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ABSTRACT

The study reported in this paper represents the first stage of a five-year project aimed at improving the quality of teaching and learning in undergraduate mathematics courses for science and engineering students. Students were surveyed about their confidence in their mathematics background, their confidence with current mathematics topics, and the reasons for any lack of confidence with current mathematics topics. Students also took a diagnostic test before the start of the academic year which helped them enroll in the course most suited to their mathematics background. Students with weak backgrounds were directed to remedial materials to help them overcome their deficiencies. The study highlighted a number of important issues concerning students' mathematics backgrounds, the appropriateness of course material and the method of delivery, the amount of material covered, the speed at which it is covered, the choice of lectures as the principle instructional technique, and the need to re-examine weekly tutorials and assessment structures. Some gender differences in confidence were found for confidence in mathematics background, but less so for confidence in current studies. Contains 26 references. (Author/PVD)

Identifying Avenues for Curriculum Development in Undergraduate Mathematics

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The study reported in this paper represents the first stage of a five-year project aimed at improving the quality of teaching and learning in undergraduate mathematics courses for science and engineering students. Students were surveyed about their confidence in their mathematics background, their confidence with current mathematics topics, and the reasons for any lack of confidence with current mathematics topics. Students also took a diagnostic test before the start of the academic year which helped them enrol in the course most suited to their mathematics background. Students with weak backgrounds were directed to remedial materials to help them overcome their deficiencies. The study highlighted a number of important issues concerning students' mathematics backgrounds, the appropriateness of course material and the method of delivery, the amount of material covered, the speed at which it is covered, the choice of lectures as the principle instructional technique, and the need to re-examine weekly tutorials and assessment structures. Some gender differences in confidence were found for confidence in mathematics background, but less so for confidence in current studies.

INTRODUCTION

During the last decade there has been an increasing emphasis on reform of post-secondary mathematics curricula (for example see Dubinsky, Schoenfeld, & Kaput, 1994; National Research Council, 1989; National Research Council, 1991). Of foundational importance in these considerations is professional development for teaching staff, and the needs and expectations of the recipients of undergraduate mathematics curricula, specifically students in science or engineering programs. As the initial phase of a five-year project aimed at curriculum renewal in undergraduate mathematics, this study examined students' mathematics background and their perceptions of their competencies.

There were a number of factors which led to the development of the project of which this study represents the initial phase. The mathematics department at this university is responsible not only for its own mathematics and statistics majors, but also for a large number of mathematics courses run as service courses for other departments within the Division of Science and Engineering. Recently, the university has undergone a number of quality audits, leading to a renewed interest in the outcomes of teaching as well as research, and in the opinions of students towards the quality of teaching they receive. Within this context, questions had been raised by other departments as to the relevance of the mathematics department continuing to offer service courses. Faculty of other departments were willing and able to teach the same content. Clearly, it was time for a major evaluation of the freshman service units.

Other background factors were also important in initiating the renewal process. In Australia, most students stay in their home state to attend university. A recent major reform of secondary mathematics curricula in Western Australia (Parker, 1995; Parker, Thomson, & Tims, 1993) aimed to update syllabi, the use of technology, and pedagogical and assessment practices to reflect social reconstructivist views of knowledge and learning. It reflected current trends in mathematics education reform such as that suggested by the National Council of Teachers of Mathematics in the USA (National Council of Teachers of Mathematics, 1989; 1991; 1995). These state-wide changes in secondary mathematics curricula in Western Australia have had a direct impact on the background skills and knowledge of freshman science and engineering students.

Another impetus to initiating this curriculum renewal process was the concurrent mandating of graphics calculators to be used in pre-university mathematics courses. Consequently, students would in future be coming to university mathematics with a substantially different background than in previous years. Additionally, the freshman student intake was becoming more diverse in its mathematics background with a new prevalence of overseas enrolments, and mature-age students pursuing further studies. This diversity encompassed language competencies, as well as culture, gender and socio-economic backgrounds. Although the student body was changing in many ways, the curriculum and teaching methods had remained static for many years.

There had also been many changes in the employment environment of graduates. For example, technology, particularly in the form of sophisticated calculators and computer hardware and software, was becoming increasingly prevalent in many professional endeavours. All of these factors led to an increased awareness of the need to be innovative and progressive in addressing the changing mathematical competencies graduates would require.

AIMS OF THE RESEARCH

Overall, the curriculum renewal project aimed to develop the teaching of undergraduate mathematics courses through identifying deficiencies in the mathematical background of entering students, utilising in lectures technology such as computer-generated presentations and graphics calculators, and developing teaching and assessment practices that more fully meet the needs of the diverse range of students now studying mathematics. The project, starting with freshman level, would progress to other levels over time. The study reported in this paper is the first stage of this five-year process, carried out in the first three months of the life of the project. Specifically the study focused on four research objectives:

1. To determine the strengths and weaknesses of freshman science and engineering students' mathematics backgrounds.
2. To identify the level of confidence students have in their mathematics background.
3. To identify the level of confidence students have in areas of current mathematics coursework.
4. To determine reasons students' perceived lack of confidence in their mathematics background or current course work.

The importance of addressing these objectives lies in the fact that until post-secondary educators address and more clearly understand the needs of their students, they are not in a position to assess fully the quality of their programs, and cannot fully understand the effects on students of related teaching. For students, the significance of the research findings are in their potential to inform curriculum development and related teaching and learning.

FRAMEWORK

Two areas of research have been useful in formulating this study. The first concerns world-wide calls for reform in mathematics education from a variety of sources (Apple, 1995; Dubinsky, et al., 1994; National Research Council, 1991; National Research Council, 1994). That mathematics education has recently been undergoing somewhat of a paradigm shift from an absolutist paradigm, to a social reconstructivist paradigm, has been commented on by a number of researchers (Burton, 1995; Parker, 1995). Absolutists see knowledge as a knowable truth that can be transmitted to passive dependent students. Learning is thought to be linear and best carried out as a solitary exercise. The shift to a more social reconstructivist paradigm, which posits that knowledge is socially constructed and learning is knowledge- and context-dependent, demands active learning environments which foster the use of language and interpersonal social processes. This new way of viewing mathematics learning is one which is requiring a great deal of change, particularly in higher education, mainly because of the great deal of inertia controlling the culture of undergraduate mathematics (National Research Council, 1994).

In Australia, recognition of the essential role of mathematics in educational programs can also be seen in recent efforts to relate aims and achievements in mathematics education to societal contexts, employment and national needs (for example, see the Finn review, 1991; Mayer Committee Report, 1992; Willis, 1994). Recent changes in some secondary school mathematics programs reflect a growing recognition worldwide of a need to re-examine the content, teaching techniques and assessment practices within mathematics curricula. Mathematics is a required course for most undergraduate students aiming for careers in science, engineering, business, education, health related professions, and various other fields. Reasons for inclusion of mathematics in various curricula focus on the need for a nation's scientific, technical, educational, and managerial workforce to be competent in a range of quantitative, reasoning and problem solving skills. A nation's position in a global economy depends upon scientific and technological strength. Thus, as a foundation of science, engineering and technology, mathematics education is key to a nation's future.

The second area of research concerns the role of affect in mathematics learning, the effects of which are now clearly acknowledged. There is a growing body of research on the topic (for example, see Leder, 1993). Beliefs, attitudes and emotions that are positive such as confidence, relevance, and happiness, seem to improve the capacity to construct concepts and to solve problems. Negative beliefs, attitudes and emotions like hate, fear and loathing can hinder concept formation and problem solving. Skemp (1989) claimed that the two most influential factors in the ability to use mathematics in adult life were whether a person enjoyed mathematics and whether they were confident in their own capabilities in mathematics. McLeod (1992) found that there is a trend internationally for students to become less positive with respect to confidence about and enjoyment of learning mathematics as they progress through school.

Fennema (1989) concluded there are differences in the ways that males and females attribute success and failure in mathematics. Males tend to attribute their success to ability while females tend to attribute their failure to lack of ability. Attribution theory attempts to relate cognitive and affective factors to learning, and is based on the notion that beliefs about causes of success and failure affect performance and expectations (Bar-Tal, 1978). The interaction between affective factors and mathematics learning are complex, and are still a main area of research within mathematics education. Motivation, referring to the reasons why a student approaches a task, is yet another affective factor that influences learning. Differences in motivation have been suggested (Sternberg, in Silver, 1985) to account for differences in performance that have been observed in studies in which the range of abilities of students has been restricted. The five-year project, of which this study is the first phase, will build on the outcomes of this study with continued monitoring of student confidence and background skills.

METHOD AND DATA SOURCES

This study was primarily concerned with identification of factors related to students' skills and experiences, and therefore used surveys and a diagnostic assessment instrument as data collection methods. Three hundred fifty undergraduate science or engineering students enrolled in a first or second semester course in calculus and linear algebra were surveyed. These students were from a large metropolitan university in Australia.

To address the first research objective, a twenty-item multiple-choice diagnostic test was developed. The items were designed to assess students' knowledge and skills in those topics considered essential background for these freshman courses. Students completed the test before the beginning of first semester. In addition to providing data for this research, the results of the diagnostic test were used in the context of the larger curriculum development project to inform students of their weaknesses and direct them to appropriate remedial materials.

To address the remaining three research objectives, a forty-six item questionnaire was developed that asked students to respond about their level of confidence with their mathematics background and their current mathematics course work. Responses were recorded on a four-point Likert scale ranging from "Very Confident" to "Very Unconfident", with an additional response point for the student to indicate if they had not studied the topic. Two open-ended items were included to elicit responses about the reasons for any lack of confidence.

The survey was conducted towards the end of second semester 1995 (ie. July - November 1995). There were four different units in which the surveyed students were enrolled. The unit names were Mathematics 101, Mathematics 102, Mathematics 171 and Mathematics 172. The 101 and 171 students were repeating that unit from first semester because of having previously failed it. The 101 and 102 students were enrolled in computer science, mathematics, physics, chemistry and geophysics, while the 171 and 172 students were enrolled in engineering courses.

RESULTS

Student Diagnostic Tests

The student diagnostic test has now been run twice. The first diagnostic test was based on a test developed by Stephen Hibberd at the University of Nottingham (Hibberd, 1995). It was designed for students who have completed the British A-level mathematics, and as a consequence was aimed at much too high a level. Because of the way in which it was set up and implemented, there was no way of changing the content. It was a good pilot test for the second year which has proved to be much more productive. For the second test, the questions were written by faculty in the department, and were at a more appropriate level in terms of the students' skills. The second test results were still being collated and analysed at the time of writing of this paper.

The diagnostic test was extremely useful in orienting students to tertiary mathematics. At the time of taking the diagnostic test, students were given counselling by the test administrators (faculty working on this project) as to the most appropriate unit in which to enrol. Students were also encouraged to consult with faculty from their major department about the most appropriate mathematics unit for them. This has resulted in much greater enrolment in units which provide extra lecture and tutorial time to help students make up deficiencies in their mathematics backgrounds. Students were also directed towards printed and computer-based remedial materials which were used effectively by some students throughout the first year of the project. The use of remedial materials will become more formalised in the second year of the project through their incorporation into tutorials.

Student Survey

Regarding their mathematics background, students had a high level of confidence. Students were least confident with areas related to use of technology, specifically use of graphics calculators and mathematics computer software packages. Many students indicated that they had had little experience of these areas in their school studies. Students were reasonably confident with basic algebraic skills, but were less confident with graphing techniques and interpreting written mathematics explanations and problems. The mean confidence level for mathematics content areas that are considered a pre-requisite for the 101/102 and 171/172 courses are shown in Table 1.

Although we do not have any achievement data for these students, it has traditionally been typical for quite a number of students to fail the first semester course. Those students in 101 and 171 in second semester were nearly all repeating because they had previously failed. Given this, the confidence levels of the students as a whole seemed quite high, and although there were slight differences in confidence levels between the groups, these differences were not significant. For current mathematics course work, students were least confident with those topics in which they had had the least background preparation in high school mathematics courses, namely sequences and series, and Taylor and Maclaurin series. The open-ended responses illuminated students' perceived reasons for difficulty with current course work. The most common reasons given were that there was no justification or context given with the explanation of concepts, making it difficult to visualise or connect to other areas of mathematics or other subjects. Table 2 shows the mean response for each topic studied in the freshman courses for science and engineering students.

Table 1

Mean response for confidence with mathematics background

Question	*Topic*	Mean
7	Simplifying algebraic expressions	4.35
8	Solving algebraic equations	4.35
9	Solving triangles with trig formulae	4.29
10	Using trig functions	3.97
11	Graphing polynomials	4.04
12	Graphing trig functions	3.85
13	Graphing more complicated functions	3.44
14	Matrices	3.88
15	Limits	3.56
16	Differentiation	4.19
17	Integration	3.88
18	Vectors	3.59
19	Complex numbers	3.48
20	Exponential and log functions	3.81
21	Using a scientific calculator	4.41
22	Using a graphics calculator	2.46
23	Using mathematics computer software packages	2.42
24	Reading a mathematics text book	3.89
25	Interpreting the meaning of written questions	3.9

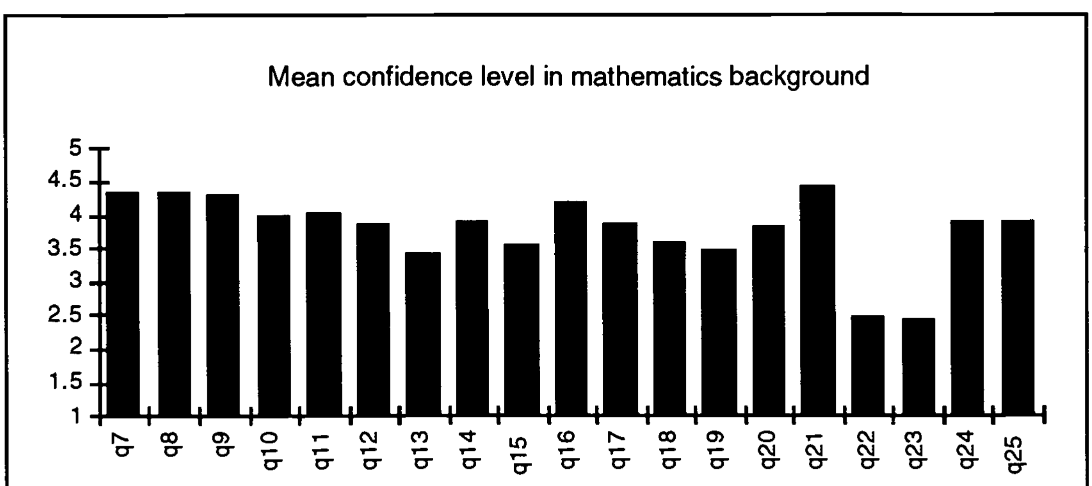
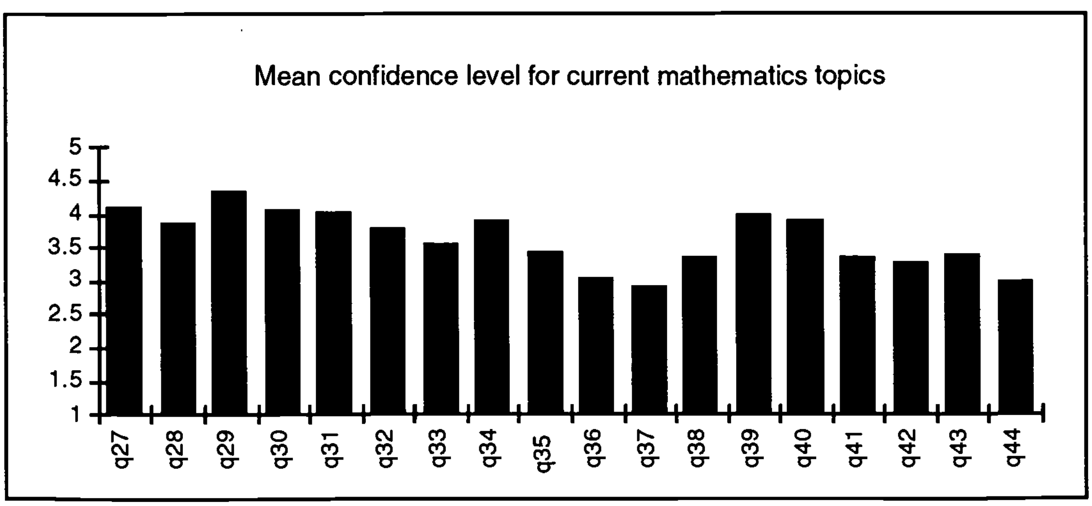


Table 2

Mean response for confidence with current mathematics topics

Question	*Topic*	Mean
27	Functions and their graphs	4.09
28	Limits and continuity	3.88
29	Derivative rules - power, product, quotient	4.35
30	Derivative rules - chain, implicit, trig and inverse trig	4.08
31	Maxima, minima, curve sketching	4.04
32	Integration techniques - by substitution, by parts, by partial fractions	3.79
33	Integration of trig and inverse trig functions, integration by trig substitution	3.54
34	Exponential and log functions	3.92
35	Hyperbolic functions and their inverses	3.41
36	Sequences and series	3.04
37	Taylor and Maclaurin series	2.93
38	Root finding algorithms	3.35
39	Matrices	3.97
40	Systems of linear equations	3.89
41	Vector spaces	3.35
42	Eigenvalues and eigenvectors	3.27
43	Differential equations	3.39
44	Numerical methods	2.98



When the survey data was examined to compare responses from males and females some significant differences were apparent. Using the effect size ([mean for females - mean for males]/pooled standard deviation), which is considered a better statistic than the t-test (Glass, 1977; Keeves, 1992), there were significant differences between males and females in confidence in their mathematics background for about one third of the items (6 of 19 items). Effect differences of size greater than 0.2 (ie. greater than 0.2 or less than -0.2) are considered significant. Specifically, the females were less confident in some aspects of trigonometry, graphing, exponential and log functions, using a scientific calculator, and interpreting the meaning of written questions. In these cases the males were more confident than the females. Table 3 shows the effect sizes for males compared to females for confidence in their mathematics backgrounds.

For the effect size of males versus females in confidence in current course work the picture was somewhat different. There were not as many items (only 2 of 18) for which males were more confident than females, again using the effect size as a measure of difference. A significant difference was found for the topics of hyperbolic functions and their inverses, and for maxima, minima and curve sketching. Further, there was only one item (hyperbolic functions and their inverses) for which the difference was significant. Table 4 shows the effect size for males compared to females in confidence with current course work.

Reasons for this change in confidence differences for background compared to current course work are not clear. The research literature (reference?) indicates that it can be expected that females are in general less confident than the males, which is the case in this study for confidence in mathematics background. Since this changes to some degree with the females similar in their level of confidence to males in relation to current course work, it would be worthwhile to investigate why this might be so. Is it due to the females increasing in confidence more so than the males, or is it because the males have decreased in confidence while the females have not changed, or have both decreased in confidence but the males more so than the females? The answers to these and various related questions are beyond the scope of this study, since the data reported here can only point to the fact that differences exist. To find reasons for these differences would require further research.

The survey data was also analysed to examine if there were differences in confidence levels between the four different classes surveyed (Maths 101, 102, 171, 172). One might expect possible differences to exist between the 101 and 102 classes compared to 171 and 172, since the latter courses are for engineering students and the first two are for general science students. One might also expect the possibility that 101 and 171 students might be less confident than 102 and 172 students because the majority of students in 101 and 171 are students who are repeating the course after having failed a previous semester. However, no significant differences were found between the groups. In spite of this fact, it is noteworthy to look at the trends in the related data. Table 5 shows the mean confidence level in mathematics background for each of these four groups, while Table 6 shows the means for the four groups for confidence in current course work. Although any differences between the groups are not statistically significant, the general trend in the data is that 101 students are the least confident, and 101 and 102 students are in general less confident than 171 and 172 students. That is, the science students were in general less confident than the engineering students. Reasons for this general trend cannot be determined from the data presently available. Another point that emerges if one examines the general trends in Tables 5 and 6 is that in many cases the 171 students (ie. students who had previously failed that course) were often the most confident of the four groups. Since one would not generally expect students with a record of failure to be overly confident in their work, even though the differences are not statistically significant, one might wonder why so often the 'failing' students were the most confident. This would be yet another avenue worthy of further research in future studies. Might it be that having several more months of exposure to various topics can lead to a sense of familiarity that might play a role in confidence? This question and a number of related ones cannot be answered here.

Table 3

Effect sizes for males compared to females in confidence in their mathematics background

Question	*Topic*	Effect Size
7	Simplifying algebraic expressions	0.00
8	Solving algebraic equations	0.04
9	Solving triangles with trig formulae	-0.30
10	Using trig functions	-0.13
11	Graphing polynomials	-0.29
12	Graphing trig functions	-0.26
13	Graphing more complicated functions	-0.18
14	Matrices	0.10
15	Limits	0.00
16	Differentiation	-0.06
17	Integration	0.11
18	Vectors	-0.12
19	Complex numbers	-0.05
20	Exponential and log functions	-0.30
21	Using a scientific calculator	-0.26
22	Using a graphics calculator	-0.05
23	Using mathematics computer software packages	-0.10
24	Reading a mathematics text book	-0.05
25	Interpreting the meaning of written questions	-0.38

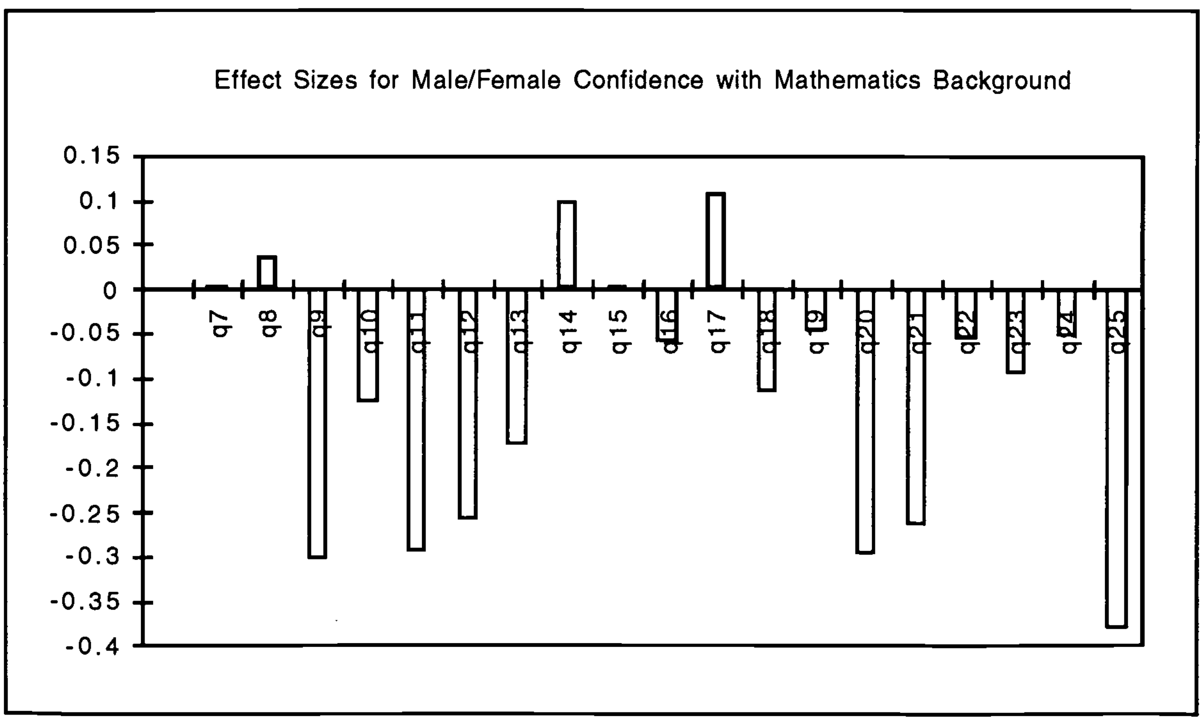


Table 4

Effect sizes for males compared to females in their confidence in current topics

Question	*Topic*	Effect Size
27	Functions and their graphs	-0.16
28	Limits and continuity	-0.19
29	Derivative rules - power, product, quotient	-0.07
30	Derivative rules - chain, implicit, trig and inverse trig	-0.09
31	Maxima, minima, curve sketching	-0.21
32	Integration techniques - by substitution, by parts, by partial fractions	0.10
33	Integration of trig and inverse trig functions, integration by trig substitution	0.17
34	Exponential and log functions	-0.14
35	Hyperbolic functions and their inverses	-0.27
36	Sequences and series	-0.05
37	Taylor and Maclaurin series	-0.06
38	Root finding algorithms	-0.15
39	Matrices	0.14
40	Systems of linear equations	0.17
41	Vector spaces	0.06
42	Eigenvalues and eigenvectors	0.14
43	Differential equations	0.17
44	Numerical methods	-0.10

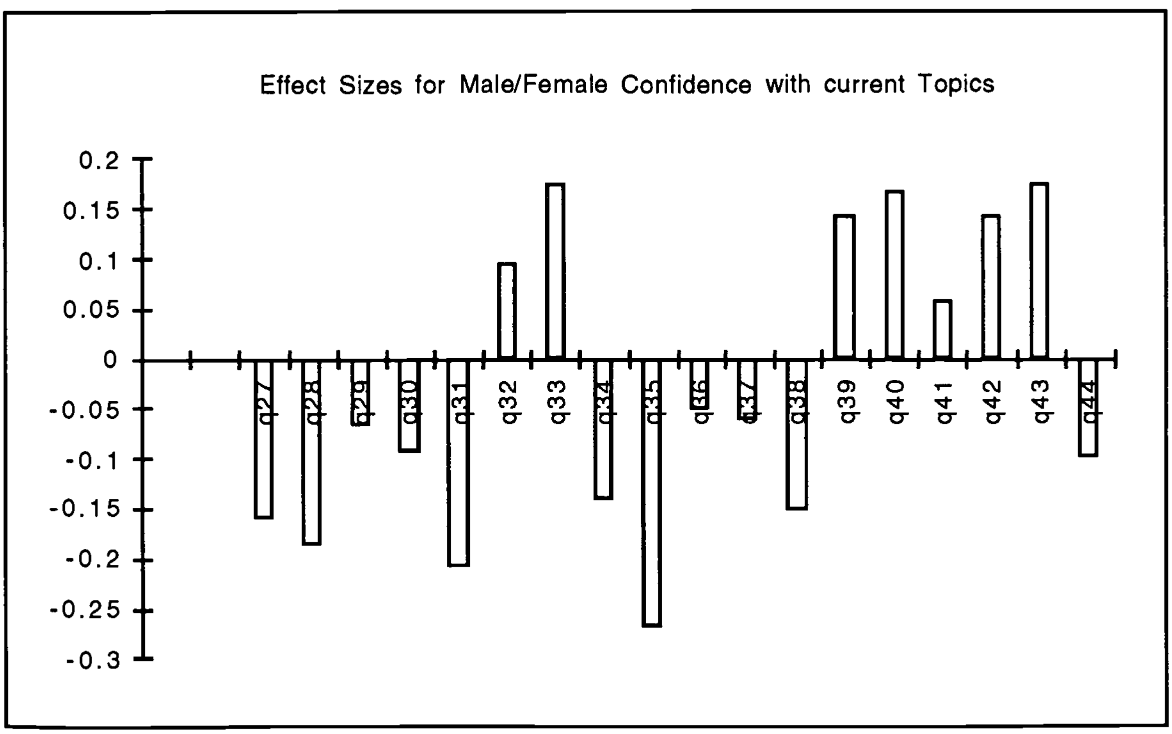


Table 5

Mean confidence level in mathematics backgrounds for different classes

Question	*Topic*	101	102	171	172
7	Simplifying algebraic expressions	4.14	4.29	4.46	4.49
8	Solving algebraic equations	4.17	4.09	4.50	4.49
9	Solving triangles with trig formulae	3.95	4.28	4.54	4.44
10	Using trig functions	3.55	4.03	4.15	4.06
11	Graphing polynomials	3.60	4.13	4.27	4.08
12	Graphing trig functions	3.43	3.88	4.35	3.94
13	Graphing more complicated functions	3.25	3.57	3.60	3.53
14	Matrices	3.85	4.16	3.83	4.29
15	Limits	3.46	3.67	3.96	3.74
16	Differentiation	3.97	4.17	4.42	4.39
17	Integration	3.58	3.96	3.77	4.06
18	Vectors	3.66	3.94	3.80	3.99
19	Complex numbers	3.31	4.10	3.76	4.21
20	Exponential and log functions	3.56	3.84	3.65	3.97
21	Using a scientific calculator	4.32	4.39	4.58	4.50
22	Using a graphics calculator	3.73	3.68	3.75	3.63
23	Using mathematics computer software packages	3.52	3.84	3.54	3.58
24	Reading a mathematics text book	3.82	3.96	4.08	3.99
25	Interpreting the meaning of written questions	3.69	3.95	4.08	3.92

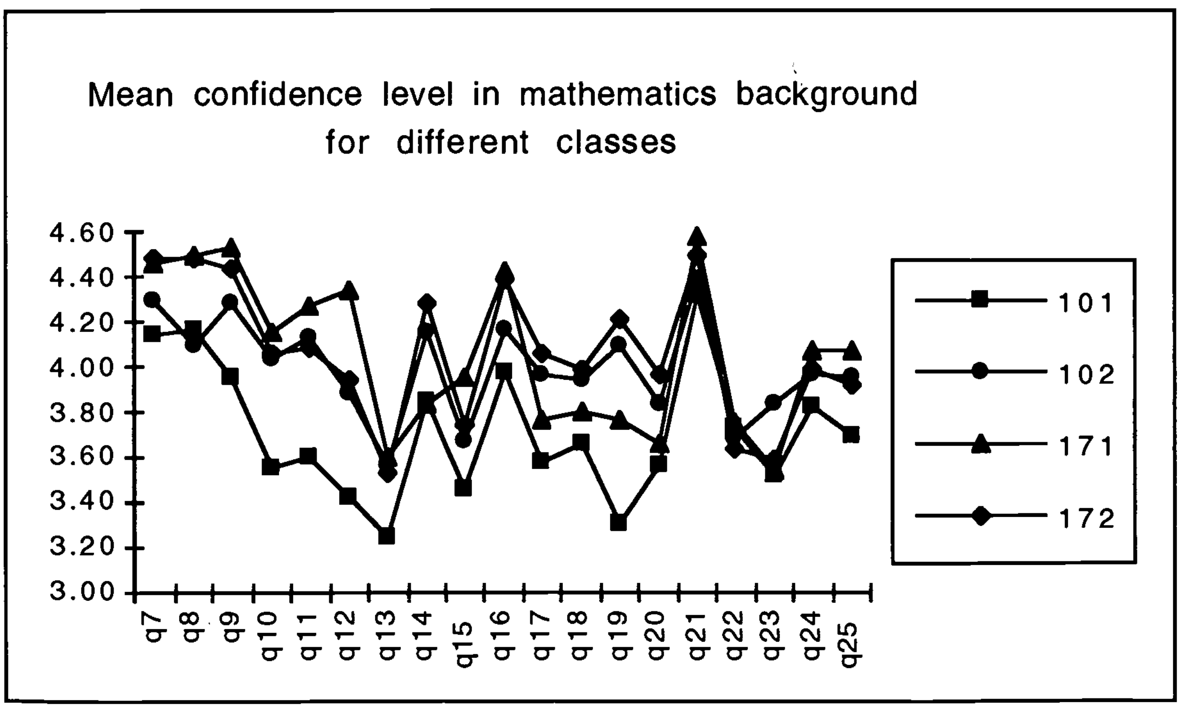
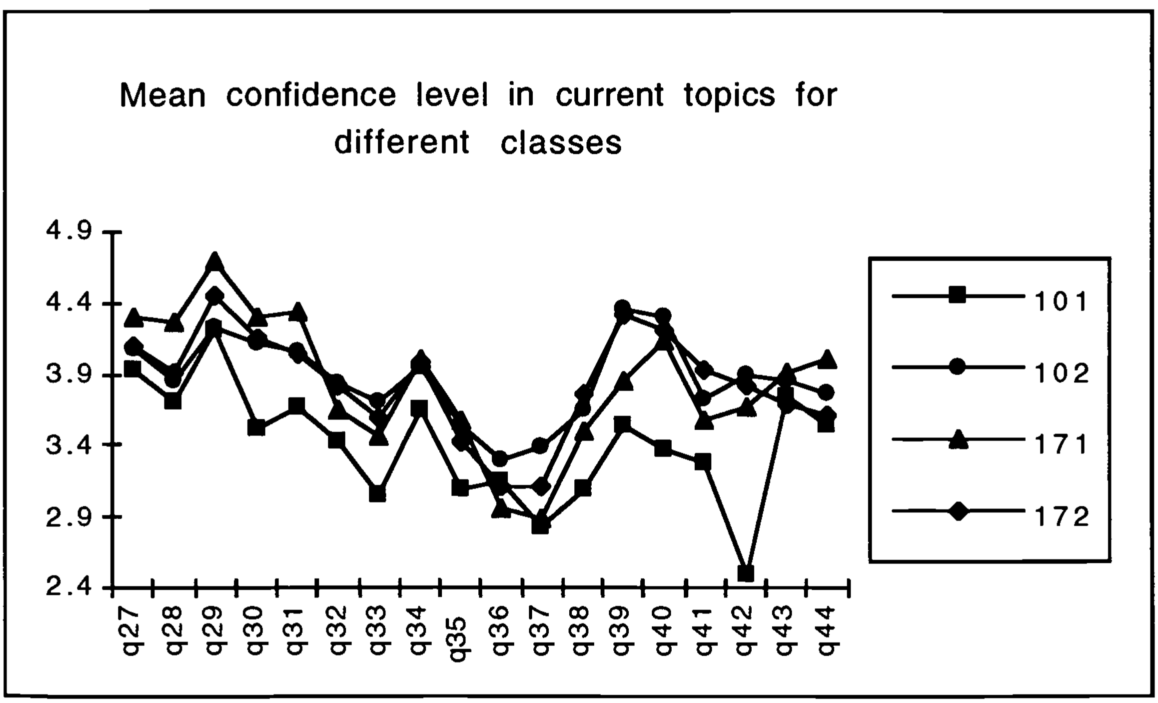


Table 6

Mean confidence level in current topics for different classes

Question	*Topic*	101	102	171	172
27	Functions and their graphs	3.93	4.08	4.31	4.09
28	Limits and continuity	3.71	3.85	4.27	3.91
29	Derivative rules - power, product, quotient	4.21	4.22	4.69	4.45
30	Derivative rules - chain, implicit, trig and inverse trig	3.52	4.12	4.31	4.15
31	Maxima, minima, curve sketching	3.67	4.06	4.35	4.05
32	Integration techniques	3.43	3.83	3.65	3.82
33	Integration of trig and inverse trig functions	3.05	3.71	3.46	3.59
34	Exponential and log functions	3.64	3.94	4.00	3.98
35	Hyperbolic functions and their inverses	3.10	3.54	3.58	3.43
36	Sequences and series	3.14	3.30	2.95	3.11
37	Taylor and Maclaurin series	2.83	3.39	2.89	3.11
38	Root finding algorithms	3.09	3.64	3.50	3.75
39	Matrices	3.54	4.37	3.86	4.32
40	Systems of linear equations	3.36	4.30	4.13	4.20
41	Vector spaces	3.27	3.72	3.57	3.92
42	Eigenvalues and eigenvectors	2.50	3.89	3.67	3.82
43	Differential equations	3.73	3.85	3.91	3.69
44	Numerical methods	3.55	3.76	4.00	3.62



Open-Ended Responses

There were two open-ended questions at the end of the student survey. The first asked students to list reasons why they lacked confidence with their current course material. The second asked them for suggestions as to how these courses could be improved in future. The responses from both questions have been grouped into three areas: course material, delivery, and student skills and background.

Course material

Many of the 101 and 102 students said they had weaknesses in their backgrounds that led to present difficulties. Sequences and series, and Taylor and Maclaurin series were most frequently mentioned as causing problems. These are done late in the course, and students found the concepts difficult. Many just don't bother to study these topics as they feel the cost to outweigh the benefits. Some commented that there was too much repetition of high school material and not enough time spent on new material. Some commented about the number of formulae to remember. Many commented that they could not see the relevance of much of the course material to their own major course of study. A few mentioned that the text was hard to understand and should be updated. Some of the students' comments in relation to these points included the following:

> Unable to come to terms with sequences and series, maybe because I didn't do calculus in high school and I didn't do any bridging courses. (101 student # 27)
>
> Weakness in my background. I have tried many approaches but I simply could not understand it still. (101 student # 13)
>
> These topics [Taylor and Mclaurin] were not covered in Years 11/12 as the others were so there is no background to fall back on. (172 student # 18)
>
> Sequences, series, Taylor and McLaurin series covered too fast in lectures. All my understanding comes from tutorials, not lectures. (172 student # 14)
>
> Hyperbolic functions and Taylor and McLaurin series hard to follow as I hadn't covered them in Year 12 maths. There was too much to learn and given too quickly for me to follow. (172 student # 24)
>
> Generally anything to do with sequences and series, due to not knowing the physical context where these can be applied. (172 student # 127)
>
> Taylor and McLaurin series covered in the last week of semester 1 and that was the busiest week of that semester and I had no chance to cover that part. (172 student # 142)
>
> Bad choice of textbook - confusion more than help. (102 student # 110)
>
> Not enough time to grasp certain concepts. Often too many rules, formulas and theorems given in a single lecture. (172 student # 121)
>
> Know exactly what was done in Year 12 so those topics can be done quickly and new topics more thoroughly. (101 student # 31)
>
> More examples from 20th century; more multimedia presentations; strong emphasis on practical and relevant uses; worked examples. (102 student # 1)
>
> Should have course that just brushes up on Year 12 stuff and then spends more time on the new material so that students with good Year 12 are better served. (102 student # 9)
>
> It should be more specific to the types of engineering studied. (172 student # 85)

Delivery
Most of the comments about the delivery of the courses were about the speed of lectures, the amount of material students were expected to copy down in one lecture, and the difficulty of simultaneously copying and listening to the lecturer explain concepts. They would have liked to have had the course notes available in some accessible printed form. Many commented that they would have liked more practical and relevant (and in some cases more complicated) examples in lectures, and would have liked more tutorial time and more examples worked by the tutor during tutorials. A few mentioned that in the bigger lecture theatres, a microphone is needed, and that the white board in some of the lecture theatres is hard to see. Some requested that the assessment structure be changed to include more course work and less weighting on the exam. Some suggested that using graphics calculators and computer software packages would enhance understanding. From the structured responses to questions about confidence regarding the use of technology, only a few students had had any experience using technology in their mathematics classes. Examples of students' comments with regard to these issues are:

> Not enough practice at some. Too heavy workload in other subjects to devote enough time to this one. (172 student # 71)

> There is too much in the course. The lecturer crams so much into the time he has that nobody learns anything. Everybody is too busy writing and catching up because he goes too quick, that they don't have time to listen to him. (172 student # 79)

> I have no background. Also some worked examples are inappropriate - not hard enough for some questions. (102 student # 105)

> Higher level maths, adjusting to new learning method; less time to pay attention to maths. (102 student # 67)

> More worked examples of hard and easy; make it more relevant to the course. (102 student # 14)

> Concentrate more on applications. Are you sure we have to use this stuff? (102 student # 10)

> Keep it interesting with everyday applications to our course of study. (102 student # 11)

> Lecture notes in closed reserves would be useful especially for overseas person [English as a second language]; more tutorial time with students talking to each other. (102 student # 67)

> Too much covered in too little time. We have other subjects you know, and only causes last minute cramming that is quickly forgotten after the exam. (172 student # 1)

> Implementation of maths computer packages such as Maple and Mathematica would be advantageous especially when considering 3D graphing. (172 student # 3)

> The lectures are very fast paced. It is all I can do to copy down what is on the overheads let alone hear and understand what is being explained also. (172 student # 25)

> The lecturing system is hopeless. All we are doing is blindly copying notes. We should have the notes photocopied and then be able to listen to the lecturers as they talk. (172 student # 111)

Student skills and background

Those students who didn't have the prerequisites or had not recently studied maths had considerable problems with the speed of the course. A few requested more lecture time. Many cited the number of courses they were required to take in their programs as reasons for not having sufficient enough time to study mathematics as much as they needed to. Mathematics is not a priority for them. If they are sick, miss lectures or otherwise fall behind, it is very hard for them to catch up. Lecture notes and worked examples provided before the lectures, or at least in printed form after the lecture, would greatly facilitate the making up of work. A number of these factors overlap with those that have been categorised under course material and delivery, indicating that there is interplay between various aspects of students' learning. Some additional comments made by students in relation to their backgrounds and experiences in their university mathematics courses include the following:

> Had no background in trig and geometry and did not have opportunity to catch up. (171 student # 13)
>
> Missed lecture and have not been able to catch up. (102 student # 57)
>
> Lecture notes given before lecture so that concentration is at max. (172 student # 71)
>
> Provide notes before attendance so we can devote our time to listening and understanding rather than writing furiously. (172 student # 74)

CONCLUSIONS

There are a number of issues concerning curricula that need to be addressed by curriculum developers. First, is the issue of how much content is really needed in undergraduate mathematics courses. Many courses are so crammed with content, that instructors naturally use the easiest and fastest mode of transmitting information, namely large traditional-type lectures that assume knowledge is a knowable truth that can be transmitted to passive dependent students. In the current climate of technological advances, the need to know facts has largely diminished with instant access to information on almost every topic imaginable through the Internet. The speed at which students perceive that material is presented to them was the most prevalent issue students commented upon. A great many commented that too much was covered too quickly so that all they did in lectures was write "furiously" in a manner that did not allow them time to think or try to understand material. Clearly, if students see lectures in their present format as ineffective and inefficient, then lectures are not successful in assisting students in their mathematics learning. Alternative and additional avenues for instruction and learning need to be explored.

Second, is how to incorporate relevant practical real-world applications into all areas of mathematics: students have the right to expect that what they are learning has some relevance to their other courses, and faculty have the obligation to help them make those connections. The main criticism students had of course material was that it did not connect to their other studies and in particular did not give them any sense of where the concepts and skills could be applied in real world, practical situations. How to use contexts that are applicable to all students' interests and experiences is a challenge curriculum developers will have to face.

Third, is how to better communicate between departments the requirements for students' course work so as to avoid overloading: mathematics departments provide service courses for many other departments at the university and curriculum developers need to be aware of the course loads of those students. Communication about the nature of the mathematics used in other disciplines is also important, as highlighted by another recent study (Frid, 1996).

Fourth are considerations as to how to better prepare students for a technological society: new approaches to mathematics require new syllabi, pedagogical and assessment practices. Students are expected to know how to use computer graphing packages, for example, in courses other than mathematics. It remains to be decided as to whether it is the responsibility of the mathematics department to teach these skills. These new approaches will not happen by themselves, and curriculum developers must give due thought and consideration as to how to implement change.

Some additional areas that emerged in this study that are in need of further research are the general trends in confidence levels that appeared: females becoming more confident in comparison to males once involved in their university level mathematics studies, and particular groups of students feeling more confident in general than others. Further studies to investigate if these patterns occur regularly are needed, as are investigations into explanations for these or other patterns.

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