MATHEMATICS OR COMPUTERS? CONFIDENCE OR MOTIVATION?
How Do These Relate To Achievement?

Patricia C. CRETCHLEY
University of Southern Queensland
Department of Mathematics and Computing, Toowoomba 4350, Australia
cretchle@usq.edu.au

Peter GALBRAITH
University of Queensland
Graduate School of Education, University of Queensland, St Lucia 4067, Australia
edpgalbr@mailbox.uq.edu.au

ABSTRACT

The use of computers in the teaching and learning of undergraduate level mathematics raises many still unanswered questions about the relationships between students' perceived abilities and attitudes towards mathematics and computers (both separately and interactively), and their performance on assessment tasks.

This paper reports on an investigation of the correlations between first-year mathematics students' performances on a range of assessment items, and the following affective factors:

- students' levels of confidence in their ability to do and learn mathematics
- their motivation when doing mathematical tasks
- their levels of confidence in the use of computers
- their motivation to use a computer
- their attitudes to technology in the learning of mathematics.

The study targeted a class of students in a typical first-year Australian Linear Algebra and Calculus course. Support for the use of MATLAB was integrated into their learning, and students did both hand exercises, and tasks requiring the use of technology, in tutor-supported weekly computer laboratory sessions. The USQ MTech scales and Galbraith-Haines scales, instruments already well tested for internal consistency and reliability, were used to assess students' confidence levels with mathematics and with computers, their mathematics motivation and computer motivation, and their attitudes to technology in the learning of mathematics.

Scatter plots and correlation coefficients are offered where appropriate, to illustrate the relationships between the students' mean scores on each of these scales, and their achievement levels on a range of assessment items: three assignments and two examinations. The trends and significant findings are discussed in relation to the overall nature of the assessment items. The data collected are also used to further establish the reliability and validity of the scales used.

KEYWORDS: Mathematics, technology, attitudes, undergraduate, achievement.

1. Introduction

1.1 Outcomes and effects: Increasing student access to the use of technology is providing impetus for the development of a wide range of innovative programs that invite or compel undergraduate mathematics students to interact with computers for learning and for problem solving. This raises many as yet unanswered questions about the effects, both cognitive and affective, of technology-rich learning experiences. While many developments in this area seem to offer exciting and stimulating new approaches to learning, there are relatively few careful attempts to assess the effects of the increasing role of technology on learning preferences and on attitudes.

One reason for this neglect is that outcomes are often difficult to measure and compare. Resources and timetabling often make controlled studies difficult, if not impossible. Equity issues also arise when different levels of access to technology are granted to different groups of students. Many commonly used methods of assessing learning outcomes are unreliable when extended to comparisons between different learning environments. Crucial questions about our objectives and instruments must be answered before we can fairly compare the performance of students who have been exposed to different tasks, approaches and emphases.

Clearly it is necessary to establish what common outcomes we seek, both cognitive and affective, and to investigate ways to assess these.

1.2 The critical balance of Affect and Cognition: Reported studies have continued to pose the direction of the relationship between *attitude* and *performance* as an open question. Thus while Tall and Razali (1993) argued that the best way to foster positive attitudes is to provide success, Hensel and Stephens (1997) concluded that "it is still not totally clear whether achievement influences attitude, or attitude influences achievement". Shaw and Shaw (1997) noted that among a certain group of engineering undergraduates (labelled downhillers) performance and motivation both deteriorated during tertiary studies - leaving the direction of any causal mechanisms open. Certainly if a learning experience is unpleasant for the student, any gains in cognitive achievement and performance may be offset or diminished by attitudinal losses. Raised levels of dislike or feelings of inadequacy may deter the student from studying further in the area. When evaluating learning programs, therefore, our goal of cognitive gain must be tempered by attention to affective outcomes. We might refer to this critical balance as ACE: that combination of Affective and Cognitive outcomes that yields an Effective learning program.

Cognitive issues have long been a primary focus of attention in assessment. While there is much debate about the value of different types of assessment, most educators feel that at least some of the cognitive outcomes of a mathematics learning program can be assessed by evaluating students' performance on a carefully balanced range of assessment tasks, usually a combination of tests, assignments and projects. Affective issues, outcomes and their measurement, on the other hand, have been seriously neglected (McLeod 1992) and have produced far less consensus. Yet their importance is undeniable in an era when a growing number of attractive alternatives are enticing students away from the study of mathematics.

It seems unlikely that affective issues are under-valued, for teachers report frequently and quite strongly on students' attitudes and reactions - but usually relatively informally. Many published reports on innovative programs address affective outcomes in a relatively ad hoc way, if at all. Most common are summaries of student responses to a course evaluation questionnaire, specially designed or generic to the institution. While they may be informative about that particular program, such evaluations do not enable comparison with programs elsewhere.

How can and should we assess the cognitive and affective outcomes of our mathematics programs? How should we balance them? And in particular, on the attitudinal side:

- What common affective goals do we have for mathematics programs?
- Are the goals different for technology-enriched mathematics programs?
- How can we measure the affective outcomes of such programs?

1.3 Significant attitudes, and scales for their measurement: Recent work done independently by two sets of researchers in this area has aimed at designing and testing instruments for measuring attitudes to mathematics and to computers in technology-enriched undergraduate mathematics programs. Most existing instruments, including the well-known Fennema-Sherman scales (Tartre & Fennema 1995), designed for school level students, are inappropriate for assessing attitudes in this particular environment.

The University of Southern Queensland (USQ) project team (Cretchley, Fogarty, Harman & Ellerton 2000, 2001) identified 3 fundamental affective factors, *Mathematics Confidence*, *Computer Confidence*, and *Attitudes to Technology in the Learning of Mathematics*, and developed three Likert-style attitude scales for their measurement.

Galbraith and Haines (University of Queensland, and City University, London) identified six relevant factors; *Mathematics Confidence*, *Computer Confidence*, *Mathematics Motivation*, *Computer Motivation*, *Mathematics Engagement*, and *Computer-Mathematics Interaction*. *Mathematics Engagement* correlated very strongly with *Mathematics Motivation* so five Likert-style scales were retained (Galbraith & Haines 1998, 2000).

A comparison of the above sets of scales reveals that the respective *Confidence* scales seek remarkably similar attributes. The notable difference is that whereas the G-H scales deliberately separate *confidence* and *motivation* into four 8-item scales, the two slightly broader USQ *confidence* scales (11 and 12 items, respectively) include some measure of *motivation*.

The two interactive mathematics/technology scales measure quite different attributes, however. The USQ *MathTech* scale assesses attitudes to the notion of using technology for learning mathematics, and is worded so that it is appropriate for a wide range of students (from those who have little or no experience of using technology for the learning of mathematics to those who are very experienced). The term technology is used to include graphics calculators as well as computer-based resources. A sample item:

"*I like the idea of exploring mathematical methods and ideas using technology*".

The G-H *Computer-Mathematics Interaction* scale is more computer-specific, and refers to specific types of reaction. Sample items:

"*I rarely review the material soon after a computer session is finished*"

"*I find it helpful to make notes, in addition to copying material from the computer screen or obtaining a printout*".

Both sets of scales have been tested in a number of universities over several years and demonstrate strong reliability and internal consistency, yielding Cronbach alphas of around 0.8 and higher, well above frequently cited benchmark values for internal consistency reliability.

Used quite independently in different technology programs, the scales have produced some remarkably robust findings (Galbraith, Pemberton & Cretchley 2001). For example, both sets have yielded consistently low correlations between attitudes to mathematics and attitudes to computers. Furthermore, both sets have indicated that attitudes to technology in the learning of mathematics are much more strongly associated with computer attitudes than with mathematics attitudes.

1.4 The Research Questions: With the background and objectives outlined above, this study targeted both the affective and cognitive domains in the first semester of a technology-enriched undergraduate mathematics program in Australia. Students' perceived abilities and attitudes towards mathematics and computers were investigated both separately and interactively. Based on the literature and observation, mathematics confidence and motivation, and computer confidence and motivation, were selected as factors likely to impact on progress in that kind of learning environment, as were attitudes to technology in the learning of mathematics. The specific questions posed were:

A: What relationships exist between the five affective factors listed below, as defined by student responses in a technology-enriched mathematics program?

- students' *confidence* in their ability to do and learn *mathematics;*
- students' *motivation* when doing *mathematical* tasks;
- students' levels of *confidence* in the use of *computers;*
- students' *motivation* to use a *computer* generally;
- students' attitudes to using *technology* in the *learning of mathematics*?

B: How does each of these attitude scales correlate with performance on a range of assessment items?

C: What is the significance of these findings for course design?

2. The Study

The investigation targeted a class of first year undergraduate students in the Linear Algebra and Calculus course at the University of Southern Queensland, Australia, in the first-semester of 2001. Support for the use of MATLAB was integrated into their learning, and students did both hand exercises and tasks requiring the use of technology, in tutor-supported weekly computer laboratory sessions. A literature survey revealed no more appropriate or carefully developed scales than the University of Southern Queensland (USQ) and Galbraith-Haines scales, to measure students' attitudes to the factors listed above. Hence pre- and post- administrations of the following scales took place in the first and last lectures of the semester. An initial letter G indicates a Galbraith-Haines scale -otherwise scales are USQ.

- *mathematics confidence*: *MathConf* and *GMathConf* scales
- *computer confidence*: *CompConf* and *GCompConf* scales
- mathematics motivation: *GMathMotv* scale
- computer motivation: *GCompMotv* scale
- attitudes to technology in the learning of mathematics: *MathTech* scale

The Galbraith-Haines *Computer-Mathematics Interaction* scale was not appropriate for the pre-test because at that stage many students had not yet used a computer for learning mathematics.

The Likert-style attitude questionnaire containing the items invited students to place a cross on a *continuous* scale from 1 to 5, with 1 indicating strong disagreement, 3 a neutral view, and 5 strong agreement. Intermediate responses were recorded to the nearest decimal place. Almost all students present in the first lecture completed the pre-test (N=196), and performance scores on 3 assignments and 2 end-of-semester examinations were obtained for most of those students. Because of the pressures of the course, post-test attitudinal data could only be obtained from 92 students who attended the final class late in the week before the examinations. A full set of pre- and post-data, as well as assignment and examination data, was therefore available for 82 of the original 196 students. It could reasonably be assumed that this subgroup contained conscientious students.

Students' mean scores were calculated for each of the 7 attitude scales, and relationships between these were investigated graphically and analytically. Students' performances on each of the assessment items were explored for relationships with the affective factors, and correlations calculated where appropriate. Relevant Pearson correlation coefficients are provided below.

It is recognised that correlations do not enable directional inferences to be made about relationships within the data. However it has been noted that the direction of causality between attitude and performance appears to be left open in the literature, and the approach here is consistent with that conservative stance.

3. Analysis and Findings

3.1 Attitude scale data and correlations: Students' mean scores on each of the six attitudinal scales were roughly normally distributed, with pre-test data yielding the group means and standard deviations shown in Table 1. Group means were all above 3 indicating positive attitudes, on average.

Table 1: Group mean scores on the attitude scales (1 = min, 3 = neutral, 5 = max)

	N	*Mean*	*Std. Dev.*		*N*	*Mean*	*Std. Dev.*
MathConf	176	3.66	.60	*CompConf*	176	3.87	.72
GMathConf	176	3.51	.60	*GCompConf*	171	3.69	.67
GMathMotv	174	3.46	.57	*GCompMotv*	171	3.58	.68
				MathTech	172	3.67	.54

Table 2: Pearson Correlations between *Confidences*, *Motivations* and *MathTech* Attitudes

	MathConf	*GMathConf*	*GMathMotv*	*CompConf*	*GCompConf*	*GCompMotv*
MathConf	1.00					
GMathConf	.83** (.83)	1.00				
GMathMotv	.76** (.84)	.62** (.80)	1.00			
CompConf	.12 (.02)	.16* (.01)	.17* (-.01)	1.00		
GCompConf	.14 (.07)	.21 (.04)	.12 (.02)	.87** (.85)	1.00	
GCompMotv	.14 (.09)	.13 (.10)	.22 (.14)	.79** (.73)	.75** (.65)	1.00
MathTech	.28** (.18)	.31** (.20)	.28** (.14)	.49** (.50)	.51** (.47)	.58** (.66)

** Corr. is significant at the 0.01 level (2-tailed). * Corr. is significant at the 0.05 level (2-tailed).

Table 2 gives the Pearson correlation coefficients for the pre-test data (N=196) with the post-test data coefficients (N=92) shown in brackets. These indicate the following:

- Mathematics and computer attitudes (both confidence and motivation) correlate surprisingly weakly (up to a maximum of 0.22 for this data).
- Attitudes towards technology in the learning of mathematics correlate far more strongly with computer confidence and motivation than they do with mathematics confidence and motivation (0.47 and above, compared with 0.31 and below).
- Confidence and motivation data correlate strongly within the mathematics scales and within the computer scales, as expected. In particular, *post-test mathematics* motivation data yielded very high correlations of 0.84 and 0.80 with the 2 mathematics confidence scales.

The correlations confirm earlier findings (Cretchley et al 2000, 2001, Galbraith & Haines 1998, 2000), and establish the stability of these findings over a period of some years in which there has been further steady growth in the use of computers generally.

Administering the USQ and G-H confidence scales in parallel revealed the following:

- There are consistently very strong correlations between the two mathematics confidence scales (0.83) and the two computer confidence scales (0.87) (0.85 on post-data).
- The pre-test *GMathMotv* motivation data correlate more strongly (0.76) with the *MathConf* confidence data than they do with the *GMathConf* data *(*0.62). This may be the effect of a few items in the *MathConf* scales that target some aspects of *motivation*: for example, "I don't understand how some people seem to enjoy spending so much time on mathematics problems".

3.2 Mathematics attitudes and performance: Examinations A and B covered a range of tasks which, for equity reasons, were designed so that manipulation of data could be done quite easily and quickly by hand. However, graphics calculators were permitted in both A and B, and laptops were permitted in B. Exam A tested the basic concepts and techniques of the course far more directly than Exam B, which placed greater emphasis on applications and required more problem-solving skills. Appendix A elaborates this distinction.

Appendix A outlines typical tasks on the assignments. Tasks in Assignments 1 and 3 required direct use of technology to the value of 10% and 18% of the respective totals. Assignment 2 did not include any computer-based tasks. Hence while use of technology could be readily avoided in the examinations and Assignment 2, its non-use presented an impediment to the efficient completion of Assignments 1 and 3, and its use could enhance performance on Exam B. Tables 3 and 4 offer correlations of performances on these assignments and examinations, with the *pre*-test mathematics attitudes data measured at the start of the semester, and with *post*-test attitudes measured only a week before the examinations.

Table 3: Pearson correlation coefficients for *pre*-test *mathematics* attitudes & performance on assignments/exams (N » 130)

	MathConf	*GMathConf*	*GMathMotv*	Asn1	Asn2	Asn3	ExamA	ExamB
Asn1	.28**	.21**	.27**	1.00				
Asn2	.33**	.31**	.19**	.63**	1.00			
Asn3	.17	.16	.14	.66**	.51**	1.00		
Asn Ave	.29	. 23	.20					
ExamA	.47**	.37**	.34**	.65**	.67**	.59**	1.00	
ExamB	.45**	.34**	.29**	.57**	.55**	.50**	.85**	1.00
Exam Ave	.46	.36	.32					

Table 4: Pearson correlation coefficients for *post*-test *mathematics* attitudes & performance on assignments/exams (N » 81)

	MathConf	*GMathConf*	*GmathMotv*
Asn1	.41**	.48**	.39**
Asn2	.45**	.34**	.42**
Asn3	.44**	.45**	.37**
Asn Ave	.43	.42	.39
ExamA	.65**	.63**	.59**
ExamB	.60**	.55**	.50**
Exam Ave	.63	.59	.55

** Correlation is significant at the 0.01 level (2-tailed).

Corresponding coefficients in Tables 3 and 4 indicate that *post*-test attitudes correlate better with performance on all the assignments and examinations than do *pre*-test data. Since post-test data collection took place closer to the timing of Assignment 3 and Exams A and B, this finding is not surprising for those three items. However, post-test attitudes also correlate better with performance on Assignments 1 and 2. This may be due to the nature of the post-test sample – conscientious students who attended the optional final class and completed the course**.**

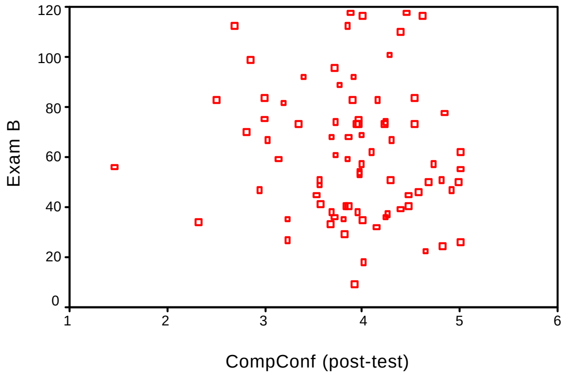
The following trends are worthy of note:

- Columns 1, 2 and 3 of Tables 3 and 4 indicate moderate correlations between mathematics confidence and motivation levels, and performance on the assignments and examinations. The *post*-test data reveal much stronger correlations than the *pre*-test data: in particular, Assignment 3 correlations with post-test data were significant – not so the pre-test data.
- Mathematics *motivation* yielded slightly weaker correlations with performance on average than did mathematics *confidence*.
- Despite considerable differences in the type of questions in Examinations A and B, correlations with the three mathematics attitudes scales were quite consistent.
- Correlations of mathematics attitudes with performance on the 3 assignments were similarly consistent, despite differences in the range of concepts and the nature of the tasks.
- Correlations with mathematics confidence and motivation were consistently lower with the 3 assignments than they were with the 2 examinations.

Computer attitudes and performance: Graphical investigation of the relationships between *computer attitudes* and performance on the mathematics-based assignments and examinations revealed very scattered data. Figure 1, for example, is a plot of students' levels of performance on Examination B against their post-test (N=82) computer confidence levels. Statistical analysis confirmed the lack of correlation generally, and hence no tables corresponding to Tables 3 and 4 are presented for computer confidence and motivation. This lack of correlation with performance is perhaps not surprising when we consider that the assessment tasks were strongly mathematical, and that computer attitudes and mathematics attitudes correlate weakly.

Figure 1: Scatterplot of Exam B results

against Computer Confidence levels



What is of interest here is the lack of strong correlations between computer confidence and motivation levels and performances generally on mathematics tasks in a technology-rich mathematics learning environment. That lack of correlation is evident with performances on *both* examinations, even on Exam B in which students were encouraged to use a computer (see Appendix A). It is further suggested by the fact that computer attitudes did not yield significantly different correlations with performance across the assignments, despite the different composition and relative weighting of computer-based tasks: 18% of Assignment 3, 10% of Assignment 1, and 0% of Assignment 2. Tasks requiring the use of technology or inviting its use (see Appendix A), were generally well done by the majority of students, not only by those who were confident with and enjoyed using computers.

4. Summary and Conclusions

This study confirmed the weak relationship between mathematics and computer attitudes (both confidence and motivation), and that students' attitudes to using technology in the learning of mathematics correlate far more strongly with their computer attitudes than with their mathematics attitudes.

Mathematics attitudes (both confidence and motivation) correlated quite strongly (up to P=0.65) with levels of achievement on a wide range of mathematical tasks, some of which invited the use of technology. Mathematics attitudes measured late in the learning program correlated much more strongly with performance on assessment items, even the earliest ones, than did attitudes measured early in the course.

Computer attitudes demonstrated little or no correlation with performance on mathematical tasks, even on items of assessment that invited or required the use of technology. This raises questions about how we can best harness the enthusiasm for computers that some students have, and what types of computer-based mathematical tasks might capitalise on strong positive computer attitudes. This area clearly needs much more investigation, but it is possible that computer confidence is a poor predictor of the likelihood of a mathematics student being empowered by the use of technology in learning mathematics. To those who seek to use technology to enliven and empower the learning of mathematics, such a finding remains a continuing challenge. Of particular interest, because of the potential for technology to advance or hinder learning, are those students with mixed confidences: high computer confidence but low mathematics confidence, or vice versa. Future research has been planned that aims at identifying more particularly the learning characteristics of such students, as part of the wider search for methods that will empower the learning of student groups within which a wide range of attitudes prevails.

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Appendix A

	Hand tasks: Of the standard typical of those in first-year texts.	**Examples of the set computer-based tasks**	**Technology skills: MATLAB or similar**
Assignment 1	Sketch vectors with given properties, use vectors to investigate properties of a parallelogram, applications of dot and cross product, applications of projections, finding equations of lines, planes & applications thereof. Investigate properties of given functions, find & use the inverse of a function.	Plot and explore the graph defined by $f(x) = (\ln x)(2 - \sin x)$. Establish the domain, range & explore the properties of f & f^{-1}. Find or confirm function values like $f^{-1}(1)$ & $f(f^{-1}(1))$. Plot a given exponential growth function and use it to predict populations. Approximate rates of change from a graph using the difference quotient with decreasingly small intervals.	Generating appropriate input values, typing in functions correctly, plotting, zooming, reading the scale correctly, axis control, overlaying graphs, labelling plots, printing.
Assignment 2	Find intersections of planes, set up systems of linear equations to fit a polynomial to 5 given points, model supply & demand systems. Interpret the meaning of derivatives and definite integrals, & find them algebraically & numerically. Applications to rate of change, average value & distance.	Use of a computer was not permitted.	
Assignment 3	Find determinants, find the inverse of a matrix by row-reduction and via the adjoint, apply matrix algebra to elementary networks and cryptography. Use derivatives to investigate slope & acceleration, curvature & concavity. Use calculus for optimisation. Find the area under a curve. Approximate a definite integral with Riemann sums.	Find the inverse of a given 3x3 matrix by row reduction. Use technology to calculate values and confirm properties of matrix inverses & determinants. Solve systems of linear equations & matrix equations using technology in different ways: unknowns typically 3x1 or 3x3 matrices. Plot a graph of the amplitude of a spring and use it to confirm rates of change & accelerations found analytically. Calculate Riemann sums to approximate a definite integral with increasing accuracy.	Defining & using pre-defined matrices, det & inv commands. Solving linear equations using rref or rrefmovie, the \ command, and matrix inverses, where possible. Defining & refining intervals for left & right Riemann sums, calculating function values, summing products.
Exam A	Emphasis on demonstrating understanding of fundamental concepts and mastery of basic techniques. A broad range of typical first-year mathematics major exercises, on topics like those listed above.	No access to computers was allowed. Graphics calculators were permitted but not required.	
Exam B	Quite different to Exam A: An open book exam, with emphasis on modelling and problem solving. Typical introductory applications of basic linear algebra and calculus, including a few tasks quite different to those attempted over the semester.	Laptops & graphics calculators were permitted but not required. Though all tasks were designed to facilitate reasonably quick hand calculation, there was ample opportunity to use a computer: for matrix multiplications (2x3, 3x3), row reduction (2x4), to plot graphs and find range, signs, average value and optimum values, and to calculate Riemann sums.	Most of the above skills would have been useful.