Computers, Mathematics, and Undergraduates: What Is Going on?

Peter Galbraith
The University of Queensland
<p.galbraith@mailbox.uq.edu.au>

Mike Pemberton
The University of Queensland
<mrp@maths.uq.edu.au>

Patricia Cretchley
University of Southern Queensland
<cretchle@usq.edu.au>

We report on research at two universities into attitudes of students relevant to the integration of mathematical software packages (MAPLE and MATLAB) in first year undergraduate courses. Both similarities and differences were found between the respective implementations. Separate constructs for mathematics confidence and computer confidence were confirmed, as were systematic gender differences between attitudes to mathematics and computers. On the other hand comparison of pre and post responses indicated some differences in the impact of the respective programs. Implications of the findings are considered against a background of increasing use of technology in tertiary mathematics teaching.

The relevance of studying attitudes to information technology in conjunction with those relating to mathematics is emphasised and reinforced by the increasing use of technological devices in mathematics instruction. Templer et al. (1998) raised problems perceived to arise as a direct result of a symbolic manipulator (*Mathematica*) environment. They observed that having mastered the rudiments; the majority of students “began to hurtle through the work, hell bent on finishing everything in the shortest possible time”. The following comment, or a close relative, was noted as occurring frequently “I just don’t understand what I’m learning here. I mean all I have to do is ask the machine to solve the problem and it’s done. What have I learned?” Several studies have referred incidentally to attitudinal impacts in conjunction with proficiency measures. For example (Mackie, 1992; Park, 1993) make reference to the impact of computer-supported instruction on the disposition of students as well as recording their performances. It is not generally made clear in the mathematically focused studies just which ‘attitudes’ have been affected by technology, as the reporting tends to be non-specific. By inference it appears that it is ‘attitude’ to mathematics that is intended. While the study of *attitudes* in mathematics learning has a substantial history, the directional relationship between *attitude* and *performance* is not clear-cut although positive correlations have often been noted between these characteristics. Following studies over many years the Tartre and Fennema (1995) comment that described confidence as the affective variable most consistently related to mathematics achievement was probably a safe summary of the position. Recent studies have continued to pose the direction of the relationship as an open question (Hensel & Stephens, 1997; Shaw & Shaw, 1997).

The study of attitudes towards information technology (most frequently computers) has a shorter but more intensive history, probably because information technology, while newer, is all-pervasive in its permeation of curriculum areas. Reports specifically involving mathematics students appear relatively hard to come by, although some have included affective variables when evaluating outcomes (see above). It is this very breadth of discipline background that has served to keep the investigation of attitudes to technology use at a general level, appropriate to the majority who will not be called upon to use computers in the same technical sense as mathematics students working intensively with specialised software.

The consistent relationship between mathematics confidence and performance (whatever the direction of causality), means that the implications of a nexus between technology and mathematics needs specific research attention, for the broad reporting of studies makes it difficult to disentangle whether affective outcomes are associated with changed attitudes to mathematics, or are linked directly to the technology. So theoretically we are moved to ask about the interpretation of outcomes if students possess high mathematics confidence and motivation, but low computer confidence and motivation, and vice versa. Given also that students' prior access to and experience with computers is continually increasing, will differences identified between mathematics and computer based responses to parallel attributes such as confidence and motivation diminish with time, or do they represent distinctive sets of characteristics with a permanent presence in computer-assisted mathematics learning? The report, Mathematical Sciences-adding to Australia (NBEET, 1996) noted then that the mathematical sciences were becoming increasingly laboratory based, with significant implications for how they should be taught, and recommended that mathematics departments re-design their courses to make best use of the increased computer power (via packages such as *Derive, Maple, Mathematica,* MATLAB) becoming available. Simultaneously cuts in university funding have caused institutions to rationalise resources, so that teaching programs have had to make do with what they can in seeking to support innovative uses of technology in course delivery. Within this context we report on research conducted among first year undergraduate students at the University of Queensland (UQ), and the University of Southern Queensland (USQ). Both used software packages in the preparation and delivery of programs.

Research Questions

Following interests guided by the issues visited in the previous section, the following aims have motivated the research presented here.

1. To investigate structural relationships between attitudes to mathematics and to computers among beginning undergraduate students.
2. To investigate the impact of computer assisted teaching-learning programs on the attitudes of undergraduate mathematics students.
3. To investigate gender differences between attitudes to mathematics and to computers among undergraduate mathematics students.

The Setting

University of Queensland

The first year mathematics course at UQ taken by commencing engineering and science undergraduates is characterised by the following. As taught in 2000 the course, which is an introductory (tertiary) course in calculus comprised a lecture series complemented by weekly workshops, in which approximately 40 students are timetabled into a laboratory containing networked computers equipped with *Maple* software. The lecture room is fitted with computer display facilities so *Maple* processing is an integral and continuing part of the lecture presentation. To support their workshop activity students are provided with a teaching manual (Pemberton, 1997), continually updated to contain explanations of all relevant *Maple* commands, together with illustrative examples. Weekly two-hour tutorial/laboratory sessions are provided. During the tutorial hour questions arising from the *Maple* based treatment of mathematical content are addressed. During the laboratory hour two tutors and frequently the lecturer also, are available to assist the students working on tasks structured through the provision of weekly worksheets. The students can consult with the lecturer during limited additional office hours, and unscheduled additional access to the laboratory is available for approximately 5 hours per week. The course is also available on the Web. Solutions to the weekly worksheets are provided subsequently. Formal course assessment is constrained by departmental protocol and the availability of facilities. It comprises pen and paper exams at mid-semester (10%), and at end of semester (70%), supplemented with three *Maple* based assignments (total 10%), and a mark assigned on the basis of tutorial work (10%). Consequently to succeed students must transfer their learning and expertise substantially from a software supported environment to written format. This means they must be able to develop understanding through the symbolic manipulator medium with which they work, while simultaneously achieving independence from it; involving the necessity to learn, practise, consolidate and maintain pen and paper procedures that a *Maple* environment provides access to, and support for, but does not enforce. Access to and mastery of the required mathematics is obtained by participating in activities provided through the structured *Maple* environment. This is a defining feature of the program.

University of Southern Queensland

The software package selected for implementation at USQ in an introductory algebra and calculus course was MATLAB. Support for MATLAB was provided to the full class of first-years, within which two-hour small-group tutorials were divided into one hour in the classroom, and one hour in a computer laboratory, with students attempting weekly tasks set by the lecturers. Lectures were offered to the class of around 200 on-campus students, with some of that time being used to demonstrate basic MATLAB commands. Students also had MATLAB support from their tutor in a computer laboratory in the second hour of their 2-hourly weekly tutorial. It was agreed that the primary purpose of the technology would be to support concept development and facilitate ease of computation and graphing, but that too quick and deep an immersion in the use of technology in this early stage of first semester might crowd concepts and problem solving too much. The application deliberately did not focus on symbolic algebra, so avoiding many of the potential syntax and interpretation challenges faced by students using symbolic manipulators such as *Mathematica* or *Maple.* In particular, the decision was taken not to require computer algebra as an integral part of the course as noted above. Students were encouraged and invited to explore the facilities available in MATLAB in their own time, and to use them as a check on their handwork, or for more tedious manipulations. It was made clear to students, by the nature of their assessment work, that basic hand skills are valued and that they should be able to communicate the basic concepts easily and fluently by hand. Students were required to submit 5 assignments each one of which included a substantial number of tasks that invited the use of technology, and these were the major incentive for the use of MATLAB. All students were given a MATLAB Handbook, especially written to cater for their needs in this subject, and basic commands and use were demonstrated in lectures.

Data Sources (UQ)

Five attitude scales (Galbraith & Haines, 1998) were administered to the 2000 cohort during the lecture session in the first week (N~160), and again during the final lecture period on the last day (N~115). Confidence and motivation scales were chosen because of their extensive appearance in the literature for both mathematics and technology, and because this choice enables two circumstances of particular interest to be considered viz. situations where students hold strong positive feelings towards mathematics and negative feelings towards technology, and vice-versa. A further scale included additional factors considered important for the learning context. This Computer-Mathematics interaction scale assesses the extent to which students bring their mathematical thinking into active inter-play with the computer medium. The construction and testing of these eight item Likert scales has been reported extensively elsewhere (Galbraith & Haines, 1998). As with earlier administrations the (alpha) reliabilities exceeded 0.8 except for the interaction scale where its value is 0.7. Students were asked for a measure of their agreement (or rejection) with respect to item wording, which resulted in a 13-point scale. Sample items are provided in the Appendix, in which those chosen are the ones that attracted the most positive response within each scale, or for reverse polarity items, those that featured the strongest rejection.

Data Sources (USQ)

Motivated by similar theoretical and background considerations as the UQ team the nature and impact of affective factors was addressed by means of a questionnaire designed to capture students' views on attitudes to mathematics and computers, on a 5 point Likert scale (Cretchley et. al., 2000). Responses to the survey were captured on entry to the subject (N~180), and again just before the end of the semester (N~150). Factor analysis was used to refine the instrument, and the resulting four scales were identified.

- confidence in doing and learning mathematics: the Mathematics Confidence scale
- confidence with using computers: the Computer Confidence scale
- attitudes to technology use in the learning of math: the Math-Tech Attitudes scale
- views on experience with software in learning math: the Math-Tech Experience scale

The scales proved reliable and consistent for the measurement of the above attributes, yielding high Cronbach alpha ratings (between 0.83 and 0.92) and strong test-re-test reliability. See the Appendix for sample items.

Research Outcomes

Differences in Attitudes to Mathematics and Computing

University of Queensland. To follow an interest in the stability of relationships we include parallel output (in brackets) from administration of the scales to a 1997 student group (N~140) in a similar course. All data are from responses of students on course entry.

Table 1
Pearson Interscale correlations UQ

	Mmotiv	Cconf	Cmotiv	CMint

Mconf	0.51 (0.68)	0.22 (0.21)	-0.04 (0.19)	0.04 (0.16)
Mmotiv		-0.07 (0.23)	0.00 (0.29)	0.15 (0.26)
Cconf			0.62 (0.75)	0.56 (0.58)
CMotiv				0.65(0.66)

The interscale correlations (Table 1) indicate that the confidence and motivation scales are strongly associated within mathematics and within computing respectively, but are weakly associated across the areas. The Computer-Mathematics interaction scale is much more strongly associated with the computer confidence and computer motivation scales than with the mathematical scales where correlations are again weak. A factor analysis involving the five scales, and using an oblimin rotation following a principal components analysis, produced the loadings shown in Table 2. The two-factor solution confirms that the computer and mathematics related scales define different dimensions with computer properties dominant in the interaction scale.

Table 2
Factor Pattern Matrix UQ

	Factor 1	Factor 2
Mconf	0.02 (-0.06)	0.88 (0.87)
Mmotiv	-0.02 (0.03)	0.87 (0.89)
Cconf	0.84 (0.89)	0.05 (-0.03)
Cmotiv	0.89 (0.90)	-0.11 (0.02)
CMint	0.85 (0.83)	0.06 (0.02)

Note. Percentage of variance explained: 75.3 (69.7).

University of Southern Queensland. Table 3 shows interscale correlations for the USQ 1999 results based on post-test data. Similar correlations were found in the slightly larger sample of pre-test data.

Table 3
Pearson Interscale Correlations USQ

	Computer Confidence	Math-Tech Attitudes	Math-Tech Experience
Maths Confidence	0.11	0.14	0.23
Computer Confidence		0.51	0.52
Math-Tech Attitude			0.75

As with the UQ data a striking feature is the very weak correlation between Maths Confidence and Computer Confidence (r = 0.11). This notable and initially surprising result provides further evidence that attitudes to mathematics and to computers are distinct constructs that should indeed be measured separately. Again, consistent with the UQ outcomes, the two Maths-Tech scales shared stronger inter-correlations with Computer Confidence (0.51, 0.52) than with Maths Confidence (0.14, 0.23). Correlations between the Math-Tech Attitudes and Math-Tech Experience scales were high, as expected (r = 0.75).

Attitude Changes Over the Semester

The pre and post group means are summarised in Table 4 (UQ) and Table 5 (USQ).

To detect changes in attitudes over the semester, pre- and post-test means for each of the scales can be compared. The USQ pre-data reveal generally neutral levels of mathematics and computer confidence, and comparisons with post-data reveal no significant change in either of these. Nor did students' espoused attitudes to technology in the learning of mathematics change significantly over the period of intervention. The biggest discernible change was in espoused views on personal experience of using software for learning mathematics. This slight upward trend needs to be interpreted with care, as some students responded to pre-test items without having had such personal experience, hence their initial views are more likely attitudinal than experiential. However, it is encouraging that after a semester of exposure to the program, the data show an upward trend. This contrasts with pre-post comparisons in the UQ data, where the mathematics scale scores are reasonably stable but the means on computer confidence and motivation drop by about a scale point. The question arises as to what differences between the programs at the universities may help to explain this observation.

Table 4
Scale Means UQ (Pre & Post): 13 Point Scale

Mathematics confidence	8.6 (8.0)	Computer confidence	8.7 (7.8)
Mathematics motivation	8.0 (7.8)	Computer motivation	7.7 (6.7)
Comp/Math interaction	7.2 (6.7)		

Table 5
Scale Means USQ (Pre & Post): 5 Point Scale

Mathematics confidence	2.7 (2.6)	Math-Tech attitudes	2.8 (2.9)
Computer confidence	3.0 (3.0)	Math-Tech experience	2.7 (2.9)

Analysis by Gender

Figure 1 contains an item-by-item plot of the differences between the means registered by females (F) and males (M) at the University of Queensland, using the pre-data. The vertical bars delineate the five 8 item scales, which, reading from left to right, are Mathematics confidence, Computer motivation, Mathematics motivation, Computer confidence, and Mathematics-Computer interaction. It is clear that females score more highly on the mathematics scales, and males more highly on the computer scales suggesting a systematic gender difference exists. A similar pattern occurs using post-data.

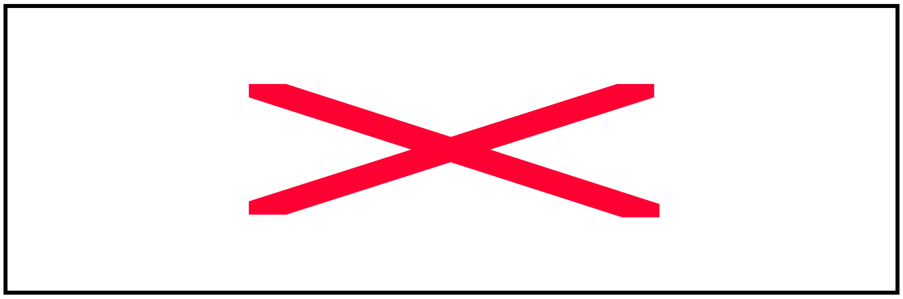

Figure 1. Gender differences on attitude scales (UQ).

Consistent with the UQ findings entering female students at USQ ($N = 26$) espoused significantly higher levels ($p<0.04$) of mathematics confidence than male students (N=156): (scale mean 4.0 vs 3.7). But they espoused significantly lower levels of computer confidence ($p < 0.01$), than their male counterparts; (scale mean 3.7 vs 4.1). However it was reassuring to find no significant gender difference in espoused views on their Math-Tech Experience towards the end of the MATLAB enriched teaching program. Post-test data also indicated that females had slightly increased their scores on Computer Confidence and Math-Tech Attitudes and that there were slightly reduced gender differences in the mean scores on these two scales at the end of the semester's MATLAB experience.

Reflections

Pedagogies to support the use of technologies in undergraduate teaching are still in the process of development. Within this enterprise the interaction between mathematics and technology is of significant importance, and we note the properties independently confirmed among students from different cohorts at different times. Firstly with respect to structural relationships, given the robust behaviour of the scales across time and place, we have confirmed earlier evidence that the respective attitudes to mathematics and to computers occupy different dimensions, with interactions loading with the computer scales. Secondly, this finding provides an interim answer to the ancillary question. Given that students' prior access to and experience with computers is growing, will differences identified between mathematics and computer based affective responses to parallel attributes such as confidence and motivation diminish with time, or do they represent distinctive sets of characteristics with a permanent presence in computer-assisted mathematics learning? The data so far suggest the latter!

The gender specific responses to the attitude scales continue to keep the matter of gender preferences a key issue as the challenge of understanding more about technology supported mathematics learning is pursued. Data from both universities presented a clear and consistent picture. Females felt more positive and confident about mathematics, and males more positive and confident about their interaction with computers.

While the data from both sites gave consistent pictures of structural relationships and gender specific responses to the attitude scales, they differed in the pattern of pre-post movements. Where the UQ students exhibited a loss of confidence and positive feelings towards computers this was not evident in the USQ responses, and we search for possible explanations of this outcome. A potentially significant influence lies is the respective nature of the two programs. For the UQ students the *Maple* environment was an effective gatekeeper to success in mathematics because of the central role it played in the program. Feelings about computing would likely be integrated with concern for success, even among the supremely competent, and it is most unlikely that such high stakes featured in their earlier computer experiences. The structure and teaching within the course was rated exceptionally highly by the students (6.3 on 7 point scale), so alternative explanations associated with pedagogy may be reasonably discounted. For the USQ students MATLAB was provided as a support, indeed a powerful support but not a gatekeeper to success because of the continuing priority accorded parallel approaches such as hand calculations. This meant that the computer power on offer had an element of choice, with students able to access it as they saw the opportunity and value in doing so. The students were in control. We believe that the commonalities and differences identified within our programs serve to highlight the complexity involved when powerful technology is introduced into undergraduate mathematics teaching. Much more is involved than trying to do faster and more cheaply that which was done formerly with blackboard, chalk, and paper.

References

Cretchley, P., Harman, C., Ellerton, N., & Fogarty, G. (2000). MATLAB in early undergraduate mathematics: an investigation into the effects of scientific software on learning. *Mathematics Education Research Journal*, *12*, 219-233.

Galbraith, P. L. & Haines, C. R. (1998). Disentangling the nexus: Attitudes to mathematics and technology in a computer-learning environment. *Educational Studies in Mathematics 36*, 275-290.

Hensel, L. T., & Stephens, L. J. (1997). Personality and attitudinal influences on algebra achievement levels. *International Journal of Mathematical Education in Science and Technology 28*, 25-29.

Mackie, D. M .(1992). An evaluation of computer-assisted learning in mathematics. *International Journal of Mathematical Education in Science and Technology 23*, 731-737.

NBEET, (1996). *Mathematical Sciences-Adding to Australia*. Canberra: National Bureau of Employment, Education, and Training.

Park, K. (1993). A comparative study of the traditional calculus and mathematics course. Unp[ublished Ph.D.dissertation, University of Illinois at Urbana-Champaign.

Pemberton, M. R. (1997). *Introduction to Maple* (revised edition). Brisbane: University of Queensland Mathematics Department.

Shaw, C. T., & Shaw, V. F. (1997). Attitudes of first year engineering students to mathematics – a case study. *International Journal of Mathematical Education in Science and Technology 28*, 289-301.

Tartre, L. A., & Fennema, E. (1995). Mathematics achievement and gender: A longitudinal study of selected cognitive and affective variables (Grades 6-12). *Educational Studies in Mathematics 28*, 199-217.

Templer, R., Klug, D., & Gould, I. (1998). Mathematics laboratories for science undergraduates. In C. Hoyles., C. Morgan., & G. Woodhouse (Eds.), *Rethinking the Mathematics Curriculum* (pp. 140-154). London: Falmer Press.

Appendix

Sample Scale Items (UQ)

MC	Mathematics is a subject in which I get value for effort	Mathematics is always difficult for me (*)
CM	I like the freedom to experiment a computer provides	If I can avoid using a computer I will (*)
MM	I continue to think about math that puzzles me	The challenge of understanding math does not appeal to me (*)
CC	I am confident I can master any computer procedure	As a (M/F) I feel disadvantaged in having to use computers (*)
CMI	Computers help to link knowledge e.g.,	I find it difficult to transfer understanding

	from a computer screen to my head (*)	the shapes of graphs and their equations

Sample Scale Items (USQ)

For the confidence scales the items were similar to those for the parallel UQ scales. Additionally:

M-TA	I like the idea of exploring math methods and ideas using technology	I think technology is too new and strange to make it worthwhile for learning maths (*)
M-TE	I will use computer software for mathematics again by choice	Learning to use computer software to do mathematics is frustrating (*)

*Items involving reversal of polarity