Investigating weaknesses in the underpinning mathematical confidence of first year engineering students

Ross Cuthbert
Queensland University of Technology, Brisbane, Australia
r.cuthbert@qut.edu.au

Helen MacGillivray
Queensland University of Technology, Brisbane, Australia
h.macgillivray@fsc.qut.edu.au

Abstract: *The engineering community is becoming increasingly aware of the impact of the changes in mathematics education and culture throughout schooling over the past decade. Because the mathematical needs of engineering are specific* ***and*** *generic* ***and*** *immediate, and because of other pressures on engineering and engineering education, simplistic views and superficial "solutions" are tempting but at best hide the problem and at worst exacerbate it. The problems are complex, multi-faceted, and far-reaching. Tackling them requires understanding and identifying the essential issues, pragmatic but deep-thinking approaches, honest acknowledgement by all parties of the nature and diversity of the specific and generic mathematical needs of engineering, and real collaborative work. This paper tackles some of the understanding and identification aspects within a pragmatic framework that puts student welfare always at first priority. The initial and longer term effects of different first year student backgrounds are investigated within a framework of highly-supportive first year teaching and learning strategies. The paper also discusses the design and analysis of a diagnostic test with the dual aims of contributing to student self-help and to development of better engineering understanding and identification of weaknesses and strengths in current student backgrounds. Although the paper demonstrates the extent of the problems, it also demonstrates both the short and long term value of constructive and careful approaches.*

Keywords: *mathematical underpinning, first year engineering, specific and generic mathematical skills.*

Introduction

Since the late 1980's there have been fundamental and far-reaching changes in mathematics syllabi and curricula from grades P-12 in Australian schools. Each state has its own authorities responsible for syllabi, with a certain amount of national referencing and coordination taking place through the Ministerial Council on Education, Training, and Youth Affairs (MCETYA). The state authorities responsible for P-10 syllabi and grades 11-12 syllabi tend to be separate to some degree from Education Departments, and until recently have also tended to be separate to each other. They tend to be in charge of moderation and assessment of syllabi. Control and/or moderation of assessment tends to be mostly for grades

11, 12 with some combination of school-based and external assessment/moderation. Queensland seems to be the only state with complete school-based assessment moderated by a core skills test rather than some form of central examinations system.

The National Statement for Mathematics was published in 1990. It is not a national syllabus but has significantly influenced syllabi in grades P-10. Its form and emphasis embody much of the philosophy and culture of school mathematics education since 1990 and hence are a guide to the driving forces at school level over the past 10-15 years. Its emphases include

- maths enjoyment and achievement for everyone
- hands on approaches with emphasis on what is immediately practical and "useful"
- "real life" problem-solving and investigations involving experiments and collecting data and information
- technology

Its "syllabi" guidelines tend to be expressed in terms of a few main headings of the form "Experiences with ….. should be provided which enable children to….." with three to six possible activities under each main heading.

A characteristic of the past decade in school syllabi has been their expression in bullet point form, assuming that users possess sufficient knowledge and expertise to build sound, systematic and coherent development of student understanding and skills around those bullet points. Syllabi documents also tend to be written on the assumption that a range of base resources will be available for teachers and schools who will be comfortable in judging, choosing and using resources. Authorities tend to produce limited resources for grades 11-12, and in P-10 elaborations for teachers and some resources for classroom use.

A major component of the emphasis on "usefulness" has been the inclusion of statistics via Chance, Data (and Statistics) strands throughout the twelve years of schooling. This inclusion without sufficient resourcing, professional development and statistical input has produced its own set of effects and problems but statistics is not considered at all in this paper. In contrast to most disciplines, the mathematical requirements of engineering are of such extent and significance that they automatically cover the mathematical requirements of core statistics for engineers, and considerations of statistical education for engineers need to focus on the development and synthesis of statistical concepts, statistical thinking, tools and skills. Some strategies for this are discussed in MacGillivray (2002).

In school mathematics education the freedom of syllabi, the emphasis on holistic, life-related and inclusive approaches, and the move to criteria-based or outcomes-based assessment, have enabled the development of some outstanding mathematical teaching and learning strategies and resources by teachers with confidence, commitment and expertise for the relevant levels, with appropriate professional and authority support. However the past decade has also been one of increasing scarcity of mathematically-trained or mathematically-comfortable teachers and mathematically-aware educational authorities. Consequently there have been many downsides, particularly from grades P-10, that impinge on senior school, on an increasingly wide range of tertiary disciplines, and significantly on disciplines such as engineering that depend crucially on both specific and generic mathematical skills and confidence.

Similarly there have also been some outstanding teaching and learning developments in mathematics, statistics and engineering by individuals and groups in tertiary education, but the constantly increasing pressures from the changes in schooling; from the emphasis on flexible entry but non-flexible first year courses; and from the general tendency to trivialise the roles and needs of mathematical skills; have increased the challenges as rapidly as the innovations. For further discussion and references on some aspects, see MacGillivray and Moody (2001).

Before moving to the specific educational contexts in which the data have been collected and analysed, some general examples that are representative of Australia, and of other countries also, illustrate the types of challenges facing senior mathematics and tertiary teachers, particularly in disciplines such as engineering, science and technology. After outlining the specific educational contexts and teaching and learning strategies for the first year engineering groups that are the subject of this paper's investigations, the paper examines the effects and outcomes of student backgrounds, study and support during their first year, and analyses the results of a diagnostic test with reference to the overall first year data.

Some general mathematical challenges in the tertiary context

Many of the downsides of school mathematics over the past decade are associated with widespread lack of understanding of the pivotal and underpinning roles of specific and generic mathematical skills, the time necessary for their development, the need to provide nurturing across the full spectrum of mathematical capabilities, and the interdependence of mathematics and technology. A characteristic of weaknesses in mathematical skills and confidence is that such weaknesses often make their presence felt only when they are needed as stepping stones to further conceptual development or as small steps in larger or more complex real problems, and the "older" the weakness, the more difficult it is for students and teachers to strengthen it.

A prime example is the lack of attention to developing confidence in fractions, which seems to have its roots in misunderstandings of the role of technology, and which causes difficulties and frustrations for teachers and students at senior and tertiary levels across many disciplines, with complaints coming from areas ranging from accounting to nursing. Without comfort and confidence with addition, inversion, simplification and "cross-multiplication" of fractions, a student has a gnawing weakness that can constantly inhibit quantitative development.

Lack of understanding of the many roles of mathematical development plus emphasis on inclusivity and the immediately "useful", have delayed or inhibited algebraic development for many in the "top half" of primary and junior secondary cohorts, leaving them vulnerable to a range of weaknesses whenever algebraic thinking or skills are required for further development at senior secondary or tertiary level. Such skills and thinking are often taken for granted in disciplines that depend on representational thinking (such as in computer programming) or the representational modelling that is essential in quantitative business areas, sciences and engineering. What is called "mathematical modelling" at the school level with its emphasis on data collection and trial and error matching with a small number of simple already known models, has little in common with tertiary level mathematical modelling that depends crucially on confident representational thinking and skills.

The mathematical modelling of quantitative business, science, engineering and information technology also depends on confidence with functional thinking that in its turn depends on algebraic skills. An interesting example for engineering contexts of the combination of over-emphasis on spatial aspects and under-emphasis of algebraic and functional aspects, is the increasing student difficulties with sine and cosine as functions, resulting in such mistakes as treating sinx as sin*x or sin(cx) as sin(c)sin(x).

It is sufficiently difficult for tertiary teachers in mathematics departments to keep well-informed and to allow for the details of changes of school backgrounds unless they are directly involved in school syllabi. For tertiary teachers in engineering departments it is doubly difficult, not only because of lesser contact with the broad area of mathematics education but also because the specific and generic mathematical thinking and skills they personally use in their discipline have become so familiar to them that it is not possible to retain full awareness of how and when they acquired these skills.

The educational context of the subject cohort

At the Queensland University of Technology (QUT) the stated assumed mathematical background for engineering and science is a pass in Queensland's senior Mathematics B (or equivalent) which is outlined below. Considerably more than half the entering engineering students also have Queensland's senior extension mathematics subject, Mathematics C (or its equivalent), also outlined below. It is not permitted to sufficiently cater for the two different groups of engineering students by allowing those without the extension Maths C to do an extra subject as it is for Science and other students planning a major, co-major or minor in mathematics. Under the restrictions, the most that can be done is to provide different first semester subjects for the two groups, aiming to provide as much as possible similar bases for all the engineering subjects including the second first year engineering mathematics subject, with enriched consolidation and applications for those entering with the extension mathematics. For ease of reference in the remainder of the paper, the subject for those entering with passes in Maths B and Maths C (or equivalents) is coded MAB131, and the subject for those with a pass in Maths B only (or equivalent) is coded MAB180.

QUT's School of Mathematical Sciences collects data on every entering student to carefully screen and advise students to ensure that all students are appropriately enrolled. This task becomes more demanding each year, but is of the utmost importance for student welfare in both the short and long term. Note that experience has demonstrated that it is counter-productive for students with reasonable passes in Maths B and C to be in the same initial subject as those with Maths B only. Students without Maths B have almost no algebraic skills and have never seen the concept of a function. These students need to do a subject that attempts to "make up" for Maths B before they can cope with any engineering subjects, but it takes extraordinary strength and dedication on their part to make up for the lack of a core algebra- and function-based senior high school subject.

To provide maximum opportunity for the diversity of first year engineering students to engage, to gain mathematical confidence, and to combat false confidence, a system that enables students to combine flexible, formative and summative assessment in an individual but highly supportive way, was introduced in 1999 (Coutis, Farrell and Pettet, 2001). The exam assessment is divided into three sections, A, B and C, tests on which can be taken in weeks 5, 9 and 13. Tests on each are also provided at the end of the semester and students can choose for each paper to take their during-semester mark or to sit the end of semester paper(s) with their best result in each section used. In addition the weekly tutorials involve a 5-10 minute quiz and these tutorials can also be used to contribute to assessment. Most students take the opportunity to try the tests during the semester, and the weekly tutorials have almost full attendance. For example in 2003, 96% of MAB131 students chose to do paper A in week

5, and 89% of MAB180 students chose to sit their paper A in week 5 also. All students no matter what their background or capabilities, approve this highly structured, maximum opportunity, system.

Tables 1 and 2 provide a brief outline of Maths B and Maths C. As the semester 2, year 1 subject MAB132 includes Laplace transforms and introductory differential equations in engineering contexts, it can be seen how much the students need to gain in their first semester.

Topic	Comments	Proportion of subject
Introduction to functions	First time seeing notion of a function	1/6
Rates of change	Introduction to concept of instantaneous rate, rate of change and derivative; derivative of sums, differences, products	1/7
Periodic functions and applications	Sine, cos and tan – graphs and applications; Pythagorean identity; derivative of sin and cos	1/7
Exponential and logarithmic functions and applications	First time see log and exp; includes index laws; compound interest; derivatives of exp(x) and log(x)	1/6
Optimisation using derivatives	Max and min; stationary points; applications	1/8
Introduction to integration	Area under curve and definite integral; integral of x^n, exp(x), 1/x	1/8
Applied statistical analysis	Exploring data; distribution, expected value; use of binomial and normal; test of a proportion	1/8

Table 1: Outline of Queensland's senior Mathematics B syllabus

Topic	Comments	Proportion of subject
Introduction to groups	A little on concepts and uses	1/30
Real and complex numbers	Roots of quadratic with negative discriminant; cos(x) + i sin(x); complex plane	1/8
Matrices and applications	Emphasis on arrays; matrix multiplication	1/7
Vectors and applications	Scalar product; forces; winds	1/7
Calculus	Integration; solving simple differential relationships	1/7
Structures and patterns	GP's, AP's, sequences, series, permutations, combinations, induction	1/7
School option (six options provided including linear programming and introductory modelling with probability)	Dynamics is a popular choice. Another is Advanced periodic and exponential functions, e.g. sinh, cosh,..	1/7
School option (a school may submit one of its devising)		1/7

Table 2: Outline of Queensland's senior Mathematics C syllabus

The Maths Access Centre support and the outcomes

As in other universities in Australia and the UK, a mathematics support centre has also been established, in 2001, called the Maths Access Centre (MAC) (Coutis, Cuthbert and MacGillivray, 2002). The MAC provides at least some support to all students studying at least one mathematics subject, but provides particular support sessions and test preparation workshops for first year engineering students many of whom are grateful and enthusiastic supporters of the MAC, to the extent that there are now also provisions for second year engineering students. Cuthbert and MacGillivray (2003) give an overview discussion of the impact of the MAC support.

For the first year engineering students, who have the opportunity to attend student-driven support weekly support sessions and/or test preparation workshops, data have been collected and analysed, providing informative quantitative evidence that support staff and student qualitative experience. In the regression analyses below, regression diagnostics are not reported but all indicate model validity. It is also to be noted that attendance at test preparation workshops is highly correlated with support session attendance in all three subjects.

In their first semester, for those entering with Maths C, attendance at the test workshops has more effect than support session attendance (see below), but ***within*** those students who attend at least some segment of one of these, the amount of time spent at either workshops or tutorials is not significant. However for those students with just Maths B, not only are both workshop and support session attendance significant (see below), but within the group who attend at least some segment, the amount of time spent at support sessions is significantly beneficial. Below are the regression outputs analysing the effects in 2002 of the optional week 5 assessment (a1), the number of test workshop hours (wshop) and the number of support session hours (tuts) on the final % in the unit for those entering with Maths C (finalC – 224 students) and entering with Maths B only (finalB – 220 students).

The regression equation is
finalC = 17.8 + 0.797 a1 + 1.59 wshop + 0.588 tuts

Predictor	Coef	StDev	t	p
Constant	17.770	2.419	7.34	0.000
a1	0.79709	0.04749	16.8	0.000
wshop	1.5854	0.8740	1.81	0.071
tuts	0.5882	0.8493	0.69	0.489

s = 14.49 R-Sq = 58.6% R-Sq(adj) = 58.0%

The regression equation is
finalB = 26.4 + 2.06 a1 + 1.05 wshop + 1.12 tuts

Predictor	Coef	StDev	t	p
Constant	26.411	2.195	12.03	0.000
a1	2.0613	0.1099	18.76	0.000
wshop	1.0487	0.3512	2.99	0.003
tuts	1.1220	0.3474	3.23	0.001

s = 10.60 R-Sq = 63.2% R-Sq(adj) = 62.7%

In the second semester subject, MAB132, after allowing for the first semester result (sem1%), the optional week 5 assessment (a1) and workshop attendance (wshop) (all three being statistically significant and beneficial), the students' school background (sem1unit – an indicator variable) is still highly significant, on average giving a difference of 10% in the final mark (final2) after allowing for the other variables, as shown in the output below. The strength and size of the effect of their school background after successfully completing semester 1 has surprised staff who expected to see some effect but not of this magnitude.

The regression equation is
final2 = - 27.4 + 0.313 a1 + 1.07 wshop + 10.5 sem1unit + 0.946 sem1%

Predictor	Coef	StDev	t	p
Constant	-27.417	4.218	-6.50	0.000
a1	0.31350	0.05287	5.93	0.000
wshop	1.0664	0.3519	3.03	0.003
sem1unit	10.459	1.846	5.66	0.000
sem1%	0.94640	0.07297	13.0	0.000

s = 12.82 R-Sq = 70.9% R-Sq(adj) = 70.5%

The above analyses indicate that all students benefit from attendance and participation in classes designed to directly support student learning. Those without the extension school mathematics need to engage ***and*** they benefit significantly from time with extra face-to-face help. For those with the extension school maths subject, the advantages are not only clear but are also long-lasting. The year after the establishment of the MAC, there was a significant drop in failure rates in 2nd year mathematics subjects for engineers, indicating that the MAC not only helped students in their first year, but also helped students acquire sufficient confidence and learning skills to take with them into subsequent study.

The 2003 diagnostic test and results

During the past two years, diagnostic tests have been researched and pilots developed and trialled. It has been found that local details are of such importance that tests developed elsewhere are of little value. It has also been found that web-based diagnostic tests are of very limited usefulness for both students and staff. In 2003, a diagnostic test was administered in the second week of classes with 211 MAB180 students and 242 MAB131 students taking the test. The test was based entirely on Maths B core work with 19 multiple choice questions in 20 minutes. No prior warning was given so the only preparation was the revision of the first week. The students were very happy to do the test as it is designed to help them identify their individual strengths and weaknesses in core skills.

Great care is needed in designing such tests to balance a range of factors including: coverage of typical problems without combining too many in individual questions; and helping the students feel at least some confidence in themselves. For most questions, incorrect alternatives embodied typical mistakes, but for others the alternatives were completely "off the mark". The table below reports the questions and responses with comments. The original order of the questions is retained rather than grouping them by topic because of the significance of the non-responses over the test.

	Question in brief	Choices	% of cohorts all	180	131	**Comments on responses**
1	Factorise $4xy-12x^2y$	Correct $4xy(1-3x)$	84	83	85	Most students can do simple factorisation
		$4(xy-3xy)$	2	1	2	Saw 4 as a common factor but not x or y
		$4x(y-3y)$	3	3	2	Saw 4 and x but not y as a common factor
		$xy(4-12x)$	8	9	8	Not recognised that 4 was a factor of 12
		No response	2	3	2	Some did not know what factorisation was.
2	Solve $3x-5=x+15$	Correct 10	87	87	87	Most can solve a simple linear equation
		2.5	1	1	1	Could not change sign when rearranging.
		5	10	11	10	Could not rearrange the formula correctly
		4	0	0	0	
		No response	1	1	1	
3	$\sin^2(\frac{x}{2}) + \cos^2(\frac{x}{2}) =$	Correct 1	77	74	80	Most students are familiar with this
		1/2	7	8	7	Angle halved so answer should be also?
		x/2	5	5	5	
		None of above	5	7	3	
		No response	6	6	6	
4	Differentiate $y=3x^2+5$	Correct $9x^2$	96	96	96	Compare with question 8.
		$9x^2+5$	2	2	2	
		x^4+5x	1	1	1	
		$3x^2$	-	-	-	
		No response	2	1	3	
5	Factorise $9ax^2-36ay^2$	Correct $9a(x-2y)(x+2y)$	70	57	81	Most MAB 131 students could factorise completely but only over half of MAB 180
		$9a(x-4y)(x+4y)$	10	14	6	Knew it was the difference of two squares but did not see that $2^2 = 4$
		$9a((x-2y)^2$	14	19	9	thought that $x^2-4y^2=(x-2y)^2$
		$3a(3x-2y)^2$	3	6	1	Could do partial common factor then as above
		No response	4	4	3	
6	Solve $x+2=-\frac{1}{x}$	Correct -1	62	47	75	Less than half MAB 180 could solve this
		1 or -1	16	20	12	Thought required two answers.
		-1/3	6	10	4	
		-1/3 or 1/3	7	11	3	
		No response	9	11	6	A few did not know how to do this
7	$\int \frac{1}{x^3}dx$	Correct $-\frac{1}{2x^2}+c$	29	21	35	Typical of all first year students
		$\frac{1}{4x^4}+c$	11	9	14	Common mistake
		$\ln x^3+c$	41	51	31	An increasingly common mistake
		$\frac{-3}{x^2}+c$	13	11	15	Common confusion of differentiation and integration.
		No response	6	8	5	

8	Derivative of $3x+b$ wrt x	Correct 3	40	73	11	
		$3+b$	8	14	2	did not see that d/d*x* of constant is zero
		4	7	7	7	d/d*x* (3*x* and *b*) = 3 + 1 = 4
		b	36	1	65	Very puzzling responses from MAB131
		No response	9	4	17	
9	$\frac{d}{dx}$ $\sin(2x)\cos(x)$	Correct $2\cos(2x)\cos(x)$ $-\sin(2x)\sin(x)$	33	59	11	**Note** the high correct response for MAB 180 compared to MAB 131 - MAB 180 had just reviewed the product rule
		$\sin(2)(\cos^2 x - \sin^2 x)$	4	4	4	
		$2\cos^2 x - \sin(2)\sin^2 x$	21	5	35	Part product rule but made mistake while using the chain rule
		$2(\cos^2 x - \sin^2 x)$	31	13	47	Note the effect of no revision on MAB131
		No response	10	18	3	
10	The graph of $y=(x+1)^2$ is (choices provided)	Correct	64	36	88	MAB 131 more confident than MAB 180
		like $y = x^2$	6	3	8	
		like $y = x^2 + 1$	22	46	2	MAB 180 thought it was shifted up
		like $y = x^2 - 1$	2	4	1	
		No response	6	11	1	
11	$\int e^{-2x} dx$	Correct $-\frac{1}{2}e^{-2x}+c$	51	47	55	
		$-2e^{-2x}+c$	26	17	34	Typical mistake
		$\frac{1}{2}e^{-2x}+c$	6	10	2	Nearly correct but forgot the negative sign at the front
		$2e^{-2x}+c$	2	2	1	
		No response	15	23	7	High percentage MAB180 not responding
12	Derivative of ax^2+b with respect to *a*	Correct x^2	35	12	55	MAB 180 demonstrate typical result of lack of maths familiarity
		$2ax$	41	53	31	
		$2ax+b$	8	10	6	As above but also did not see *b* as a constant
		x^2+1	3	2	3	
		No response	13	22	5	Again high % MAB180
13	Evaluate $f(x)=\frac{3x+2}{3x-2}$ $when\ x=\frac{1}{2}$	Correct **-7**	66	42	87	MAB 131 general numerate confidence
		-3	4	6	2	
		-7/4	8	12	5	Typical of fraction problems (-7/2)/(1/2)
		2/7	2	3	2	
		No response	19	37	4	MAB 180 students slow
14	$\frac{d}{da}(x^a)$	Correct $x^a \ln x$	12	6	17	
		ax^{a-1}	45	47	43	Correct if diff wrt to *x*
		$a \ln x$	14	6	22	MAB 131 recognise d/da but not good with exponent
		x^a	5	4	6	
		No response	24	37	12	High % MAB180

15	$\frac{d}{ds}(s \ln s)$	Correct $\ln s + 1$	24	17	31	Very low correct response
		1	19	16	21	Did not use product rule
		$\ln s + s$	6	6	6	Some use of product rule
		$\frac{1}{s}$	23	18	27	Know that d/dx of ln x = 1/x
		No response	28	44	15	Note rapidly increasing % MAB180
16	$g(x) = \frac{2x^2+1}{x-1}$ find g(-2)	Correct -3	51	24	74	MAB 131 students doing well
		-5/3	7	5	8	
		9	4	4	3	
		5/3	4	3	5	
		No response	35	63	10	Very high % MAB180 – very slow
17	Factorise $x^m - x^{2m}$	Correct $x^m(1 - x^m)$	34	18	49	
		$x^m(1-x^2)$	15	10	20	Indice rules $x^{2m} = x^m \times x^2$
		$x(x^{m-1} - x^{2m-2})$	4	4	5	Indice rules $x \times x^{2m-2} = x^{2m}$
		None of above	8	5	11	Thought all choices wrong
		No response	38	64	14	near end of paper
18	Simplify $\frac{a^2-1}{a+1}$	Correct a - 1	39	18	57	
		$\frac{1}{a+1}(a^2-1)$	11	5	16	Did not see diff of two squares - so altered the format which is true but not simplified
		$(a+1)(a^2-2a+1)$	6	5	7	
		a+1	2	1	2	
		No response	42	70	18	near end of paper
19	Complete the Square x^2+3x-7	correct $(x+\frac{3}{2})^2 - \frac{37}{4}$	25	8	40	
		$(x+3)^2 - 7$	7	5	9	guess or didn't divide 3 by 2
		$(x+\frac{3}{2})^2$	12	10	13	left off constant
		$(x+\frac{3}{2})^2 - \frac{9}{4}$	5	5	6	Did not subtract the 7
		No response	50	71	31	

Table 3: Diagnostic test 2003, results and comments

Conclusion

It must be emphasized that the diagnostic test is on core skills of the senior maths subject (or its equivalent) that all the students had passed. As well as helping students (and staff) identify individual and general technique strengths and weaknesses, the diagnostic test also illustrates the over-riding challenge for students and staff at senior secondary and tertiary levels, and why support programs such as the MAC make such a difference, and why students with the extension senior maths subject have such an advantage – provided they also engage in their learning. Those entering with the extra extension subject are better, more confident and comfortable with the core techniques of Maths B simply because they have greater contact with generic mathematical skills. The challenge for all is that the students who need mathematical skills and confidence post-school have not gained sufficient mathematical comfort and confidence in grades 1-10. As an experienced teacher from both school and tertiary levels commented:

'The problems occur when a "basic" is a tiny part of a larger problem ... Because the "basic" is not second nature they rush it or confuse it and hence get it wrong. For example, engineering students" ...with problems... "will often know how to proceed in a given complex problem but mess up a "basic" and as a result get to a point where they can proceed no further. Even if we could find the time to devote to "basics" there is the question of the morale of the students who are weak in "basics". I have a feeling that this is a reason that many who need help do not seek it. They feel foolish because they cannot do things that they see as "simple".' Carter (2002)

References

Carter, G. (2002) Private Communication, Queensland University of Technology.

Coutis, P., Farrell, T. and Pettet, G. (2001) Tackling diversity with depth and breadth: A paradigm for modern engineering mathematics education, *Proc. Australasian Engineering Education Conference* (397-402), The Institution of Engineers, Australia.

Coutis, P., Cuthbert, R. and MacGillivray, H. (2002) Bridging the gap between assumed knowledge and reality: a case for supplementary learning support programs in tertiary mathematics *Proc. Engineering Mathematics and Applications Conference* (97-102), The Institution of Engineers, Australia.

Cuthbert, R. and MacGillivray, H.L. (2003) The gap between assumed skills and reality in mathematics learning, *Proc. AAMT Conference*, Australia

MacGillivray,H.L. (2002) Lessons from engineering student projects in statistics, *Proc. Australasian Engineering Education Conference* (225-230), The Institution of Engineers, Australia

MacGillivray, H.L. and Moody, J. (2001) Enabling Student Ownership Of Mathematics And Statistics In Their Engineering Learning, *Proc. Australasian Engineering Education Conference* (111-117), The Institution of Engineers, Australia.