

Concerns Relating to the CAS Use at University Level

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While the use of technology at university level is an accepted part of some courses such as statistics and applied mathematics, there is still considerable resistance toward its use in pure mathematics courses in some universities. Regardless of whether one is sceptical or favourably inclined about the inclusion of technology, there are concerns relating to its implementation and instrumentation that are worth considering. As part of this research 502 stage one pure mathematics students at The University of Auckland volunteered to express their views on the use of TI-89 calculators in their course. The results for these questionnaires are discussed in this paper.

Over the last two decades an increasing number of mathematics educators have implemented technology as part of their teaching. Research in areas such as mathematics for information technology, geometry using technology, computer algebra, graphics calculators, teaching using technology, integrating technology into mathematics education and so on has also been the main focus for many. Technology use in mathematics is on the agenda in many conferences and there have been hundreds of papers on this topic published and discussed around the world each year. In addition, influential companies such as Texas Instruments, Casio etc have been offering their most up to date technologies to educators, universities and schools.

But, where is it all taking us? Are we trying to alter our courses to suit the growing demand of the technology, or to tame and mould the technology to serve our purposes? How convinced are we in the direction this whole scenario is moving? Do we pay much attention to carefully designing frameworks that will serve our students needs? Or are we so blindly confident that we are quite happy to simply throw some technology into the fray and see what will happen? Or do we just follow what is fashionable?

In this study my focus was to collect students opinions, as part of building a picture of concerns related to CAS introduction.

Theoretical Background

One of the technologies which has been of especial interest over the past two decades, is the CAS calculator. Some researchers believe that these calculators have greater advantages over computers in the learning of mathematics (Hackett & Kissane, 1993; Jones, 1991; Leary, 1991, cited in Penglase & Arnold, 1996) simply because these sophisticated devices, which are as capable as computers, are portable and more affordable for students to buy. However, there is not a body of research at the university level, particularly such courses as linear algebra, to provide evidence that would convince a sceptic that CAS calculators are capable of making a difference in teaching and learning mathematics provided they are given the right environment and attention. Research by Povey and Ransom (2000) on the use of IT at university level concentrated on students' perceptions of using technology and their resistance toward its use. They suggested, "we are more likely to be able to support the development of authoritative learners of mathematics if we heed them" (p. 47). A study by Quesada (1999) is another example of

working with undergraduates, which reveals how the use of the TI-92 calculators helped to change a traditional linear algebra course to a matrix-oriented one. The goals were to improve students' conceptual understanding of linear algebra, reduce the calculations by using TI-92 calculators and to think geometrically. A survey showed that students "found the calculators very helpful to solve problems, to investigate, to cover the material in more depth, and to facilitate the study of different applications. They seem to believe that the calculator helped them to better understand the course content and to feel more confident doing linear algebra". (Quesada, 1999, p. 321)

However, their results differed to some extent from the study by Stewart and Thomas (2004). They introduced the TI-89 calculators as an optional part of a first year undergraduate linear algebra course, but no evidence of benefits of CAS use in the understanding of the course was found, rather it supported the findings of Thomas and Hong (2004), who found that instrumental genesis (the transformation of a tool to an instrument) of CAS is gradual and requires careful attention.

Tall (2000) considers simply using technology does not automatically mean that we understand the concepts. He argues, in some cases we may even lose some of our basic abilities. Stewart and Thomas (2004) also claimed that it is easy to lead students into button pushing and consequently the loss of basic mathematics skills. They found that students primarily used CAS calculators to check their answers, indicating the fact that they are not interested in distinguishing between *tool* and *instrument* use of CAS. This has concerned French researchers Artigue (2002), Guin and Trouche (1999), and Lagrange (1999) as none of the students they worked with gave any information about when and how they decided to use the TI calculator, even though it was required from them.

Flynn, Berenson and Stacey (2002) are also concerned with being able to judge between when to use the CAS and when to use by-hand techniques. They believe that historically students have been encouraged to develop proficiency in by-hand algebraic techniques. Lagrange (1999) declares that the traditional techniques may be replaced by CAS activities, and so students will need to master new techniques. He asserts it is important that every student who uses CAS comes to an understanding of how to use the technology to learn mathematics. In many cases this will depend on "the student forming a partnership with it in their everyday mathematical work. Through their individual interactions they have to decide what CAS is useful for and what will be better done by hand" (Thomas, et al., 2004). It is also important that students at university level realise the fact that using technology is not just about finding the answers, the aim of using technology is to increase students' conceptual understanding by investigating different ways of looking at the problems. In other words, technology may give students a sense to explore by themselves rather than being confined within a set of instructions.

The initial aim of this study was to investigate the influence, effectiveness and integration of TI-89 calculators among Auckland University stage one mathematics students. In this paper I report the reactions of these students toward the use of TI-89 calculators and briefly discuss the reasons why the majority of students refused to use them.

The Study

This case study involved questionnaires from 186 volunteer stage one (Maths 108) mathematics students in the first semester of 2004 and from 316 in the second semester at the University of Auckland. The volunteers were mainly 19-22 year old Asian students and

nothing was known about their background. Over the whole year 1600 students were enrolled in this course that covers both calculus and linear algebra.

This was the first time that TI-89 CAS calculators had been introduced as an optional part of the course and there was a section at the back of the course manual on how to use the calculators. These instructions were prepared by mathematics educators in the department who had experience with the use of TI-89s in the past in other courses where they used them as part of their lectures. The TI instructions for Maths 108 covered most topics discussed in the course. None of the lecturers in either semester used the TI calculators during the lectures or in the tutorials, but some of them asked the students to buy them and use them if they wished. However, when we first collected the responses from the first semester the immediate responses seemed to indicate that lecturers never mentioned the calculators, therefore until nearly the end of the course students never knew they even existed. To resolve this problem and bring the calculators to students' attention the researcher offered two hours TI-89 tutorial each week and a brief demonstration of TI-89 in front of all three streams at the start of the second semester. Unfortunately the TI tutorials eventually had to stop, as students were not attending. At the end of one of the course tutorials toward the end of both semesters students were given a questionnaire (see Appendix) requesting information on their attitudes toward the use of TI calculators.

There were four separate sections in the questionnaire. Section A consisted of 22 3-point Likert scale statements which ranged from 3 (agree) to 1 (disagree), and some open questions for those who used the TI-89 calculators. Section B consisted of 8 3-point Likert scale statements for those who chose not to use the TI calculators, and section C was for all students to give their comments. The sample was a convenience one of just over 30% of students in the course, so findings are only indicative. It is likely students were the more conscientious ones which could imply that the findings are somewhat biased.

Results and Discussions

The TI-89 Users

From those who participated in this study only twenty-four (12.9%) in the first semester and thirty-seven (11.7%) in the second semester indicated that they used the calculators during the course. Table 1 shows the mean response scores for the TI-89 users of first and second semesters.

Table 1 reveals that despite the fact that we had different samples, students' views toward the 22 statements stayed basically the same. Students used the calculators primarily to check their answers and when they got stuck doing a problem. Thomas and Hong (2004) also noticed that students are mostly using the calculators to check their answers. The first semester students showed that they were keen to learn to use the calculators fully and all the students seemed glad that they could use them in the examination. When it came to statement 1 relating to the improvement of conceptual understanding by using CAS the responses stayed neutral. The implication is that if we have the ability to do mathematics "by hand" we can "understand" it, not realising that it is possible to execute pen and paper methods yet still not "understand" (Povey & Ransom, 2000). Herwaarden and Gielen (2002) consider one of the reasons that students show lack of conceptual understanding while using CAS is the fact that they do not seem to be able to incorporate the technology into their mathematical thinking. Knowing how and when to use the calculator can help the sceptic to realise that we do allow time and room for pen and paper and acknowledge the fact that not all mathematics can be done by CAS calculators. The first semester

students showed positive responses relating to the use of both TI-89 and pen and paper in statement 16. Most students were also hoping to be able to use the calculators in other courses. A few students in the second semester indicated that they had used TI-89 in a previous course and they were happy to continue to use them in the Maths 108 course.

Table 1

The Means of the Questionnaire Responses (semester1 (S1) and semester2 (S2) with TI89)

<i>Statement</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>	<i>9</i>	<i>10</i>	<i>11</i>
Mean (S1)	1.88	2.00	2.83	2.65	2.21	1.67	2.37	2.50	2.96	2.46	2.92
Mean (S2)	1.92	1.84	2.78	2.54	2.39	1.78	2.28	2.59	2.61	2.47	2.72
<i>Statement</i>	<i>12</i>	<i>13</i>	<i>14</i>	<i>15</i>	<i>16</i>	<i>17</i>	<i>18</i>	<i>19</i>	<i>20</i>	<i>21</i>	<i>22</i>
Mean (S1)	2.29	2.54	1.83	1.37	2.92	1.78	1.74	1.92	2.17	2.50	1.67
Mean (S2)	2.22	2.55	1.86	1.67	2.64	2.11	1.39	1.83	2.19	2.14	1.89

The means in statement 10 concerning the technology being the way to learn mathematics and in statement 13, regarding exploring the TI-89s, were the closest (almost the same) for both semesters. Results also revealed that the largest difference in means was from statement 21, as the second semester students were happier with the support outside the lecture time for using the TI-89 calculators than the first semester students. This may be due to the extra tutorials that we provided for them. The differences between the means for both semesters were relatively large in statements 9 and 18. Students in the first semester indicated their interest to learn more about the calculators in statement 9. However, in statement 18 those same students were not quite sure whether it was a good idea to buy the calculators in the first place. This could suggest the lack of clear instructions on how to integrate the technology into the course.

Why majority of students didn't use the TI-89

The overall results revealed that 441 students (162 first and 279 second semester students) from both semesters did not use the TI-89 calculators, a figure that cannot be ignored or brushed aside. Table 2 shows the mean response scores for both semesters. Although the sample sizes were different the means are identical in statement 4 where we asked about the affordability of the calculators, and the values of the means stayed very similar for the rest of the statements. We also received 71 comments from first semester and 78 from the second semester participants.

Table 2

The Means of the Questionnaire Responses (semester1 (S1) and semester2 (S2) no TI89)

<i>Statement</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>
Mean (S1)	2.28	2.78	2.28	2.53	2.34	2.41	2.20	2.21
Mean (S2)	2.21	2.79	2.25	2.53	2.39	2.30	2.23	2.20

Statistical Analysis of the Questionnaire and Students' Perspectives (with no TI-89)

The statistical analysis using the software package "R" of the 8 statements and students' comments may provide some reasons for why most students decided not to use the TI-89 calculators. The statistical details and the students' comments here are taken from the data that was collected in the second semester where 279 students did not use the

TI-89. However, there are occasional references to the data from the first semester that will be clearly specified.

When we asked students in statement 8 if they wished they had a TI-89 calculator, 37% agreed whereas 46% were not sure. Consequently 39% of students agreed with statement 1 that they did not need a TI-89 and could do everything without having one, while 47% remained undecided. This supports the fact that since students never had an opportunity to work with a CAS calculator, especially since it was not a crucial part of the lectures, they had very little idea about its usefulness. Hence their reaction to statement 5 was that we do not know if they are good or not until we have tried one (54% agreed). And when we asked them in statement 7 if someone showed them how useful they can be, would they consider buying one, 41% agreed and 40% stayed neutral. As one of the students mentioned, "I don't know whether it is useful and also I am not sure we can use it during the final exams."

It is interesting that the usefulness is related to being able to use it in the final examination. So when it came to the fact that they are allowed in the examination and the unfairness of it in statement 6, half the students agreed that they should not be allowed to use them in tests and examinations, since it is not fair on those who cannot afford one.

It was noticed throughout the course that those who had the calculators were not yet confident in using them. It is important for students to be familiar with these devices and know when and how to use them effectively and not to waste time.

Most students were concerned by the cost of the calculators, 74.5% agreed with statement 2 about the cost factor of the calculators. Only 2% disagreed with this statement, and the rest remained unsure, probably because they were not aware of its price. Here a comment from a student who seemed to have done all his homework on the matter, "they are way too EXPENSIVE \$230.00 how on earth are we supposed to afford it!! We can barely afford the food this uni sells at the shops!!"

So when the students were asked in statement 4 whether they would like to have a TI-89 if they become more affordable, 61% agreed while 30.4% still had doubts and 9% disagreed.

We assumed that the lecturers not using them in the class had an effect on students' willingness to buy the TI-89s. Surprisingly 47% of students were undecided when we asked them in statement 3, why should you bother if the lecturers are not using them. 39% agreed with this statement, and 14% disagreed. The same results for this statement were also true from the first semester data as 152 students replied to this question, where 41% agreed, 14% disagreed and 45% remained neutral.

It is interesting that students were not highly influenced by the examples set for them in the class. This suggests that they had made up their minds about how to learn mathematics perhaps from their school years, and their university experience had not caused them to change their views. Povey and Ransom (2000) noticed that students views in their study were not just "one-off or idiosyncratic, if we are going to work successfully using the new technology we will need to heed and respond to these perspectives of resistance" (p. 61). One student summarised all his thoughts in the following comment, "we should all suffer and learn to do maths the hard way."

Most of the points discussed above were reflected in students' comments. Some mentioned that they could only use them for one semester and were not allowed to use them in the stage two examinations. There were other comments that indicated some of the students' difficulties:

- It's so confusing. Harder to master than the actual course.
- Harder to learn to use than just learning how to do problems by hand and normal calculator.
- Math is knowledge in brain not in computer or calculators.
- Calculations for matrices often take just as long by hand than the TI-89.

Whatever the reasons for refusing to use calculators are, I believe that a well-organised course that considers students needs and hears their voices will be a better vehicle to combat obstacles along the way and teach mathematics in the best possible manner to the new generation. This research also raises alternative questions to be investigated such as:

1. Why did the lecturers not encourage calculator use?
2. How should pre calculator curriculum be modified?

Conclusions

We are living in a time and age where technology use is growing rapidly that, we cannot keep up with it all. In many cases we may not have the time or even the ability to use it to its full potential. Over the past two decades we have seen that it is possible to give mathematical power to students and achieve great benefit from its sensible use (Arnold, 2004). However, it is of concern that, even though the use of CAS is becoming more common, there seems to be less emphasis given to designing suitable frameworks to facilitate its usage. It seems that the companies sell the remedies, we as educators prescribe them and only a few university students use them. Hence, sceptics say there is not enough evidence that they actually work.

Unfortunately, these powerful devices were reduced to little “extra options” (Arnold, 2004) in Maths 108 course. Students disappointment and frustration due to the lack of affordability (for one semester), and because the lecturers themselves did not use the calculators, was of concern. Lack of support and guidance and appropriate planning made many students walk away with rather a negative attitude toward calculator use.

The findings from this study address some issues that are worth considering and may have an effect on the future of mathematics learning and teaching with the aid of technology at university.

This year the Maths 108 teaching team seems to be keen to use the TI-89 and acknowledges that they are useful tools. However, there is still no structured framework in place showing how to incorporate them into teaching.

References

- Arnold, S. (2004). Handheld classroom technology. In I.Putt, R. Faragher & M. McLean (Eds.), *Mathematics education for the third millennium: Toward 2010* (Proceedings of the 27th annual Conference of the Mathematics Education Research Group of Australasia, pp. 16-28). Sydney: MERGA.
- Artigue, M. (2002). Learning mathematics in a CAS environment: The genesis of a reflection about instrumentation and the dialectics between technical and conceptual work. *International Journal of Computers for Mathematical Learning*, 7, 245-274.
- Flynn, P., Berenson, L., & Stacey, K. (2002). Pushing the pen or pushing the button: A catalyst for debate over future goals for mathematical proficiency in the CAS-age. *Australian Senior Mathematics Journal*, 16(2), 7-19.

- Guin, D., & Trouche, L. (1999). The complex process of converting tools into mathematical instruments: The case of calculators. *International Journal of Computers for Mathematical Learning*, 3, 195-227.
- Herwaarden, O., & Gielen, J. (2002). Linking computer algebra systems and paper- and-pencil techniques to support the teaching of mathematics, *International Journal of Computer Algebra in Mathematics Education*, 9(2).
- Lagrange, J. B. (1999). Learning pre-calculus with complex calculators: Mediation and instrumental genesis. In O. Zaslavsky (Ed.), *Proceedings of the 23rd Conference of the International Group for the Psychology of Mathematics Education* (Vol. 3, pp. 193-200). Haifa, Israel: International Group for the Psychology of Mathematics Education.
- Penglase, M., & Arnold, S. (1996). The graphics calculator in mathematics education: A critical review of recent research. *Mathematics Education Research Journal*, 8(1), 58-90.
- Povey, H., & Ransom, M. (2000). Some undergraduate students' perceptions of using technology for mathematics: Tales of resistance. *International Journal of Computers for Mathematical Learning*, 5, 47-63.
- Quesada, A. R. (1999). On changing the focus of a linear algebra course with a TI-92. In D. A. Thomas (Ed.) *Proceedings of M/SET 99 an International Conference on Mathematics/Science Education & Technology* (pp. 321-326). San Antonio, Texas: Association for the Advancement of Computing in Education.
- Stewart, S., & Thomas, M. O. J. (2004). The learning of linear algebra concepts: Instrumentation of CAS calculators. In W. Yang, S. Chu, T. de Alwis & K. Ang (Ed.), *Proceedings of the 9th Asian Technology Conference in Mathematics* (pp. 377-386). Singapore: ATCM.
- Tall, D. O. (2000). Technology and versatile thinking in mathematics, In M.O.J. Thomas (Ed.), *Proceedings of TIME 2000 an International Conference on Technology in Mathematics Education* (pp. 33-50). Auckland, New Zealand: The University of Auckland & AUT.
- Thomas, M. O. J., & Hong, Y. Y. (2004). Integrating CAS Calculators into Mathematics Learning: Issues of Partnership. In M. J. Høines & A. B. Fuglestad (Ed.), *Proceedings of the 28th Conference of the International Group for the Psychology of Mathematics Education* (Vol. 4, pp.297-304). Bergen, Norway: International Group for the Psychology of Mathematics Education.
- Thomas, M. O. J., Monaghan, J., & Pierce, R. (2004). Computer algebra systems and algebra: Curriculum, assessment, teaching, and learning. In K. Stacey, H. Chick & M. Kendal (Eds.), *The teaching and learning of algebra: The 12th ICMI study* (pp. 155-186). Norwood, MA: Kluwer Academic Publishers.

Appendix

Section A: (For TI-89 users only)	Likert Scale	1(disagree)-2-3(agree)
For each statement below please circle the number which most closely corresponds to your own view.		
<ol style="list-style-type: none"> 1. The TI-89 CAS calculators do not improve my understanding of mathematics. 2. I waste a lot of time trying to get the TI-89 CAS calculator going. 3. I am glad that I can use the TI-89 CAS calculator during the exam. 4. TI-89 CAS calculators help me to visualise the problems. 5. I can solve problems using TI-89 CAS calculators even though I don't understand the theory. 6. My answers are usually different from the answers that the TI-89 CAS calculator gives me. 7. I think the TI-89 manual at the back of my book is very helpful. 8. I often check my answers using the TI-89 CAS calculator. 9. I would like to learn more about the TI-89 CAS calculators, so I can use them fully. 10. I believe technology is the way to go to learn mathematics. 11. I hope to use my TI-89 CAS calculator in other courses when applicable 12. My lecturers are very supportive and encouraging in using the TI-89 CAS calculators. 13. I explore the TI-89 by myself. 14. I find it difficult to decide when to use the TI-89 in maths problems. 15. Since I have been using the TI-89 CAS calculator, I have forgotten how to do the basic skills. 16. I like to use both TI-89 CAS calculator and pen and paper when working on maths problems. 17. I only use TI-89 CAS calculator when I am stuck using pen and paper for mathematics problems. 18. I bought a calculator at the beginning of the year but never used it, so I think I wasted my money. 19. I find all the TI-89 menus and key presses too difficult to remember. 20. TI-89 CAS calculators make mathematics fun. 21. There is not enough support outside lecture time for using the TI-89 calculator. 22. I believe the TI-89 gives me an unfair advantage in learning mathematics. 		
Section B: (For those who don't use the TI-89)		
For each statement below please circle the number which most closely corresponds to your own view.		
<ol style="list-style-type: none"> 1. I can do everything without a TI-89. In other words I don't need one. 2. The TI-89 CAS calculators are far too expensive. 3. The lecturers are not using them so why should I bother. 4. I would have liked to have one if they were more affordable. 5. I really don't know if they are good or not until I have tried one. 6. I believe students shouldn't be allowed to use them in test and examinations, because it is not fair on those of us who can't afford one. 7. If someone showed me how useful they can be I might consider buying one. 8. I wish I had a TI-89 that I could use. 		
Open questions (For TI-89 users only)		
-What do you like using the TI-89 calculator for? (Why?) -How do you feel about using the TI-89 calculators this year? -Should the TI-89 calculators be used in the mathematics lectures? If so, how? -How do you decide when to use the TI-89 calculator? -Has the TI-89 calculator helped you learn any mathematics? If so, what? -How much do you feel you rely on your TI-89 calculator? For example, could you still do the problems without having one? -Do you just try to apply the applications of the TI-89 calculators in the course manual or do you explore for yourself? -Did you buy the TI-89 calculator at the beginning of the year but never used it? (If yes, why?) -Why did you buy a TI-89 calculator? When did you find out there were notes at the back of your course book (notes on the CD for 150 students) on TI-89 calculators?		
Section C: (All Students)		
Please write below any other comments you would like to make.		