2. There was strong modelling of the appropriate pedagogy. Many teachers commented upon the way each of the PD providers modelled good pedagogy, and many saw that appropriate teaching was the key ingredient of the project. One remarked that the "modelling of how work can be presented to students as [if we were] being students [helped us] feel what students feel". Another commented how the pedagogy was "moving away from an algorithmic to a constructivist, student-centred [approach]". One teacher liked the diversity in the presentations.

3. While the pedagogy was modelled, teachers commented that the presenters did not reduce their professionalism as teachers. "[It] gives the base material and leaves the implementation to the teacher," said one, while another commented, "[The PD presenter showed] ways to use the CAS (activities and resources) but teachers were left to implement it in their own way."

4. Having lesson plans and "off the shelf" resources, that teachers could take with them was seen positively.

5. Both PD presenters were seen as being highly effective, with one being described as "one of the top presenters in the world". The emphasis was largely on the pedagogical approach to teaching, based on exploration and self-discovery. The teaching style was seen as very appropriate in general, and not restricted to the use of technology in the classroom.

6. Learning how to use CAS was seen as being an important feature by many teachers. They liked the way this had been blended with ways to teach using the CAS as a learning tool. Most felt there were sufficient ideas about how to use CAS to get by. One teacher said, "[There was] enough on the technology side so we can learn with our students", while another said, "[You] picked up [how to use] CAS as you went along."

7. Teachers, the PD presenters, and the PD coordinator saw having two teachers per school as a strong feature of the PD strategy. One PD provider commented on how effective this was, and referred to one school where the two teachers "work together like Trojans", and another where the two teachers give general support on technical issues.

8. The option to have continued email "helpdesk" support from either of the PD presenters was viewed positively. Even though it was not used frequently, having it as a backstop was helpful.

9. Teachers commented about being challenged mathematically and as teachers. Quotes illustrating this included:

   > [There are] challenging tit bits. [It has] stimulating thinking.
   >
   > [We have] achieved deeper understanding.
   >
   > [It is] good for us because we have to think deeply.
   >
   > [We have been] given material that challenges what we have done in the past and how we have done it.
   >
   > The way we are training students to think is good. [It is] challenging to students, [and they are] more willing to challenge the teacher.

10. Having time to reflect was seen as good. "[I] didn't initially realise the value of the PD. [Now it has] crystallised and affected [my] teaching," one teacher mused.

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

   > [We are] developing greater link between the strands, doing maths rather than the strands, [and it is] great making connections. They [students] suddenly realise that it is all connected and the teachers were wrong [to partition it].
   >
   > Integration of graphing, tables, and algebraic expressions [was effective].
   >
   > As I go on, I think it is good for everything. It is usable everywhere.

Areas for improvement

Although the general consensus was that the PD was highly effective, some areas for improvement were mentioned. None of these concerns were common to more than a few of the teachers.

1. A minority felt they needed more information and time to explore how to use the CAS. The teachers at one of the schools felt they needed more instructions, and said that a simple menu of these would have been a help. They saw a need for written guides to support verbal instructions in all units, and also for more time to be spent on file management.

2. More guidance for lesson plans, especially in geometry, was mentioned.

3. More emphasis on junior mathematics was needed. There was too much emphasis on senior mathematics examples in the training sessions.

4. The PD coordinator suggested that the linking together of otherwise isolated activities in a programme could have aided the teachers at times.

5. Some teachers found teaching geometry easier than teaching algebra during the pilot, while some saw it the other way around:

> Geometry was most successful. [We] spent 4 hours on material [and there were] good extensions.
>
> Materials to help the process of learning about the calculator are needed. [It is] important to bring this material into the algebra unit. This removes a barrier.
>
> Algebra was most successful. [Students gained] much deeper understanding than what they have ever had before.
>
> [The] equation material was excellent, and students found it very valuable.

Future professional development requirements

The teachers and PD professionals indicated a number of key training issues for future PD. Several of these were already evident in the PD for the 2005 pilot teachers.

1. Several teachers said that they needed the training to extend to all strands:

   > It has to go across all strands.
   >
   > [We] need to learn to use it in new areas of maths.
   >
   > Each new application needs an overview of how to use it.

   One teacher said that "seeing what the calculators can do" would widen the boundaries of how she could incorporate them more widely into her teaching. Another teacher saw the need for this to extend to other technologies as well, including data loggers.

2. Teachers and the PD coordinator saw some areas of integration that could be exploited. "[Teachers are] finding it is taking more time with algebra. Algebra covers a lot of measurement. Statistics covers a lot of number." The link between measurement and geometry was also identified.

3. Some teachers suggested they needed more ideas for different ways of using the CAS pilot approach at junior levels. "Year 9 is fresh ground and [we] need more possibilities at the junior level." One teacher suggested that conferences with sessions that showed how to integrate technology in junior maths would be helpful.

4. Future support for effective teaching at the senior level, with supporting PD and resources, was seen as a need further into the future.

5. Time was a big issue. Teachers would like shared non-contact time to do the extra preparation required. Monthly meetings to plan, maybe with the Ministry of Education to fund this with teacher release days, was one recommendation:

   > Time is an issue, to play, explore, and tweak things.
   >
   > [We need] time to absorb and to enjoy the calculator.
   >
   > [Time] is the most crucial bit.

6. More assessment materials, and more information on appropriate assessment were seen to be needed. One of the debriefing sessions recommended "that time needs to be spent writing assessments that are appropriate for the technology as the current questions are not appropriate". The teachers also noted, "assessments may cover several topics rather than a strand specifically".

7. Two policies that teachers thought should be continued were the provision of opportunities to share face-to-face with other schools, and ensuring there were at least two teachers in each school who had CAS-based PD. One of the PD providers suggested a mentoring system including team teaching, observing each other teaching, and using release time for preparations on a permanent basis. These mentors could then show other teachers effective ways of teaching.

8. The issue of how to accommodate teachers who were new to a school was brought up by two teachers at different schools. One of these schools had faced this part way through 2005. Because the pilot was continuing, this new teacher was able to attend the 2006 introductory day. Once the pilot has finished, this may leave a school with just one person who has undergone the PD. Losing one of their CAS-trained teachers would clearly place an extra load on a school.

9. The PD coordinator said that the overarching aim for future PD was to continue to "shift the emphasis to exploratory teaching and student understanding".

Key points of Section 6

- Initial PD sessions focused on giving the teachers skills in how to operate the CAS calculator, and making them confident in its use.
- The algebra and geometry sessions modelled a pedagogy for using the CAS technology in an appropriate "white box" way to encourage exploration, and enhance understanding.
- Complete teaching units were given to the teachers. In principle these should model sound pedagogy, and include a coherent and linked sequence of teaching, and complete instructions, both on the mathematical ideas and instructions to operate the CAS in the prescribed manner. One PD provider was revising their material to meet these criteria.
- Teachers needed time to absorb and adapt the units in their own classrooms.
- The teachers were largely very positive about the PD.
- The interactions and sharing between teachers at different schools was a highlight of the PD for many teachers.
- Teachers requested some improvements, in particular in giving them a better knowledge of how to operate one brand of the calculator.
- The pilot teachers saw that they needed ongoing professional development.
- Each school should have at least two teachers who have undergone PD.
- A wider range of resources is needed, including ones in other areas of mathematics.

7. Assessment of learning, for learning

One of the questions that this evaluation addresses is “What are the implications for assessment of student learning as a result of using the CAS technology? Do current forms of assessment need to change, and if so in what ways?” Both formative and summative assessment were explored when addressing this question. Formative assessment, especially informal formative assessment, clearly supports the quality pedagogical approach that the CAS pilot employs. The challenge is that the summative assessments, especially the high-stakes ones, also need to work in harmony with an exploratory, understanding-focused approach to mathematics, rather than encouraging a more procedural approach.

The teachers of the CAS classes, the professional development providers, and the PD coordinator were asked their views on assessment issues. The pilot project in 2005 and 2006 focuses on the junior secondary school (Year 9 and Year 10 students only) so that any effects of NCEA examinations on classroom practice will be kept to a minimum. For this initial stage of the pilot, the only summative assessments that took place were determined by individual schools. By 2007, however, these students will be taking Level 1 NCEA. Hence summative assessment needs to address the issues of lower stakes school-based assessment, and high stakes national assessment. The major emphasis in this evaluation of the initial year of the pilot is largely on the school-based formative and summative assessments, but the report will also identify some of the issues that need to be resolved to meet the 2007 timeline, and looking further ahead to the 2010 deadline, when all NCEA mathematics examinations will be CAS enabled.

Formative assessment

There has recently been an increasing emphasis on the fundamental role that formative assessment plays in effective teaching and learning. Authors such as Black and Wiliam (1998), and Crooks (2001), plus many others, have written on this subject. Ironically Black and Wiliam’s publication is entitled *Inside the black box: Raising standards through classroom assessment*. This is a different metaphor than the black box–white box metaphor of Buchberger (1990, cited in Cedillo and Kieran, 2003). For Buchberger the black box is the technology, in this case the CAS calculator. For Black and Wiliam, however, the black box is the classroom. 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, derivatives, integrals and so on, 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.

Formative assessment is deeply embedded in the teaching and learning process. One of the professional development providers commented that "if you let the teaching and learning process occur like we've been saying [it should], formative assessment is happening every second of the day. [Teachers] will be assessing continually." The other provider made comments of a similar kind, noting that "good professional teachers can assess roughly where a student is at without doing a formal test. Often [teachers] don't place enough value on what kids are doing in the classroom." If the pedagogy is of an exploratory nature with an emphasis on understanding, rather than procedural or algorithmic with an emphasis on performance, then formative assessment naturally follows.

The strong influence on formative assessment was borne out by the 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. Some examples of questions and exchanges between the teachers were:

T: What do you notice about the two angles?

S: They are the same…. They are **always** the same. Wooo! I've learned something. (waves arms in air in triumph)

T: Do you all understand what [student X] just said?

S: Yes, it's easy.

T: Good, it's meant to be easy.

T: How did you move the lines to make the angles the same?

S: I clicked and dragged it.

T: How did you move [the lines]? Was it like this or like this? (indicates some possible ways)

S: [No, I moved them] to make them parallel.

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. An example of this from one of the classrooms we observed follows. Student one (S_1) was explaining to student two (S_2) that the exterior angle of a triangle has two opposite interior angles and they sum to the exterior angle.

> S_1: You can always get this angle by adding these two.
>
> S_2: What is the opposite angle?
>
> S_1: The exterior angle and the interior opposite angles are these ones. [points to them] Do you get it?
>
> S_2: Yeah I get it.
>
> S_1: It's confusing eh?
>
> S_2: So there are **two** interior opposite angles.

A teacher who observed this conversation would gain insight into each student's mathematical knowledge and understanding, as well as their ability to communicate mathematical ideas and to use appropriate mathematical language.

Teacher reflections on formative assessment

Ten of the 12 teachers said that they were using formative assessment in their CAS pilot classrooms. Half of these reported that this included doing "normal tests", "pre-tests", or "ten-minute tests".

Four teachers commented that they had changed their approach to assessment. In each of these cases they had shifted away from summative and towards formative assessment. The change was often towards informal assessment. One of these teachers said that they now assessed less, but in more ways. Another said they now considered assessments which do not require a pen-and-paper approach. The least experienced teacher in the pilot described a radical shift:

> Initially [assessment] was more summative and I gave a grade. I wasn't very good at coming back to them. Now I assess then reassess. I used to rank students. Now [I assess] to see where they are at. I assess earlier in the unit.

There is a mismatch between this view of informal and ongoing formative assessment and the way teachers responded to the questionnaire. Analysis of the questionnaire showed that the teachers' practice of formative assessment (descriptor 13) had dropped dramatically in their ranking from being respectively the 1st ranked practice pre-CAS to being 10th during the CAS pilot (compare Figures 2 and 3). This was not consistent with the lessons we observed, which included high levels of informal formative assessment. Teachers also said that they employed a large range of informal assessment strategies. One professional development provider suggested, "Sometimes [teachers] won't know that they are doing [informal assessment]." The other explanation of this paradox (i.e. a high practice of formative assessment coupled with it being perceived as being done relatively less often) lies in the strong belief that formative assessment is equated with more formal methods of assessment such as pre-tests or mock assessments to prepare for summative assessments. This was identified in the Shifting Balances research (Hipkins & Neill, in press, pp. 53–54). This perception was also present in this evaluation, when one teacher said they had done no formative assessment because they had "only done a mini-test". Apart from this mismatch, teachers' priorities and practices of assessment were very much in balance. The frequency of the other assessment-related practices that were addressed in the teacher questionnaire had not changed appreciably as a result of the CAS Pilot Project (see Figures 1 to 3 in Section 3).

Informal assessments

Most teachers commented on a range of informal assessment strategies that they were using in their CAS pilot classes. Many of these were seen in the classroom observations. Some of the teachers' responses are categorised and summarised below. One teacher saw that being approachable as a teacher was a key to many of these informal strategies. Another saw informal assessment as a natural part of normal teaching. The level of informal assessment in the observed lessons was particularly high. While no comparative data was available, our impression was that it did appear to be at the top end of what is seen in the mathematics classroom.

Observation

This was done in two ways, watching and listening. One method involved "going around and seeing what they are doing", or "looking over their shoulders". Observing students playing maths games was another way of seeing what students could do. Teachers also listened to students, either in conversations students were having with each other, or in the explanations they gave to a group or to the whole class. In one class students made presentations based on a poster they had prepared as a homework assignment.

Questioning

Teachers said that they used prompts such as "How did you get your answer?", "Why did you get that answer?", "Why are they the same?", or "What do you now know?" One said that it was important to "get into discussion with students", and this was seen in all the classrooms we observed. Another said that they were "asking them to challenge their thinking".

Reviewing

Teachers reported several ways they did this. Some recapped at the beginning of a lesson, reinforcing ideas from previous lessons. In one school the teachers did a review with the whole class after each investigation. Reviewing homework was another strategy mentioned.

Feedback

This was seen by teachers as giving feedback to the students on what the next learning steps might be, and also as helping them to refine their next teaching steps; "reorganising what needs to be covered again, mainly after the lesson for the next one".

Summative assessment

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

School-based assessments

Schools in the pilot had a number of different strategies for summative assessment. Four schools reported different forms of common tests across all of Year 9. Of these, two thought their students were doing better, with one commenting that the CAS pilot "stretches students to be excellent". The third school said the students were doing at least as well on the procedural skills, and the fourth made no comment. One of their teachers said they applied "a precautionary principle so students need to be prepared for situations where they can't use CAS". One teacher reported that their CAS students took much longer on the common test because they were relying on the calculator, and were using it to check on things they had already done by hand or mentally.

The form of the common tests varied from school to school. One format used was that the first one-and-a-half hours was in common between all classes regardless of whether they were in the CAS pilot, with a separate half-hour test for the two CAS classes. The second school had a similar system, but their test was in three parts. Part One allowed no CAS use, Part Two was for CAS use only, and Part Three allowed CAS to be used but the results were then recorded using pencil and paper. Two other schools had a common test that was used across all Year 9 classes regardless of whether they were in the CAS pilot or not.

The remaining two schools had no common test, but did a series of teacher-written tests at different points within the pilot. In at least one class these results were used to refine the teaching. One school said that they would be having an end-of-year exam, but that this would need to be different for CAS students.

Students' experiences of assessment

When students in the focus group were asked about any assessment they had experienced, their replies almost invariably indicated that they interpreted this as tests or exams. Only one had picked up on the idea of formative assessment, commenting that their teacher “asks random students”.

Several comments were made about the style of tests in the two schools where separate parts of the common tests were designed for the CAS pilot students only. One student said, “The special part was hard and a bit confusing”, while another said that they “got it right but didn’t know why”. Some of the students at one of these schools were concerned that they had done poorly on the common algebra items. Both the CAS classes were high-streamed. Their teachers did not concur with these students’ impressions, and saw it as an attitudinal response to the new pedagogy.

Students in one of the two schools where the teachers had developed tests that were designed for their CAS students only, saw these assessments as quite different from what they were used to. They reported that they had to do more explaining, the tests were “more technical”, and they included more information. They also commented on the different language used in these tests.

Implications for summative assessment

Teachers in the CAS pilot schools felt they needed to address a number of issues around their own summative assessments. Many of these same issues also need consideration before CAS-enabled high-stakes assessments, at Levels 1 to 3 of NCEA, come on line. One professional development provider stated that NCEA is his “biggest concern in this project, especially at Year 10 [and beyond]”. He could see that the direction at Year 10 could well be “a halfway house with a little bit of exploration and a little bit of traditional side”. He went on to warn:

> How do you develop high-stakes external exams that ensure that the big players feel their subject is not being ruined, [but] that doesn’t disenfranchise all the hard work teachers have put in to [this project]? In senior experiences overseas they don’t want to scare the horses so there weren’t a lot of changes. So there is no PD and ‘double-layering’ (putting technology teaching over the top of traditional methods) occurs. People think things will change because technology is here. … There is one thing that is found if you give kids technology and don’t affect teachers’ pedagogy. It will fail. Nothing will happen. … How do you make assessments that don’t encourage teachers to not develop their pedagogy? That’s the tricky part.

The other PD provider said:

> [Assessment] has to change because the content has changed, the technology necessitates that change, and a lot of the other stuff becomes trivial… We often get scared off because the sorts of question I ask … really challenge kids’ understanding of what’s going on and as a result people see them as much harder problems. Naturally they will be harder because they are testing understanding, not the ability to regurgitate something which has been drummed into them in the classroom. … If you are really scared of whether of not the kids are going to pass or fail then what you are really saying is ‘I don’t know if my students understand these [ideas] yet.’

The PD coordinator said:

> CAS can enable or be a catalyst for changes to the way maths is taught and learnt. … [We] need to look at NCEA. [It has] a variety of features. [This project] is about teaching and learning, and the chance to grasp a PD opportunity.

The corollary of these statements is that summative assessment should be supportive of effective teaching and learning, not just a valid and reliable way of measuring student learning. It is not just formative assessment that supports good pedagogy, summative assessment should as well. If it is valued in teaching, it needs to be reflected in the high-stakes assessment (Harlen, (2005).

Testing for understanding

There is a general consensus amongst teachers and professional development providers about the ways in which summative assessments will need to change. Assessments will have to be adapted so that, as the professional development coordinator says:

> [Assessment] is more about gauging understanding rather than skill. It is more in line with numeracy where students are exploring and gaining understanding.

Comments supporting this also came from teachers:

> The sorts of questions will best not be algebraic skills that CAS can do for anyone. [There needs to be] an emphasis on understanding, and deeper understanding.
>
> [We] need to design tests to see students' understandings. They need to record how they got their answers, or what steps they took to get a solution.

The challenge is then, in the words of the PD coordinator, based on "teachers' ability to change the style of question". "How do you show understanding of an algorithm? It is hard," commented one PD provider.

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, according to the PD coordinator. Skill-based questions can be done very quickly. Students will just need to write down the answer. Students may, however, have to record with pencil and paper how they got their answers, and not just "press a button".

Non-CAS dependent assessments

If there is to be one standard for all with a single exam, questions will need to be CAS-independent. 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 such as Brown (2001), Forbes (2001), Leigh-Lancaster and Stephens (2001), and Saunders (2003) have written on this subject. Teachers are asking to be given information on the form of the 2007 questions well in advance, so their students are not disadvantaged. Some initial models for CAS-independent questions have been circulated to begin this conversation, but much more work will be required in developing quality questions of this sort.

Even with this CAS-resistant approach, teachers have brought up questions of equity. Some suggested students could get answers more quickly using CAS, even when answering "CAS-resistant" questions. One teacher took a contrary view. They had observed that students took much longer because they were relying on the CAS calculator for things that could be more efficiently done mentally. Inequity may also extend to the teaching level if it turns out that learning with (or without) a CAS gives the student an advantage.

What to assess

The PD providers and the teachers pointed out that there should be a questioning of what mathematics is, and therefore what to assess:

> What mathematics is important?
>
> What do we want to assess?
>
> [We] may need to reprioritise some of maths. Some things that were previously seen as important aren't so important.

These show the need for this basic refocus on what mathematics is. More emphasis may be given to problem solving, framing, and laying out a problem, and less emphasis on the "doing" (solving).

Time to write summative assessments

A recommendation from one debriefing day was that "time needs to be spent writing assessments that are appropriate for the technology, as the current questions are not appropriate". A PD presenter reflected that it is still early days in the project and that he would prefer to leave the assessment issues until next year. He did say, "How do you show understanding of an algorithm? It is hard" and "It's OK to say 'We don't know yet' [how to write assessment questions] as long as we don't sell out these teachers [and the pedagogical style employed in the pilot]." Some of the teachers who had developed their own school-based assessments commented that this was a time-consuming task. One said that "teachers would have liked shared non-contact [time for planning of teaching and assessment]. This is the most crucial bit. Time was an issue." They went on to suggest monthly planning meetings, and that "maybe the MOE could fund these with TRDs".

Cross-curricula 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. This would preferably be for both teaching, and in high-stakes external assessments. Having just the one calculator throughout the whole of secondary schooling and in all subjects would be the ideal.

Key points of Section 7

- High levels of effective informal formative assessment were occurring in all the pilot classes.
- Teachers did not always recognise the high level of formative assessment that they were utilising, usually because they were not employing many formal assessments.
- Pilot schools had experimented with a number of styles of summative assessment.
- Summative assessment needs to reflect the values of exploration and understanding.
- New forms of summative assessment are needed. Some of these may need to be CAS-resistant.
- Teachers need models of assessment styles that will be used in high-stakes assessment.
- The role of CAS calculators in assessments in other subject areas needs to be addressed.

8. Technology in the classroom

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

The effective and appropriate use of CAS depends on a number of factors. Key factors include the attitudes of teachers, the professional providers, students, and their parents/caregivers towards technology in the classroom and its effective use. This chapter explores these attitudinal dimensions for each of these three groups, and also explores teacher use of, and skills in, technology in the classroom.

Attitudes to technology in the classroom

The extent of the impact that technology has in the classroom depends to a large extent on the teachers' attitudes, views, or philosophies concerning its use.

Teacher reflections on the role of technology

Teachers gave the four descriptors for technology in their practice a medium ranking for their relative priority amongst the 20 practices that they rated in the self-reflective questionnaire. The technology descriptors were ranked between 10^{th} and 13^{th} (see Figure 2). All four of the practices had a statistically significant increase in their frequency of practice during the CAS pilot compared with the frequency before it started. All had moved upwards by about 1 to 1.5 units on a 5-point scale (see Figure 1 and Table 4). This is, of course, no surprise as the emphasis of the pilot was on utilising technology, but it is noteworthy that these four descriptors showed the largest change in practice, with only three other descriptors showing a significant (but lesser) increase.

The largest increase in practice was descriptor 16 (using learning technologies to support quality learning behaviours such as exploration, conjecture, or collaboration). This was to be expected, as this is a key aim for the project. What is surprising, however, is that it no longer matches teachers' priority as well as it did prior to the CAS pilot, but is now seen as being done too often relative to other priorities (see Figure 2). While it is encouraging to see its high profile in practice, this gives some evidence that teachers' priorities may need to shift even further in the direction of exploration and conjecture, if indeed these are key features of best practice in mathematics. The mismatch may, of course, be created to some extent in the valid belief that exploration does not have to employ technology. This does appear to be the case because descriptor 1 (providing stimulus materials that challenge students' ideas and that encourage discussion, speculation, and ongoing exploration) was ranked as these teachers' top priority.

A similar pattern of increased practice but a worse match between priority and current practice was seen for descriptors 17 (creating a classroom environment where ICT is an integral component) and 18 (being a guide, facilitator and co-learner with students learning ICT in the classroom). Again, these mismatches are understandable, because both the teachers and students were on a steep learning curve on their ICT knowledge, and the CAS had a higher profile in a pilot than it would in a normal classroom.

Descriptor 19 (providing opportunities for students to engage in activities enhanced by ICT which are essentially self-evaluating, co-operative, and collaborative) has undergone the second biggest increase in practice. Prior to the CAS pilot, teachers saw that this was not being done nearly as often as they would like (see Figure 3), whereas during the pilot its practice and priority were more balanced (see Figure 2). The CAS pilot has had a significant and positive effect on the self-evaluative, co-operative, and collaborative nature of the classrooms. This was clearly seen in the lesson observations, where we observed high levels of pair or group work, and of interactions with the teacher.

Teachers' and PD professionals' philosophy on classroom technology

The views of the PD professionals may well have had a strong formative influence upon the teachers who attended the various training days. This section combines the philosophy of the teachers and the professional development professionals.

Technology is a tool with a purpose

About half the teachers reflected this theme, as did all of the PD professionals. One teacher stated, "[It is] just another tool in the box of tools you've got to teach kids with." Several of the teachers qualified their statements by saying that technology is a tool to deepen learning and understanding. There are three aspects to using the CAS as a tool. Firstly it allows exploration and discovery, secondly it supports open-ended investigations, and thirdly it can remove the relatively mundane details of a problem and allow a focus on the higher-level concepts involved. In what ways, then, did the teachers and PD professionals see technology as a tool for enhancing learning?

Exploration and discovery

The PD coordinator saw technology "as a tool that allows a greater depth of exploration". "[It is a] learning tool to help kids discover and learn," said one teacher. "Kids having access to technology that they can play with" was valued by one PD provider, who recommended that to maximise this kids "need to take them home". A teacher said that it was "a learning tool to help students discover and learn"; while another said that she "loved the creativity it can inspire".

Open-ended investigations

> It allows more open-ended investigations.
>
> [It can be a] support vehicle [that can help us] get there to solve a problem or interact with a problem.
>
> It allows you to be more open-ended in the way you ask questions that are above their level, for example explore 5 factorial.

Scaffolding for learning

The CAS can take the mundane out of computations. "It saves time, and you don't get bogged down", was one teacher's observation. It provides scaffolding that lets students focus on the mathematical concepts rather than just on the manipulative details. It can also be a time saver. This is especially true in moving between multiple representations of concepts, for example algebraic, graphical, or tabular ways of expressing a problem. It can scaffold students into exploring mathematical concepts in more depth by removing lower-level computational errors, which would obscure the higher-level concept being explored. Kutzler (2003) describes this 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 higherlevel. Both PD providers gave teachers software that allowed students to focus on higher-level algebraic ideas while performing the more mundane computations for them.

Technology allows more realistic contexts

The PD coordinator and a couple of teachers commented that the technology can deal with real expressions in a range of contexts so that students can do realistic problems, not just ones with "nice" whole number answers. "You need to adopt a real world approach and real world problems," said one teacher, while a PD provider said, "[It] affects the way teachers think about mathematics. [I have] tried to write problems [teachers] may not have thought of."

It's not about technology, it's about enhanced teaching and learning

This contrasts with the above view, but certainly does not contradict it. Comments like "It's not about technology but pedagogy", "[It's] the way you teach with it", and "Use it if [and when] it works" all say that it is more about appropriate pedagogy than about the technology itself. This key theme was repeatedly stressed by the PD providers and coordinator, both in their aims for the project, and in the associated professional development. "It's not CAS that helps [good teaching]. CAS is one small part of it," one of them said. Section 4 on teaching, teases this theme out further.

Technology has potential drawbacks

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

Changes in teachers' attitudes to technology

Half of the teachers reported that they had changed their views on technology as a result of the CAS pilot. Before the pilot began, three of these teachers had been negative towards technology or at least had reservations about it. The first had been "resistant to it before. I used to believe that pencil and paper were most important", the second said that they "used to be anti, and I didn't want to do it", while the third was "initially somewhat reserved and anxious about [my] ability to teach with it". The other three who changed their views towards technology use in the classroom had become more positive about its use as a result of using it in the pilot. At least one of these teachers was already a very strong and active supporter of classroom technology before the project began. Another made the comment that they preferred the hand-held technology to be in the classroom and "didn't like the computer lab environment". Similar comments to this had been made by a number of teachers who either preferred the immediacy of the hand-held CAS machines, or had organisational issues with respect to getting time in computer labs.

The six who had not changed their views had all been positive about the role of technology before the pilot began. By the time of the interview, all teachers had a positive view of technology in the classroom. One warned that this would not be the case if it were "in the wrong hands" (i.e. used as a black box).

Students' views on whether teachers like the CAS

This question was put to each of the focus groups. The results were a resounding, "Yes, they do!" Some of the quotes were delightful:

> Our teacher goes home and plays around on it, and finds new stuff.
>
> He knows we find it more fun and more challenging.
>
> [They] seem to be obsessed.

> Ours is over the moon.
>
> I think he's more excited about it [than us].

Students' views on technology

Students' views have been discussed in detail in Section 5 on student learning, where we concluded that, on the whole, students found learning to use the CAS to be reasonably easy, they felt confident using it once they had been using it for a while, and by and large they enjoyed using it. What was the teachers' perception of their students' attitudes to CAS technology?

Teachers were not surprised that students adapted to using the CAS calculators, as young people often are more comfortable with new technology than adults are. One student commented that the CAS is "like a computer with its menus". Another commented that the icons were also helpful, while one said, "It's pretty self-explanatory."

While students found it easy to use the CAS calculators, almost all of them agreed that they had specific problems with them at times.

- Hardware-type issues included breakdowns, freezing up (an odd combination of metaphors), batteries going flat, styluses going missing or breaking.
- Software-type issues were centred around remembering the sequences of "programming steps" that were required to perform individual tasks. "[It is] easy to get into CAS but hard to remember, [especially] changing settings", "[There were] big sequences that you had to remember", and "Sometimes you miss the littlest step and have to do it all again" reflected some of these challenges.

The relationship between the CAS technology and mathematics was the other concern. For some the issue was that they could not clearly see the linkages with mathematics. Comments that demonstrated this included:

> [It's] not about how to use it. I could do the CAS but not the maths.
>
> [I] knew what to do, but not why.
>
> [I] really enjoy using CAS but … [I] am not learning as much maths.

Some students thought that using CAS seemed to be dumbing down mathematics, and some expressed concerns that they were not learning "proper mathematics". These issues are expanded further in Section 5.

Parents' or caregivers' views on the CAS technology

A range of parents' or caregivers' views was reported by the students in the various focus groups. Some parents or caregivers were positive, and some were negative. Some saw the CAS as mysterious, while others were just not interested in them. Teachers also gave feedback on the attitudes of parents or caregivers to the CAS Pilot Project.

Student feedback on parental/caregivers' views

Positive comments

Far more students reported positive attitudes than negative ones. A selection of these follows:

> [They] think it is cool.
>
> [It] is a better opportunity to learn mathematics.
>
> My Dad saw it as an instrument from the space age. If it was given to younger children they could learn more.
>
> [My parents] always encourage me to use more technology to make me more intelligent.
>
> [They] think it is a privilege.
>
> My Dad is good at maths. He can use it. [Recounted how he commandeered it as soon as she took it home. She went on to describe]: For some weird reason [I'm understanding more maths now].

The last of these shows just how powerful positive parental attitudes can be. A number of students said that they could also get help at home, either on how to use the CAS or on mathematics in general. It also shows the hidden benefit of distributing learning beyond the school system when parents learn from, and with, their children.

Negative comments

There were about half as many negative comments as there were positive ones. Many of the negative responses came from one school. Some of the parental attitudes reported by students were:

> [It could be] affecting your grades [in a negative direction].
>
> Mum doesn't want us to be dependent on calculators.
>
> [My Dad] doesn't help with CAS but does with maths [goes on to describe how she does traditional pencil and paper at home].
>
> My Mum gets pretty annoyed when you don't know what happens.

The last comment seemed more one of frustration and suspicion that her child was not learning as much as she would like.

One focus group spent some time discussing whether their parents/caregivers might buy a CAS calculator. The results were consistently negative, but showed students had an insight into the marketing of modern technology:

> S_1: Are you off your rocker? (when told they cost over $300)

S_2: You'll have to pay?

S_3: How long will you use it for? What will the batteries cost?

S_2: Will I have to pay for programs and updates?

S_4: When will there be something better and cheaper? They could get obsolete.

Other attitudes

For some parents, the CAS was a mystery. "They don't understand them", or "Mum likes the idea, but it's a mystery [to her]. She doesn't know how to use it", were typical responses. The final, and perhaps saddest category was encapsulated by one student, who said:

> I went home on the first day all excited, but my parents didn't really care.

Teacher feedback on parental/caregivers' views

Teachers reported a variety of responses from parents or caregivers to the programme. Around a third reported that they had positive feedback, a third had negative feedback, and the remaining third had mixed feedback (though generally there were larger numbers of parents being positive).

One teacher had adopted the strategy of having four lessons focused on traditional methods to try to address some of the negative responses.

Positive views

Some very positive feedback from parents or caregivers was reported. One thanked the teacher for the change in attitude of their child, and went on to share how their child had extra confidence in mathematics now. Another parent commented on how much more time their child was spending on mathematics. "Most of the parents are positive and excited", or "[They are] largely positive. [There is] no negativity", were typical responses. One teacher said "Most of my parents [are] very open-minded", even though this same teacher had noted "Parents can't understand what we are doing so one student [has] 'moved out already' (in a student's own words)."

Negative comments

Some of the negative comments came from parents who were perceived as very conservative, and related strongly to the "proper maths" that they did when they were at school. "Why don't they teach them the way I was taught mathematics?" One teacher commented "A lot of parents think that calculators are an evil, so I predict they will be slow to come on board." Another teacher commented, "Parents need to re-examine their beliefs in what mathematics is. Negative views from students are often learnt from home." Several teachers said that the parents/caregivers were not explicitly negative but had "queries", "fears", or needed "calming" or "reassurance".

Parents had also commented that they could not help their children with mathematics. "[This] is not the maths that I did at school." One parental concern related to how a student would cope if they had to move to a non-CAS school. Parents raised some concerns at whether their child may be disadvantaged once they had to do NCEA assessments.

Many teachers saw the issue of price as a barrier for parents, while others touched on this same issue by commenting on equity. The slow uptake of graphics calculators, even with their current price at under $100, was pointed to as evidence for the effect that the price of CAS may have upon their uptake. That CAS technology use is discouraged or disallowed at university was also seen as a disincentive to invest in one. The security of the calculator, with associated insurance issues, was also a concern for some parents as well as for teachers.

Teachers' use of technology in the classroom

These teachers all had a reasonable grasp of technology, with a few of them being highly competent in a range of technologies that they regularly used in their classrooms. The 12 teachers were asked at the beginning of their self-reflective questionnaire which of a list of technologies they used in the classroom, and whether they used these routinely, rarely, or never. These were scored as 2, 1, and 0 respectively. They also rated their personal skills in each technology as skilled (2), basic skills (1), or never used (0). The results are summarised in Table 6, where they are organised according to frequency of classroom use.

Only one teacher mentioned using any other technology in their classroom. They had regularly used data loggers in their mathematics classrooms. This same teacher had also been regularly using CAS calculators in their mathematics classroom. No other teachers had used it before the pilot began.

The major item of technology regularly used by all these teachers in their classrooms (apart from the CAS calculators) was the scientific calculator, and to a lesser extent the graphics calculator (though these would presumably be with their senior classes only).

The use of spreadsheets, internet, and PowerPoint was far more limited, though the majority of teachers had used them on occasions. Data projector use will have increased as a result of the CAS pilot, and it probably had only limited use before the CAS pilot. Algebraic software or databases only had rare use from a minority of teachers, with the remainder never using them in their classrooms.

Overall the pattern of responses does suggest that these teachers were already reasonably competent in the use of a number of technologies, and were using them to various degrees in the classroom.

Table 6 ***Teachers' perceptions of their use of, and skills in, different technologies (n=12)***

Type of technology ***(Ranked by frequency of use)***	***Average classroom usage***	***Number of teachers ever using it***	***Average personal skills***	***Skills ranking***
CAS calculator – now	1.92	12	1.5	4=
Scientific calculator	1.75	12	1.92	1
Graphics calculator	1.50	11	1.5	4=
Data projector with calculator	1.42	10	1.33	7
Spreadsheets (e.g. Excel)	1.25	10	1.67	3
Internet	1.17	12	1.75	2
PowerPoint	1.08	10	1.42	6
Algebraic software (PC-based)	0.33	4	0.67	9
CAS calculator – Pre-pilot	0.17	1	0.25	10
Databases	0.25	3	0.92	8

Key points of Section 8

- The CAS pilot teachers are placing more emphasis on technology in the classroom.
- Teachers see the technology as one tool for learning, not as the driver of learning.
- Technology allows more authentic contexts to be used.
- The teachers were largely positive about the technology.
- Students enjoyed the technology, but encountered specific problems on how to use it and why they were using it.
- Many parents/caregivers were positive about the CAS, but some had reservations. They often perceived it as not being real mathematics, or as just a black box that would hinder their child's understanding.
- Schools were communicating with parents/caregivers about the potential advantages of CAS technology as a tool for learning in a variety of ways.
- The price of the technology could be a barrier for many.
- Teachers were already using scientific and graphic calculators regularly in their classrooms, and had good skills in their use. Other technologies had a far lower level of classroom use. Only one teacher had used CAS in the classroom before the pilot commenced.

9. Into the future: Sustaining the CAS initiative

One of the research questions was "What issues will need to be addressed and what support will need to be given to teachers to enable the effective and sustained use of CAS technology?" We will discuss a number of dimensions for this question, including getting teachers and parents on board, professional leadership, professional development and resources, assessment issues, as well as advice that teachers and students have for those not yet involved with the project.

Getting parents on board

As discussed in Section 8, the parents displayed a range of different attitudes towards the project. These have been discussed in Section 8 on technology. What were some of the strategies that schools adopted to try to redress the negative attitudes of some parents? One teacher reported "massive resistance initially. Parents will need to be educated in [CAS] use and reassured that their child will still understand mathematics." The key is, of course, quality communication. Schools had used several strategies to inform parents:

- Several schools had made it the major focus of their initial meet-the-teacher evening or parent interviews. One teacher who had acknowledged that "It's a big thing and a bit confusing and threatening [for parents/caregivers]", commented on the very high parent turnout for this meeting, and the good conversations it engendered.
- Two schools reported getting students to explain a mathematical idea to their parent or caregiver during a session held for parents. One of these schools stated that these "student demonstrations [were] valuable. This was very powerful at the parent report and school open nights."
- Some schools had sent written information home to parents. One school said that they want to have a parent newsletter next year, and that parents will be able to log onto the school website so they are kept up to date with the project.

Some teachers who had seen an initial resistance from parents saw it diminish with time. One said that "[they] are really positive now".

There have been many comments that the price of the calculators will present a significant barrier. One approach is to attempt to influence the priority of parents who may "buy $200 shoes and a

$20 calculator where in other cultures parents may buy $20 shoes and a $200 calculator". The PD provider stated, "Cost! I don't believe it. If [parents] see the benefits [price] won't be an issue." Schools must clearly communicate the benefits of effective teaching using CAS to parents and caregivers.

Getting teachers on board

When the pilot teachers were asked how other mathematics teachers who had not been exposed to the project might react, there was a mix of responses. About a third were positive about this, a third were negative, and some had a mix of views.

One teacher had already been working with other teachers in their school. This teacher's colleague said that "some are positive, [while] some show no interest. It depends on their views on technology." Some positive comments included:

> [The other teachers at our school] were all excited. [There is some] hesitation at the work levels.
>
> One college [nearby] was very keen to be in the scheme. 'The MOE is doing it so we need to get on board' [they told me].
>
> [There is] good support within the school. Most of the maths teachers wanted to get on board, [but there were] issues with science, economics, and geography teachers.

Some other comments show various levels of scepticism about wider teacher involvement:

> Teachers can be pretty conservative too, and can have very limited technical ability.
>
> There is teacher opposition, mainly based on ignorance.
>
> Oh, another instrument!
>
> The graphics calculator came without back-up. 'What is there left to teach?' was the teacher's response.

Teachers need to be convinced that there are real benefits for themselves and for their students to buy into any initiative or technology. The PD coordinator said that teachers "didn't buy into graphics calculators until they saw that their students were being disadvantaged [by not having them]".

"How do you get a nation of teachers to develop their pedagogy so the best use can be made [of it]?", was the challenge made by one PD provider. Some aspects of this are explored in the following sections.

Support to sustain the project

It must be remembered that the schools and teachers who were in the pilot were all volunteers. They had replied to an advertisement and were all willing and highly motivated to be involved. Several of the schools already had a strong commitment to technology in the classroom, and one was already using CAS in some of their teaching. One of the PD presenters said that they had a

> ...fear that to roll something out like this in the broader nation, without the incredible support these guys have got, there is probably no way you can expect that quite on that scale in each school.

Support must come in several ways. Committed professional leadership, appropriate teaching and assessment resources, and ongoing professional development will all be needed.

Professional leadership

School leadership

This was a strong feature in each of the pilot schools. There was active support in all the schools from the mathematics HOD. In several of the schools the HOD was one of the two teachers in the CAS pilot. One school reported that the principal had been actively involved in ensuring the school was involved with the project. Comments included:

> [Our] HOD wanted the school to stay in the forefront of technology.

> [The HOD had] pushed to get the department involved at the grass roots level.

> School leadership is very important. The leadership [needs to] inspire all staff, the staff [need] passion and training.

Strong school-based professional leadership is essential for fully effective implementation in a school. Without this support, individual teachers or even a pair of teachers who had undergone professional development could be marginalised.

System leadership

Both the Ministry of Education and the New Zealand Qualifications Authority need to have an ongoing role in the promotion of the values that underpin this project. For the Ministry, the call from the PD coordinator was “to get it out there and to promote it”. She did accept that there would be resistance and there are “those who don’t want to know about it”. There was praise for the leadership already being demonstrated. A teacher said that they “applauded the MoE and NZQA for getting stuck into technology before it’s everywhere”. This is no small ask. This same teacher wondered “if they have overestimated the readiness of teachers and parents to embrace it”. These responses suggest that some form of promotion of the benefits of the CAS pilot approach to teaching and learning will be needed to ensure widespread adoption. Significant leadership from NZQA will also be needed as they plan for NCEA assessments. Section 7 on assessment covers many of the issues that need to be addressed. For the pilot students, 2007 is the first high-stakes assessment point, and 2010 is the target for all NCEA mathematics to be CAS-enabled.

Teachers consistently identified two specific barriers to the widespread use of the CAS calculators. They were the twin issues of the amount of teacher time involved in the project, and the price of the technology. For parents, it is price, for teachers it is time. Teachers made some suggestions on these issues that the MOE may wish to consider.

- **Price:** Encouraging a second-hand market for the calculators was one teacher's suggestion. Some kind of lease option, either at a school or national level, was another idea. The issue of the security of the calculators for both parents/caregivers (if they bought them), and schools was an issue (especially if some lease or bulk purchase option were to be followed). The insurance ramifications would need to be considered and factored in.
- **Time:** Teachers reported that they found that the pilot was taking significantly more time, both in lesson preparation and in becoming competent with the use of the technology. Some allowance for this should be considered through teacher release time or some other mechanism. The continued provision of resource materials would also be helpful, although this need will diminish in due course.

Resources

The teachers in the pilot saw a need for an expanding set of resources, both for teaching but more particularly for assessment.

Teaching resources

The teachers saw a need for the continued development of teaching units. This could be done either by a central agency or by networks of teachers sharing their resources. There were also hardware needs, especially for data-shows, or emulators. The PD coordinator said it was important to have teaching materials of a high standard. She stated:

> The [teaching] material has to be user friendly to the wider teaching population. Now that means it has to be relatively easy to use, therefore it needs to be a linked sequence of learning for the teachers which you then want them to have the confidence to bring in their own activities, exploration, that sort of thing. But initially the material needs to be fairly well designed so they can pick up and pretty much use in the first instance in their teaching. We need to make sure that the quality of the material is excellent before it goes out of our hands and so if material is being written and developed for the first year of the draft now, then that is actually a trial of the material which has brought up some issues within the PD for some teachers.

Students in the focus groups had some advice on this as well:

> Keep the language simple.

> Have a glossary of the language used.

> Give more basic instructions.
>
> Edit the instructions [i.e. get rid of the errors in them].

One teacher said that they would appreciate access to appropriate research. He said, "I would love a booklet or pamphlet on CAS [with] the positives and the negatives."

Assessment resources

Teachers could clearly see that "assessment needs to change". School-based formative and summative assessment, and high-stakes national assessments both need appropriate resources. Schools need to be given models of effective summative assessment materials. The teachers also need a clear guide as to what the high-stakes assessment will look like. They requested some parallel papers for not only Level 1 of NCEA, but also for Levels 2 and 3, in sufficient time for them to prepare the students in the pilot in an equitable way. Students had also asked in the focus groups if their assessments will be same as those for non-CAS students.

Professional development

Over half of the pilot teachers believed that to sustain the project, there would need to be continuing professional development. The teachers had had a positive experience with their PD, but saw that it needed to continue:

> We've been given great support and that all needs to continue. Everything has been planned out well.
>
> Ongoing training [is needed] for new teachers.
>
> [Teachers] need an introduction [otherwise] they will say 'stuff this for a lark'.

One of the PD providers had said that there was a need for "lots of PD, [and he had an] appreciation of the inertia of the system". Changing views on pedagogy takes time.

The high level of support for this pilot may not be possible for every teacher in the country. What PD models, then, may be able to work in the future? Some different features for a PD model have been identified. These will be discussed, along with some pros and cons. Some mix of these models may be possible.

Materials approach

This basically supposes that quality materials will give teachers a large part of what they need to implement the project. While there is an expanding pool of resources for appropriate CAS use, one PD provider warned, "What is not in the [teaching] units is the philosophy. [We need to] impart upon [teachers] that this is a [new] way of approaching teaching and learning." We must stress again the message of Section 4, "It's all about the pedagogy" (it's not about the technology). These quotes illustrate the pilot teachers' concerns about what may happen if there is not ongoing PD:

> Until that sort of shift occurs [to pedagogy] it's going to be hard for some people [teachers] to accept CAS.
>
> Many teachers are book oriented, but CAS is not book oriented.
>
> In the wrong hands it could become just a crutch. It is possible that someone is using [CAS] in the wrong way, for example just give the students a book and get them to use it by hitting the 'solve' or 'factorise' key. It is the approach you take to teaching which will make the difference.

The commercial model

The material that is being developed now will become available for wider use by teachers or schools wishing to use CAS themselves. There was a suggestion from the PD coordinator that "the PD will [after the pilot] be presented by the calculator companies and the schools will buy into whichever brand they choose". The budgetary implications for schools need to be addressed.

Pairs-of-peers approach

This is the model that has been used in the pilot schools, and it has been described in Section 6. In the pilot this was very successful. The extension of this model is that a pair of teachers in all schools will go through the same type of training. It would then be up to these teachers to disseminate the approach around the mathematics profession. One teacher expressed a number of concerns with this model, saying:

> I honestly think the issue [of who facilitates how other teachers are going to be taught] is going to be a huge issue. I have a real concern that the expectation seems to be that we [the pilot teachers] will go out there and we will facilitate workshops. Logistically I know that [facilitation] is a nightmare and I am not sure that has been thought through enough, and certainly, I am not sure they are going to have enough teachers on board that have facilitation experience because it's very different skills standing up in front of your peers than standing up in front of a classroom. Some people are very, very nervous about getting up there and putting forward that they know what they are doing. [There is] almost the feeling that they are saying 'Oh heck! I'm meant to be an expert on this and I'm not.' There is a lot of training needs to go in to prepare those within the CAS project who are going to do that. There is also the fact that four days out of the classroom for each teacher, that's an amazing amount of time away from your classes. I don't think the principals are going to buy that. … Maybe what we need is to link in to the advisory and to second some people for a year to actually be the ones who do all the dog work and have the main role, but use the other [pilot] teachers.

The professional development model

The last part of the previous quote suggests using the advisory service. We believe that New Zealand has a world-class model now for professional development, namely that developed for the Numeracy Project. One of the schools in the pilot was debating whether to become involved with the CAS pilot in 2005, or to begin the Numeracy Project instead. Another school will be starting the Numeracy Project in 2006. Ironically, both projects share some common beliefs. It may be possible to create synergies between them. We repeat a quote from the PD coordinator mentioned in Section 7, on assessment. She said:

> [Assessment] is more about gauging understanding rather than skill. It is more in line with **numeracy** where students are exploring and gaining understanding.

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

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

Because of these strong similarities, we believe that it would be fruitful to explore synergies between the CAS pilot and the Numeracy Project. One student in a focus group had even recommended using the CAS with younger children. They said:

> Try it with younger [students], maybe first year intermediates.

This pilot is already distinctive in allowing junior secondary students to use the CAS. This would take the revolution one step further.

Future research dimensions

While this evaluation only looks at the CAS Pilot Project for 2005, a number of issues have arisen that will need to be addressed in research for the 2006 and 2007 pilots.

Baseline data for teachers

For the 2005 evaluation, there was no baseline data on teachers' skills, attitudes, or classroom practices. This was partially addressed by asking them to retrospectively rate their practices and attitudes before they began the CAS pilot and compare this with their practices and attitudes during it. This has the disadvantage that the views they had about their previous practice will be coloured by the glasses of the professional development and pedagogy of the pilot project.

Some baseline data has been gathered for the teachers who will be new to the project in 2006. This covers the length of teaching experience they have, their skills and use of technology in the classroom, their current classroom practices, plus their views on teaching and learning, assessment, and technology. The instrument used to collect this is in Appendix B. The analysis of this data is beyond the scope of the 2005 pilot, but will give baseline data for the 2006 teachers, which will be able to inform any future evaluations.

Baseline data for students

For students, obtaining their attitudes and achievement levels prior to the CAS project was even more fraught, not only because of their age, but also because they had moved from a primary school to a secondary school environment. They were asked about their current 2005 experiences with only minimal reflection on prior experiences. This information was only available from students in the focus groups. It would be ideal to have more comprehensive baseline data on students' attitudes and their achievements.

There is an opportunity to collect such baseline data, but this must be done before the 2006 students begin learning with the CAS. The data could be of a more comprehensive nature than that collected in the focus groups, and could be of all students in the pilot, or a sample of them if this is a more effective strategy.

Attitudinal data will require the development of a suitable instrument. This should not present too many issues as there is information in the research literature about this, and we have some in-house experience in this area as well.

Achievement data is a more challenging task that will need to be approached with care. Any shift in achievement will to some extent reflect the philosophy that underlies the assessment instruments used. One of the PD providers recounted an earlier experience he had where it seemed that the assessment instruments he used skewed the results so that traditionally trained students had an advantage over ones exposed to an exploratory pedagogy. He concluded that this was a function of the types of questions chosen in the assessment, and what those questions implicitly valued. This is the same challenge that needs to be addressed in school-based and high-stakes assessment when CAS is part of the project.

Ongoing tracking of students and teachers

Given the longitudinal nature of the CAS Pilot Project, information about students and teachers in the 2005 cohort should continue to be collected in subsequent years, for research and evaluation purposes.

Key points of Section 9

- Communication with parents/caregivers about the potential advantages of CAS technology as a tool for learning is essential.
- Mathematics teachers need to be challenged to teach using exploration and discovery that can enhance understanding, and that technology such as the CAS calculators can assist this.
- Professional leadership and support at the system level are essential.
- School leadership needs to be supportive of the values and practice of the CAS pedagogical approach within their school or department.
- A greater number of quality teaching resources that model CAS use across all the areas of the curriculum are needed.
- Assessment resources, in particular high-stakes assessment resources, are required with sufficient lead in time for the 2007 and 2010 target years for CAS-enabled assessments in NCEA. These need to be congruent with, and encourage the use of, exploration to gain understanding in mathematics.
- The best professional development model needs to be adopted. Consideration of using the PD expertise and values of the Numeracy Project should be considered.
- Further research is required; baseline data on 2006 teachers and students is essential in both attitudes and achievement levels. The latter needs to reflect the pedagogical approach of the pilot.

Conclusion

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

The major thrust of the CAS Pilot Project was all about quality teaching and learning and focused on an exploratory, self-discovery approach to gaining mathematical understanding. The teachers believed that this pedagogy had not only allowed students to improve their mathematical understandings and skills, but had also enhanced their own professional skills. The CAS technology was being used in the classrooms to support this approach, rather than being the major focus. Classroom teaching had clearly changed as a result of the training given to the teachers in the project. The professional development emphasised this pedagogy, as well as giving teachers sufficient confidence and knowledge in how to use the technology. Without quality PD it will be hard to communicate this approach to using CAS in the classroom to the wider mathematics education fraternity. There was some resistance to the project from a number of parents/caregivers and students, mainly because of concerns that it may undermine mathematical skills. Some teachers in the pilot had initially shared these views. This indicates that other mathematics teachers will need to be convinced of the benefits of this technology-supported pedagogy.

Effective assessment models will inform this debate. Assessments, both school-based and high-stakes, need to reflect the values of exploration and of understanding, as well as acquiring mathematical skills. Defining and refining assessment resources will need to continue.

While the pilot has addressed many aspects surrounding the use of CAS technology in the mathematics classroom, there are still further issues to be debated.

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Appendix A: Teacher Questionnaire

CAS Pilot Project
Term 3 2005

This Questionnaire is part of the research being done by NZCER about the CAS Pilot Project. Please complete it before we visit your school.

Your name will not be used in the 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

Please indicate by shading in 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
Spreadsheets (e.g. Excel)	O	O	O	O	O	O
Algebraic software (PC based)	O	O	O	O	O	O
CAS calculators - Pre-pilot	O	O	O	O	O	O
CAS calculators - Now	O	O	O	O	O	O
Databases	O	O	O	O	O	O
Data projector with calculator	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

CAS Pilot Evaluation: Preliminary Teacher Survey (to be completed before the visit)

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 three columns (Q1, Q2, Q3). Your responses can be discussed during the school visit. The various statements might also help you when thinking about interesting teaching and learning materials to bring to our discussions.

	Q1. What priority do you think should be given to each of these practices?					**Q2. Pre-CAS how often did these practices happen in your Year 9 classes?**					**Q3. How often do these practices happen in your Year 9 classes now?**				
	Very high	High	Medium	Low	Very Low	All/most of the time	Often	Medium	Occasionally	Hardly ever / never	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.															

	Q1. What priority do you think should be given to each of these practices?					**Q2. Pre-CAS how often did these practices happen in your Year 9 classes?**					**Q3. How often do these practices happen in your Year 9 classes now?**				
	Very high	High	Medium	Low	Very Low	All/most of the time	Often	Medium	Occasionally	Hardly ever / never	All/most of the time	Often	Medium	Occasionally	Hardly ever / never
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.															

	Q1. What priority do you think should be given to each of these practices?					**Q2. Pre-CAS how often did these practices happen in your Year 9 classes?**					**Q3. How often do these practices happen in your Year 9 classes now?**				
	Very high	High	Medium	Low	Very Low	All/most of the time	Often	Medium	Occasionally	Hardly ever / never	All/most of the time	Often	Medium	Occasionally	Hardly ever / never
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.															

	Q1. What priority do you think should be given to each of these practices?					**Q2. Pre-CAS how often did these practices happen in your Year 9 classes?**					**Q3. How often do these practices happen in your Year 9 classes now?**				
	Very high	High	Medium	Low	Very Low	All/most of the time	Often	Medium	Occasionally	Hardly ever / never	All/most of the time	Often	Medium	Occasionally	Hardly ever / never
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 Questionnaire

CAS Pilot Project
2006

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

2. "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).

	Q1. What priority do you think should be given to each of these practices?					**Q2. How often do these practices happen in your Year 9 classes?**				
	Very high	High	Medium	Low	Very Low	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.										

	Q1. What priority do you think should be given to each of these practices?					**Q2. How often do these practices happen in your Year 9 classes?**				
	Very high	High	Medium	Low	Very Low	All/most of the time	Often	Medium	Occasionally	Hardly ever / never
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.										

	Q1. What priority do you think should be given to each of these practices?					**Q2. How often do these practices happen in your Year 9 classes?**				
	Very high	High	Medium	Low	Very Low	All/most of the time	Often	Medium	Occasionally	Hardly ever / never
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 Interview

CAS Pilot Project
Term 3 2005

Background to the Project

1. **Could you tell me about how you became involved in the pilot project?**

2. **What do you consider are the key aims of this pilot project?**

Professional Development and Teacher Support

3. **Could you describe the professional development you have received as part of the pilot project?**

    - Was the PD helpful? YES / NO - If YES, in what ways? - If NO, what was needed?
    - What was the most useful aspect of the PD for you?

4. **Teacher training on CAS can be divided into two parts: technical (operating a CAS and what it can and cannot do), and cultural/professional (teachers' experiences and influences and classroom practice). During the professional development sessions, what proportion of time was spent on each of these areas?**

5. **What support or professional development do you think you will need in the future?**

Technology

6. a) **How would you describe your current philosophy of using technologies in the classroom?**

    b) **Has this changed as a result of the CAS Pilot?**

Teaching and Learning

7. **Have you noticed, or made, any changes to the way you teach your CAS pilot classes?**

8. **Have you changed the way you teach other mathematics classes or topics since using CAS?**
   YES/NO If YES, briefly describe in what ways.

9. **What percentage of class time is spent on teaching students how to use CAS and what percentage is spent on teaching content? Has this changed over time?**

10. **How have you used pencil and paper techniques in algebra and geometry with your CAS pilot class?**

11. **Here are some statements that describe approaches to teaching algebra.** (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.)

    a) **Before using CAS, which one would have best described your teaching approach?**

    b) **Which one would best describe your teaching approach since using CAS?**

12. **What challenges or organisational issues have been associated with implementing CAS in your classroom?**

Student Learning

13. **Why do you think students should learn algebra?**

14. **What do you see as the key algebraic concepts students at Year 9 need to understand?**

15. **The research tells us that students who use CAS when learning algebra have a better understanding of algebraic concepts. What has been your experience of student understanding since using CAS in the classroom?**

    - Understanding of concepts? DEEPER / SAME / NOT AS DEEP *(circle one)*
    - Speed of grasping the concepts? FASTER / SAME / SLOWER *(circle one)*

16. **Have you noticed any changes to your students' attitudes towards maths since they have been using CAS?**

    If yes, please describe.

17. **How does this compare with Year 9 classes who have not used CAS calculators?**

18. In what way has the CAS Pilot had an impact on the learning of students of:

- **a) lower mathematical ability?** **Positive / Neutral / Negative**
- **b) average mathematical ability?** **Positive / Neutral / Negative**
- **c) higher mathematical ability?** **Positive / Neutral / Negative**

19. What other impact(s) has the introduction of the CAS Pilot had on the students?

Assessment

20. What does formative assessment mean to you?

21. Do you use formative assessment in your CAS class? YES/NO

If YES, how do you use it? What do you assess?

22. What evidence do you collect to make summative judgements about students' achievement?

23. Has your approach to assessment changed since using CAS?

24. Are there implications for assessment of student learning as a result of using CAS?

Future Issues

25. If CAS is going to be introduced more widely into maths classes in the future, what implications do you see for the following groups?

- parents?
- the wider community / teachers?
- the role of the Ministry of Education or NZQA?

26. What support will teachers need to be given to enable the sustained use of CAS?

27. Are there any other issues you would like to comment on, or other issues raised by our conversation?

If time, ask the following question:

28. In terms of teaching maths, what is CAS good for? not so good for?

Appendix D: Student Focus Group Interview

School: ____________________________ Date: ________

Using CAS

1) **How long have you been using CAS calculators in your maths class?**

2) **I found it easy to learn how to use the CAS calculator. (1)**

   Rate your response to this question from strongly agree to strongly disagree, then discuss.

3) **a) I have had no problems using the CAS calculator. (2)**

   Rate your response to this question from strongly agree to strongly disagree, then discuss

   Types of problems e.g. syntax (what and how to enter information), multiple representations (rules, tables, graphs), interpreting output.)

   b) If you had problems using the CAS, how did you get help?

   From others (who?). From written instructions?

4) **I now feel confident using the CAS calculator. (3)**

   Rate your response to this question from strongly agree to strongly disagree, then discuss.

   Rate your response to this question, as you would have felt after the first couple of lessons (mark with a B), from strongly agree to strongly disagree, then discuss.

5) **I enjoy using the CAS calculator (4)**

   Rate your response to this question from strongly agree to strongly disagree, then discuss.

Teachers and Teaching

6) **Here are three descriptions of the way some teachers might teach algebra. Which one best describes your teacher? (5)**

Show cards A, B, C; circle the letter of the most appropriate one(s) and discuss.

A: My teacher makes sure I can recall all the rules of algebra.

B: My teacher lets me explore ideas and work out the rules of algebra for myself.

C: My teacher makes sure I understand all the ideas behind the rules of algebra.

7) **Has your teacher changed the way they teach since using the CAS calculators in class?**

What effect on your learning has this had?

8) **How are the CAS calculators used in class?**

How is pencil and paper used? (instead of CAS, as well as CAS)

9) **Have you had any assessments which use the CAS calculators?**

If "Yes" what types? E.g. actual use of the calculators? understanding of algebra?

10) **Lessons using the CAS calculators are just like any other mathematics lesson. (6)**

Rate your response to this question from strongly agree to strongly disagree, then discuss.

Please describe any differences

physical classroom environment/layout, teaching style, teacher-student interactions, student-student interactions

11) **Do you think your teachers like you using CAS calculators?**

Student Learning

12) Using the CAS calculators has helped me understand maths (algebra) better. (7)

Rate your response to this question from strongly agree to strongly disagree, then discuss.

If "yes", in what ways? If "no" why? *Pencil & paper vs CAS - how/when used? Types of representations (tables, rules, graphs)*

13) If you get stuck on a maths problem, how do you get help?

in class? at home? From others (who)? From notes or textbook?

14) I feel more positive towards maths since using CAS calculators. (8)

Rate your response to this question from strongly agree to strongly disagree, then discuss.

15) What do your parents or caregivers think about you using CAS calculators?

Advice

16) Imagine that another school was going to start using CAS calculators in their maths classes. If you were asked to give the school advice,

- **What would be your advice for students?**
- **What would be your advice for teachers?**
- **What would be your advice for the people organising the project?**

Student response form - CAS Pilot Evaluation

School: ____________________

Student Code : ____________________

Date: ________

Strongly Agree ↓ | Strongly Disagree ↓

1. ____

(*mark with an* ×)

2. ____

(*mark with an* ×)

3. ____

(*mark with an* ×)

4. ____

(*mark with an* ×)

5. **(A)** **(B)** **(C)** **(circle one)**

Strongly Agree ↓ | Strongly Disagree ↓

6. ____

(*mark with an* ×)

7. ____

(*mark with an* ×)

8. ____

(*mark with an* ×)

Appendix E: Professional Development Provider Interview

Background Information Code [ ]

Date: ____/____/____ **Interviewer initials: ______**

CAS Calculator Brand: ________________________________

Background to the Project

1) **How did you come to be a Professional Development provider for [Casio/TI]?**

2) **What do you consider are the key aims of this pilot project?**
   For students? For teachers? For schools? For external agencies?

3) **How would you describe your current philosophy of technology use in the classroom?**

Professional Development and Teacher Support

4) **Please describe the professional development you have provided for teachers of Year 9 maths classes.**

   Number of sessions: Time at each session: Resources provided: Style of presentation:

5) **What were the main things you wanted the professional development to achieve?**

6) **During the professional development sessions, what proportion of time was spent on how to use the calculator compared with the pedagogy behind the use of the calculator?**
   How do you address the varying technical needs of the teachers?
   How much time spent on student learning vs teacher learning
   What advice was given to teachers regarding the use of pen and paper when teaching with the calculators?

7) **Has there been on-going support between, or since, sessions for the teachers?**

   YES/NO If yes, please describe.

8) **What support or professional development do you think teachers will need in the future?**

Teaching and Learning

9) What changes do you anticipate teachers might make in their classes as a result of using the CAS calculators?

Changes to environment, student-student or student-teacher interactions

10) What challenges or organisational issues might teachers expect to face when implementing CAS in their classroom?

Student Learning

11) a) The research tells us that students who use CAS when learning algebra have a better and quicker understanding of algebraic concepts. What have been your experiences in this respect?

Feedback from teachers?

- Understanding of concepts? DEEPER / SAME / NOT AS DEEP (circle one)
- Speed of grasping the concepts? FASTER / SAME / SLOWER (circle one)

b) If deeper or faster: Why do you think this might be the case?

12) In what way do you think the CAS Pilot will have an impact on the learning of students of:

a) lower mathematical ability? Positive / Neutral / Negative

b) average mathematical ability? Positive / Neutral / Negative

c) higher mathematical ability? Positive / Neutral / Negative

13) What other impact(s) might the introduction of CAS into classrooms have on students?

Assessment

14) What advice do you give to teachers about formative assessment when using CAS calculators?

assessment of CAS use itself? assessment of algebraic/geometric understanding?

15) What advice do you give to teachers about summative assessment when using CAS calculators?

assessment of CAS use itself? assessment of algebraic/geometric understanding?

16) Are there any other implications for assessment of student learning as a result of using CAS? *Do current forms of assessment need to change? In what ways? How should students record the results of CAS work?*

Future Issues

17) If CAS is going to be introduced more widely into maths classes in the future, what implications do you see for the following groups?

- **students?**
- **parents?**
- **teachers?**
- **the role of the Ministry of Education or NZQA?**

18) What support will teachers need to be given to enable the sustained use of CAS?

19) Are there any other issues you would like to comment on, or other issues raised by our conversation?
If time, ask the following question:

20) In terms of teaching maths, what is CAS good for? not so good for?

Appendix F: Professional Development Coordinator Interview

Background Information Code [ ]

Date: ____/____/____ Interviewer initials: ______

Background to the Project

1) **How did you come to be a Professional Development Coordinator**

2) **What do you consider are the key aims of this pilot project?**
For students? For teachers? For schools? For external agencies?

3) **How would you describe your current philosophy of technology use in the classroom?**

Professional Development and Teacher Support

4) **Please describe the professional development you have provided for teachers of Year 9 maths classes.**

Resources provided:

5) **What were the main things you wanted the professional development to achieve?**

7) **Has there been on-going support between, or since, sessions for the teachers?**
YES/NO If yes, please describe.

8) **What support or professional development do you think teachers will need in the future?**

Teaching and Learning

9) **What changes do you anticipate teachers might make in their classes as a result of using the CAS calculators?**

Changes to environment, student-student or student-teacher interactions

10) **What challenges or organisational issues might teachers expect to face when implementing CAS in their classroom?**

Student Learning

11) a) The research tells us that students who use CAS when learning algebra have a better and quicker understanding of algebraic concepts. What have been your experiences in this respect?

Feedback from teachers?

- Understanding of concepts? DEEPER / SAME / NOT AS DEEP (circle one)
- Speed of grasping the concepts? FASTER / SAME / SLOWER (circle one)

b) If deeper or faster: Why do you think this might be the case?

12) In what way do you think the CAS Pilot will have an impact on the learning of students of:

a)	**lower mathematical ability?**	**Positive / Neutral / Negative**
b)	**average mathematical ability?**	**Positive / Neutral / Negative**
c)	**higher mathematical ability?**	**Positive / Neutral / Negative**

13) What other impact(s) might the introduction of CAS into classrooms have on students?

Assessment

14) What advice do you give to teachers about formative assessment when using CAS calculators?
assessment of CAS use itself? assessment of algebraic/geometric understanding?

15) What advice do you give to teachers about summative assessment when using CAS calculators?
assessment of CAS use itself? assessment of algebraic/geometric understanding?

16) Are there any other implications for assessment of student learning as a result of using CAS?
Do current forms of assessment need to change? In what ways? How should students record the results of CAS work?

Future Issues

17) If CAS is going to be introduced more widely into maths classes in the future, what implications do you see for the following groups?

- **students?**
- **parents?**
- **teachers?**
- **the role of the Ministry of Education or NZQA?**

18) What support will teachers need to be given to enable the sustained use of CAS?

19) Are there any other issues you would like to comment on, or other issues raised by our conversation?
If time, ask the following question:

20) In terms of teaching maths, what is CAS good for? not so good for?

Appendix G: Lesson Observation Schedule

CAS Pilot Project
Term 3 2005

Lesson Background

Discuss with teacher

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

How is the lesson introduced? (Time) *(Notes on blackboard (NB), notes on OHP (NOHP) Handout of notes (NH), CAS data show(CAS))*

Describe the style of teaching/ learning observed ***(e.g. lecture (L), Whole Class Teaching(WCT), Group teaching (GT), Group work (G), Individual Work (I)***

How is CAS used during the lesson?

How is the lesson wrapped up? (Time)

Record what happens during lesson, noting in particular teacher-student and student-student interactions.

Type of interaction	Initiated by.	Content?	Nature of interaction	Codes
T:S S:S Group	T S	Maths CAS		
T:S S:S Group	T S	Maths CAS		
T:S S:S Group	T S	Maths CAS		
T:S S:S Group	T S	Maths CAS		

Other Observations (e.g. individual student observation, group observation, engagement, pen & paper v CAS use)