Engineering students' views of computer algebra systems

Sabita D'Souza and **Leigh Wood**, Department of Mathematical Sciences,
University of Technology, Sydney
Peter Petocz, Department of Statistics, Macquarie University
Sabita.Dsouza@uts.edu.au Leigh.Wood@uts.edu.au Peter.Petocz@mq.edu.au

Introduction

Some educators are working towards changing the content of the mathematics curriculum and the ways in which it is taught in order to best prepare students for the 'real world' by moving from a focus on arithmetic and computational skills toward a curriculum that develops students' abilities to think, reason, and communicate mathematically (Petocz and Reid 2005; Burton 2004). The goal is to help students construct their conceptual understanding of mathematics, not just memorise facts and rules. Likewise, the teaching of mathematics is changing in order to meet these new goals. Instead of teaching by demonstration, a blend of instructional methodologies is recommended that include individual and group work and direct instruction. The aim is to provide frequent opportunities for students to explore and solve problems, individually and with others, and to develop their mathematical skills in the context of this exploration (Stacey, Kendal and Pierce 2002). Lecturers are facilitators of learning, guiding students' explorations, asking questions that extend their thinking, and encouraging students to communicate their thinking. One of the catalysts for change is the widespread and increasing use of computer algebra systems by professional mathematicians and in teaching and learning mathematics.

Computer algebra systems in learning mathematics

Computer Algebra Systems (CAS) have been recognised as highly valuable for doing mathematics and potentially valuable for teaching and learning mathematics (Galbraith and Pemberton 2002). However, the mere presence of CAS in a classroom does not mean that its potential benefits will be realised. Students must learn to use both hardware and software effectively and academics need to develop appropriate learning tasks. Artigue (2001) calls this 'instrumental genesis', a process by which such available technology becomes a powerful tool. This learning process presents a new, additional challenge for students. Atkins, Creegan and Soan (1995) expressed concern that students learning new mathematics with new technology may be distracted by the overhead of learning to use the technology. Henderson (2002) questions the use of CAS in undergraduate teaching finding that a quarter of the 362 students surveyed did not find the [computer] laboratory sessions helped their understanding of the [linear algebra] course.

In order to benefit from the availability of CAS, students must not only be able but also willing to use this new technology. Arnold (1995) observed that the participants in his study showed a range of levels of engagement with the technology. He found that students' use of the software was sometimes impeded by their beliefs about mathematics and their perceptions of what was valuable. Lagrange (1996) also commented that in his experience not all students wanted to use CAS. The value of CAS depends on how effectively it is used. Employing CAS to do mathematics requires the student to become familiar with both the hardware and the software associated with this technology. This presents students with some learning overhead on top of learning mathematics. Students' success in benefiting from the use of CAS will depend on how effectively they learn to use this technology. The efficacy of their use will depend on both technical and personal aspects: whether the student can operate the program with a minimum of difficulty; and their attitudes towards the use of CAS (Pierce and Stacey 2002). Computer algebra systems challenge the traditional mathematics curriculum with many questions. For instance, what will be the place of memorising algorithms in the future? Can we broaden the mathematics curriculum to include more generic skills such as mathematical modelling if we allow CAS to perform the algebra and calculus manipulations? What is the role of assessment in the future mathematics curriculum (Wood and D'Souza 2003)? These are just a few of the issues that mathematics education researchers have to consider.

The study

There were 343 participants (first-year engineering students studying a core mathematics subject) from a cohort of 436 in the study. They worked on collaborative group activities during their set tutorials times and computer laboratory classes for one semester. Participants were evaluated on the work they produced during the tutorials and laboratory sessions. Students completed a questionnaire on their learning style preferences. The questionnaire also sought additional information regarding students' attitudes towards using computers, attitudes towards group-based assessment, and their reactions towards group-work in mathematics. Twenty students were interviewed in depth about their attitudes. Interviews were audio taped and transcribed.

Here we present the results of the questionnaire concerning students' attitudes towards using CAS (specifically, *Mathematica*) in learning mathematics (other aspects are described in D'Souza and Wood 2003; 2004). Several quotes from the interviews are used to illustrate the questionnaire data. The questionnaire items were adapted from Whitrow (1999). The research question of interest in this paper is to determine what are tertiary students' perceptions about the use of computer algebra systems in mathematics learning, that is, do students view *Mathematica* solely as a sophisticated number cruncher or also as a tool that promotes learning and understanding of concepts, and what are the implications of the findings.

Demographic profile

Demographic information in terms of age, gender, language spoken at home, and number of years spent in Australia was sought from the 343 participants. The majority of respondents (78%) were high-school leavers who were in the age group of 17-19 years, with mature age students represented by 19% of the population sampled. This can be related to the number of years students spent in Australia, with 81% of the population having spent 6 or more years in the country and only 18% having spent 5 or less years in the country. This means that majority of the students undertook some form of study in school before advancing to university for higher studies and were therefore familiar with the Australian system of education. There were comparatively more male students in the study (88%), with only 38 female students. The cultural background of students surveyed was very diverse. There were comparatively more non-English speakers (61%) than English speakers (38%), with 42% of the sample being students of Asian/Indian background. Students of European and Middle Eastern background each represented 9% of the sample.

Results and discussion of findings

Students responded to 20 questionnaire items on a seven-point scale (1=strongly disagree, …, 4=neutral, …, 7=strongly agree) that best reflected their perceptions (see appendix for items). The results were analysed using a principal components factor analysis with varimax rotation, leading to a two-factor model accounting for 42% of the total variance (no other factor accounted for more than 7.5%). Each factor summarises an independent dimension in the data. Factor 1 was named 'Anxiety': *Students' displaying computer anxiety and who see computers as an interference tool* (based largely on items 1, 2, 9, 10, 12, 15 and 19, as well as 7, 11 and 13 negatively scored). Factor 2 was named 'Benefits': *Computers viewed as a tool for understanding concepts and used with positive self-confidence* (based largely on items 4, 5, 6, 8, 14, 16, 17, and 20). Items 3 and 18 did not contribute significantly to either dimension.

Figure 1 shows the scatterplots of the two factors plotted against each other with markers set for age, sex, and number of years spent in Australia and language spoken at home. Each of the four plots shows the effect of the categorisations on students' responses.

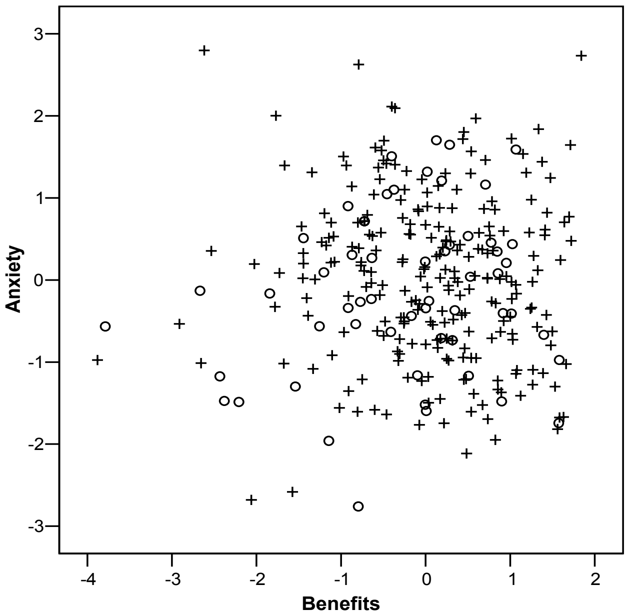

Figure 1a. Age group: + ex high school, ○ mature age

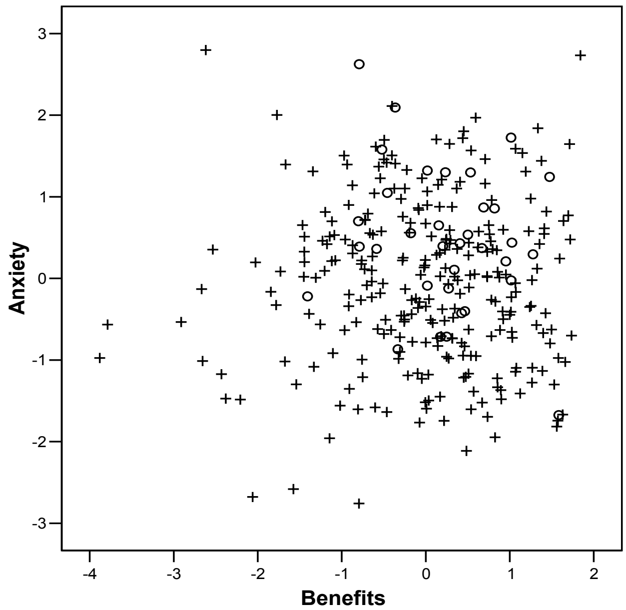

Figure 1b. Sex: + male, ○ female

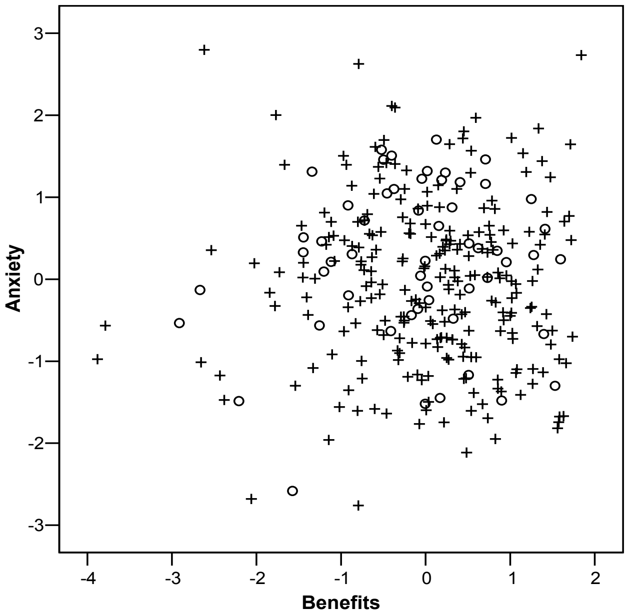

Figure 1c. Residence: + Australian, ○ recent migrant

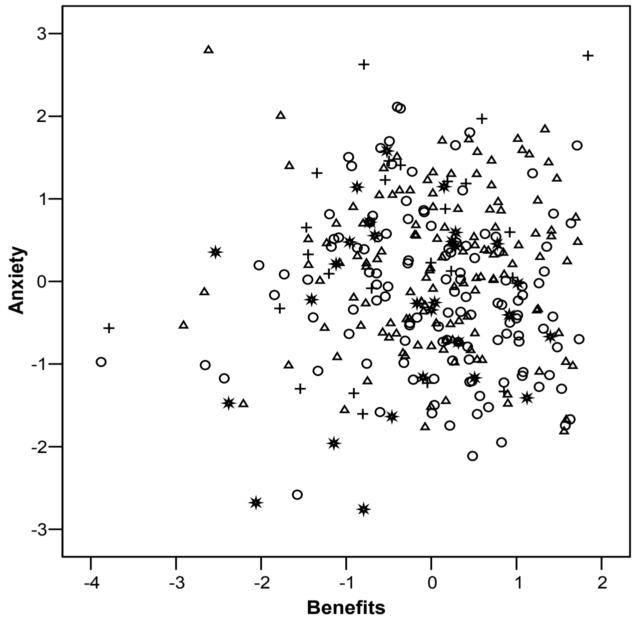

Figure 1d. Language background: ○ English, Δ Asian, + Middle East, ∗ European

Figure 1. Scatter plots of anxiety versus benefit regression factor scores with markers set by demographics

The plots in Figure 1 are a graphical way to show the relationship between the two factors (benefits and anxiety) and their interaction with the various demographic variables, for example, in Figure 1b we consider the sex variable. The plot shows that the females are generally at the top right, which means that their appreciation of the benefits is higher but also their anxiety is higher. This is shown to be significant in a multivariate analysis ($p = 0.01$). These results are similar to those found in Galbraith and Haines (2000). Similarly, the effect of language background (Figure 1d) is significant ($p = 0.02$) as shown on the plot. The Asian language background students are about the same as English-speaking background students on benefits and higher on anxiety; European language speaking students are lower on benefits and lower on anxiety. Middle Eastern language background students are lowest on benefits and by far the highest on anxiety. By examining the plots 1a and 1c, we can see that there is no obvious pattern between the variables and so there are only marginally significant differences between mature ages students and school leavers ($p = 0.06$) and no significant differences between recent migrants and longer-term Australian residents ($p = 0.30$).

It is interesting to note that language background is significant but recent migrant status is not. The recent migrants include international students. The fact that women display more computer is well known (Galbraith and Haines 2000), but it is surprising to find that this still true for women who choose to study engineering. There is an ongoing need to support some female students and non-English speaking background students with the introduction of technology in order to reduce anxiety.

How do students perceive learning of mathematics using computers?

Interviews with students were transcribed and responses were coded into themes. In regards to students' perceptions about the use of the computer algebra system, *Mathematica*, there were two views held by students. The first (lower level) view that students held was that *Mathematica* is a sophisticated number cruncher and tool for calculation as evidenced by these quotes:

> I guess computers probably just gives you an idea of how accurate or like how to draw graphs accurately and things like that umm the thing with Mathematica is that its like more of an actual language that you've got to learn to be able to write so than in itself is kind of a bit of a waste of time, but Mathematica has got its own separate language that you've got to try and figure out to be able to like draw up stuff, so in that sense I think its kind of a waste of time, but its good that you can have something where you can put your values and you can get like a precise umm graph or something like that where you can read off and see 'OK, this is how its done', but otherwise, in having to learn the actual language for Mathematica its kind of you know pointless I think.

> Oh, it's fantastic! It takes out a lot of the hard work I suppose, depending on what using, like you got things like Mathematica, I suppose when you've got to plot something particularly 'cos some yeah like power series or whatever some of those you just you could sit there and plot it yourself but it's take you all year sort of thing, by the time you sub in the values, definitely it helps a lot in that sense you learn a bit from it too vaguely, like with graphs you do, but you don't want to become too reliant on it otherwise it's gonna kick you backwards, and then when you do have to do something without the computer you're going to be up the creek a bit…

The second (higher level) view that students held was that *Mathematica* can be used as an aid for understanding concepts as evidenced by the quotes below. Students that held this view also viewed *Mathematica* as a sophisticated number cruncher with powerful calculation capabilities.

It helps us understand the math because, unless you know what the question is asking, and how to go about the question, you cannot input it into Mathematica.

> I believe it does, like what we're doing now, where we've got what we've had two labs in this semester so far, its been good because its more applying what you've learnt as opposed to using the computer to learn, which I think is a better concept 'cos you want to get the basics before you suddenly jump in and go blah blah blah… plot this…so cos then you can yeah have a look at what's going on, but then being able to plot where you're doing oh whatever you know get someone else to double check, its always good to double check just cos if you're doing it wrong then you'll know and you'll go back and do it again, whereas if you had no idea, you'd sit there going 'OK I've got it right', but then you find out you're doing it completely wrong… yeah you losing out in the long run so…

Implication of findings and concluding remarks

The data revealed hierarchical themes regarding the use of computers in mathematics instruction – a lower level theme where students viewed Mathematica as a sophisticated number cruncher and a second higher level theme where students were of the opinion that Mathematica not only could be used as a sophisticated number cruncher but also to help in their understanding of concepts. Arguments for and against use of CAS in the literature are many, most of them pedagogical but also some practical (Coupland 2000; Cretchely 2001). We have shown in this study the desirable effects of using *Mathematica* which supports the findings of many existing research studies, but not so many of these are conducted in the engineering education domain where mathematics is a service subject.

There are many implications of using computers in the teaching and learning of mathematics at university. As students in this study pointed out, it is very exciting, enjoyable and productive to use computers in class. They are keen to use computers, so the environment becomes more conducive for learning. Students' natural curiosity can be utilised to its fullest potential because they are keen to explore and discover. Sound social relationships develop as they discuss their findings amongst each other. They take a certain degree of responsibility of their own learning.

However, irrespective of the software packages used, it is important to remember that the software should *support* the learning and curriculum and not *provide* the learning. In order to use computers effectively, appropriate software that supports the goals and philosophy of teaching, enhances the curriculum, and helps students should be selected. As with any new pedagogical tool, some academics and students resist introduction of CAS, while others embrace it with enthusiasm. Change can produce stress and, unless acknowledged and managed appropriately, it can inhibit the learning process and subsequent success of the innovation. The change required will be greatest where it conflicts with students' previous educational experiences and current conceptions of learning. This study has shown that some students, in particular female students and Middle Eastern students, have high anxiety about the use of computers in their learning of mathematics. This should be acknowledged in teaching and learning and support offered to alleviate the anxiety.

We suggest that if students are to use CAS, it is important that it be blended into their everyday class work. They must therefore be introduced to CAS in a systematic way, and they need to be required to use it. In terms of assessment, examinations must emphasise concepts, so that students see the value of learning them and can appreciate the help of CAS. Software packages can influence behaviours such as cooperation and motivation, as well as how students interact with each other. Students are less likely to use computers in their learning if they see it simply as an add-on or *as another subject to learn* or simply as an aid to learn the same old curriculum. It is important to think about the experience we want students to have, the learning we want to build on, and select software carefully to encourage certain types of learning experiences. The current exploration by many researchers into the relationships between teaching, learning, computers and mathematics will help with this debate.

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Appendix: Questionnaire items with means and standard deviations

Item	Description	mean	sd
1	If I can avoid using a computer, I will.	2.7	1.8
2	The way computers force you to follow a procedure annoys me.	3.3	1.8
3	I will work at a computer for long periods of time to successfully complete a task.	5.3	1.5
4	I enjoy thinking up new ideas and examples to try out on a computer.	4.8	1.5
5	Using a computer makes learning more enjoyable.	5.0	1.5
6	I like the freedom to experiment that is provided by a computer.	5.1	1.4
7	I have a lot of self-confidence in using computers.	5.3	1.6
8	I feel more confident of my answers with a computer to help me.	5.1	1.5
9	If the computer program I am using goes wrong, I panic.	3.3	1.7
10	I feel nervous when I have to learn new procedures on a computer.	3.0	1.6
11	I am confident that I can master any computer procedure that is needed for my course.	5.0	1.6
12	I do not trust myself to get the right answers using a computer.	3.2	1.5
13	If a make a mistake when using a computer, I am able to work out what to do for myself.	4.8	1.4
14	Computers help me learn better by providing many examples to work through.	4.7	1.4
15	I find it difficult to transfer understanding from a computer screen to my head.	3.4	1.5
16	Using computers helps me understand concepts better.	4.4	1.5
17	By taking care of messy calculations, computers make it easier to learn essential ideas.	4.8	1.5
18	When I read a computer screen, I tend to gloss over the details of the mathematics.	4.4	1.4
19	Following keyboard instructions takes my attention away from the mathematics.	4.3	1.7
20	Computers help me link knowledge e.g,. the shapes of graphs and their equations.	5.1	1.5

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