Student Reaction to Online Teaching of Mathematics

Dr Nigel Shepstone
Manukau Institute of Technology
Corresponding Author Email: *nshepsto@manukau.ac.nz*

CONTEXT
Students entering tertiary institutions are often not well prepared mathematically for tertiary study. In addition, many students attempt to learn engineering mathematics by rote and never fully understand the mathematical concepts required in engineering studies. An approach to the teaching of mathematics is needed so that students can learn complex mathematical concepts with more understanding, i.e. achieve an "aha" moment with complex mathematical concepts.

PURPOSE
The purpose of this paper is to show that the students on the Manukau Institute of Technology three year engineering degree have improved their mathematics results by means of online teaching and, in addition, have reacted favourably to this approach to teaching.

APPROACH
This paper follows on from results presented at the AAEE 2015 conference in which it was shown that students are not prepared for tertiary mathematics study and that the students' mathematics ability could be significantly improved by making careful use of online teaching methods. This paper extends these results by showing that, not only do students improve their mathematical ability due to the careful use of online teaching, but they also react positively to this approach. In order to determine this, a number of student surveys were carried out during the semester.

RESULTS
This paper presents results that show three aspects of tertiary mathematics teaching. First, it will show that students are not prepared for tertiary mathematics; secondly it will show that the careful use of online teaching can significantly improve the students' ability in mathematics. Finally it will show, with some caveats that students react favourably to the online teaching of mathematics.

CONCLUSIONS
From the results presented in this paper one can conclude that the intelligent use of online teaching can improve the mathematics ability of students significantly and, in addition, the students react favourably to this approach. However, the student surveys also show that online teaching has limitations and it must therefore be used with care and applied by experienced lecturers.

KEYWORDS
Mathematics, On-line, Teaching.

Introduction

This paper extends the work reported on during the AAEE Conference held in Torquay, Australia in 2015. The current introduction is similar to the introduction in the previous paper because the problems being dealt with in the two papers are the same. This paper, however, reports on new data not covered in the previous paper, viz. surveys of the students' reaction and opinions to this approach used for the teaching of mathematics.

Many students entering tertiary education in the technical fields have poor mathematics abilities as measured by the diagnostic test discussed below. This problem is particularly severe in the polytechnic sector. This paper looks at the approach taken at the Manukau Institute of Technology to mitigate this problem and the student's views of this approach.

The poor mathematics ability of the students affects not only their ability to solve numerical problems but also affects their ability to learn technical material (Soderstrom, & Bjork, 2014). In higher level subjects, mathematics is used as a language to explain cognitively complex topics and therefore students need to be fluent in mathematics in order to understand these explanations. If a student is not fluent in mathematics they will be forced to use their working memory to figure out the mathematics that is being used to explain the complex topic rather than using their working memory to comprehend the topic itself. This is particularly a problem because working memory is very limited, i.e. typically an average person can hold only seven independent concepts in working memory at a time (Baddeley, 2004). Therefore if the students have to think about the mathematics being used to do the explaining they will be unlikely to have sufficient working memory capacity to also think about the complex topic being explained. They will then have difficulty understanding and comprehending the new topic, i.e. new learning will fail (Brown, Roediger III, & McDaniel, 2014).

However, if the students are fluent in mathematics that is, they do not have to think about the mathematics they are using, they will be able to use all their limited working memory to think about the new topic being explained which in turn will improve the possibility of learning taking place (Willingham, 2009).

This effect of the lack of fluency in mathematics affecting learning applies in particular to the learning of more advanced mathematics (Barclay, Bransford, Franks, McCarrel, & Nitsch, 1974). If students are not fluent in the basic mathematical procedures, theorems, and axioms they will have great difficulty in advancing onto more complex topics for the same reason as described above: their limited working memory will be used in figuring out the basic mathematics rather than the advanced topics when they are being taught the advanced topics. They will then not develop a deep understanding of the higher mathematical concepts, i.e. they will not easily experience the 'aha' moments that are required when learning and ultimately understanding higher mathematical concepts. This is because these 'aha' moments, or moments of understanding, depend on being fluent in the basics of mathematics (Cumming & Elkins, 1999), (Alexander, Kulikowich, & Schulze, 1994). In addition, the more fluent the students are in mathematics the more likely it is that they will be able to see and understand how the different parts of mathematics interlink and thereby have a greater appreciation of mathematics and of the beauty of mathematics.

Finally, one of the important aspects of a tertiary education is developing the ability to undertake self-learning once one has graduated. Because the language of science, technology, and engineering is mathematics it is imperative that students graduating in these fields have a wide and fluent knowledge of mathematics (Bahrick & Hall, 1991), (Ellis, Semb, & Cole, 1998), (Ellenberg, 2014).

The next section describes the study undertaken at the Manukau Institute of Technology to measure the degree of the problem, i.e. the students' poor mathematics ability, and to develop strategies to overcome the problem.

The Background to the Manukau Institute of Technology Study

The study at the Manukau Institute of Technology involved the students enrolling for the three year bachelor of engineering technology degree in electrical and mechanical engineering. The entry requirement in mathematics for enrolling on these programs is ideally year thirteen mathematics with calculus and year thirteen physics, or equivalent.

At the beginning of the semester the students enrolled in the first year mathematics course (141.514) are given a diagnostic test. This test used the school year eleven mathematics syllabus to create the questions. The year eleven syllabus was used based on the hypothesis that the students entering the first semester bachelor's degree mathematics course should be able to easily complete year eleven problems. The marks for the diagnostic test were not returned to the students. The reason for this was so as not to skew the students' view of their mathematical ability, that is, the lecturer did not want the students to develop a negative mind-set towards mathematics or to exacerbate an already negative mind-set. It has been shown by Dweck (2007) that a student's progress in mathematics is highly correlated with their mind-sets towards mathematics. It was merely explained to the students that the diagnostic test was used to aid the lecturer to target the semester's lectures at the correct cognitive level.

As shown in Appendix 1 and as presented at AAEE (2015) it is clear from these tests that the students' mathematical ability is poor. The average mark in the diagnostic test is 40.2% with a standard deviation of 25.0%. Of the 43 students that wrote the test only 15 (34.9%) achieved above 50%: which is usually taken as a pass mark. The diagnostic test provided a 'snapshot' of the students' ability in the first week of the semester.

In order to get an indication of how well the students' perception of their mathematical ability corresponded to their actual mathematical ability the students were asked to estimate the mark they thought they were going to obtain in the diagnostic test. The details of these results are also shown in Appendix 1. What these data showed is that not only was the students' mathematical ability poor but they did not realise it was poor. The absolute difference between what the students thought they were going to achieve and what they actually achieved is 12.4%, i.e. 0.5 standard deviations. In addition, as Appendix 1 shows, most of the students over estimated their mathematical ability. This combination of a poor ability in mathematics together with an inaccurate perception of their ability in mathematics makes enrolling of students in engineering degrees particularly problematic. This is because the students do not have an accurate view of their mathematical ability and, therefore, do not realise that they have a problem that is going to limit their chances of success in their degree studies (Atir, Rosenzweig, & Dunning, 2015).

It should be noted that the data shown in Appendix 1 covers five cohorts of students and five consecutive semesters of mathematics.

The Approach used at the Manukau Institute of Technology to Overcome the Problem of poor Mathematics Ability.

In order to improve the mathematical ability of the students and to make their mathematical ability more fluent two principles of learning were implemented viz. extensive directed practice and feedback (Ericsson, 2016), (Ericsson, Kampe, & Tesch-Romer, 1993), (Kang, McDermott, & Roediger, 2007), (Oakley, 2014).

To give the students extensive directed practice in solving mathematical problems all the students were enrolled on MyMathLab Global an online mathematics package published by Pearsons. This package was set up so that each week the students had to complete a quiz consisting of number of exercise/tutorial problems related to the topic covered in lectures during that week. In total eleven, thirty-question quizzes were carried out during the 14 week, one semester mathematics course and each quiz took between 1 and 2 hours depending on the ability of the students. In order to encourage the students to do the quizzes, the quizzes were allocated a total of 15% of the students final mark (most quizzes were allocated 1% and some were allocated 2% to give a total of 15%). These quizzes were directed because the lecturer was able to use MyMathLab Global to analyse the quiz results of previous cohorts of students and to put questions into the current quizzes that previous students had had difficulty with.

An important aspect of any form of learning is feedback on how one's learning is progressing. The MyMathLab Global package has a number of useful online feedback facilities. Firstly, when the students have completed a quiz they get immediate feedback on whether their answers were correct or not. Secondly, while they are doing the quiz there is a 'Help Me' function which allows the students to work through a step-by-step solution of a similar problem to the problem that they are working on. Thirdly, the package has a facility whereby the students can be referred to the section in the e-book that relates to the problem that they are working on. Fourthly, the students can get a worked example similar to the question that they are working on. Finally, while the students are working on the quizzes a human tutor is available for questions and feedback.

An important aspect of all this feedback is that it is stressed to the students, by the lecturer, that wrong answers are not a bad thing. Instead it is stressed that wrong answers facilitate learning on condition that the students make sure that they understand why the answer was wrong and how to obtain the correct answer (Duckworth, 2016).

Each week two hours of formal tutorial time is allocated to doing the quizzes and 3 hours is allocated to traditional lecture classes during which the topic theory and some worked examples are covered. During the tutorial/quiz time the students were encouraged to discuss problems and to work collaboratively. The lecturer provided tutorial assistance to the students which took the form of help with quiz problems or clarification of material covered in lectures.

Analysis of the Results

At the end of the semester all the students sat a two hour mathematics exam. This exam was more difficult than the diagnostic test because it covered topics learnt during the semester. In particular it included complex numbers, matrices, differentiation, integration, and differential equations, none of which were in the diagnostic test. Appendix 1 shows the results of the diagnostic test and of the exam. It is clear from these results that the exam marks are considerably better than the diagnostic test marks even although the diagnostic test was easier.

An exam was used to assess the students' mathematics ability because this is a requirement of the accreditation board for the three year degree. Although examinations may not be the best method of assessing ability we cannot use other methods under the current accreditation system (BET, 2016).

In order to formalise this improvement the following was done. Firstly, a t-test was carried out to confirm that the averages of the diagnostic test and the exam were statistically different. As Appendix 1 shows, the probability that the averages were different is 99.9997%, i.e. the exam average was definitely statistically different to the diagnostic test average.

Secondly, the effect size of this difference in averages was calculated and found to be 0.70 standard deviations. In the educational field an effect size of greater than 0.4 standard deviations is regarded as good, i.e. it shows that significant learning has taken place (Hattie, 2009). Therefore an effect size of 0.70 shows that the above approach to teaching mathematics has been very effective.

The main aim of the above study was to improve the students' fluency in mathematics. Using the exam results as a proxy for how fluent the students had become in mathematics it may be hypothesised, with some confidence, that the students are significantly more fluent at the end of the semester than they were at the beginning.

This paper extends the above work by analysing the students' opinions of the way in which the course was run. Two surveys covering 21 students in each survey were done to determine the students' views. After about four weeks a first impressions survey was carried out and then towards the end of the semester a course evaluation survey was carried out. The results of these two surveys are show below:

Table 1: First impression survey questions and results.

Question	Answer Choice	% Response
The work load is fair and manageable?	Strongly agree or agree.	95.46
I like the way the course is taught?	Strongly agree or agree.	100
I am enjoying my programme?	Strongly agree or agree.	95.24

The end of course survey results are shown below:

Table 2: End of course survey questions and results.

Question	Answer Choice	% Response
Overall this course is good?	Strongly agree or agree.	100
The content and level of this course has been what I expected?	Strongly agree or agree.	90.48
The work load and pace has been fair and manageable?	Strongly agree or agree.	85.72
The learning materials and assessments have been relevant and easy to understand?	Strongly agree or agree.	95.23
Teaching on this course is effective?	Strongly agree or agree.	100
Overall I am enjoying my programme and learnt what I needed?	Strongly agree or agree.	90.48

Note that questions in the surveys that did not relate to the mathematics course were not included in the above tables.

The students were also asked to state what they liked about their study at the Manukau Institute of Technology and also what they thought could be improved. A selection of these comments is given below:

> *I like the methodology of teaching and friendly atmosphere.*
>
> *The way the class is taught is simple making the information intake easy.*
>
> *The balance workload and enough practice strengthen mathematical concepts.*
>
> *The way of teaching and format of study.*
>
> *Everything is so far good and would like to have two quizzes like mymathlabglobal to all the other subjects.*

The students did not make any relevant negative comments about using MyMathLab Global for mathematics practice. See appendix two for all the students' comments on the end of course survey.

Discussion and Conclusion

As shown in the paper presented at the AAEE (2015) conference the use of an online practice package produced significant improvements in the students fluency with mathematics which should lead onto an improved ability to understand more advanced mathematics and to learn engineering subjects in which mathematics is used as a 'language' for teaching.

The above results from the student surveys show that the students did not have any negative comments to make about using an online practice package. In addition, some students felt that a similar approach in other subjects would be advantageous (see the student comment above). Subjects such as electrical circuit theory, which students historically have had difficulty with, would possibly benefit from a similar online package to the one used for mathematics.

An important point about using computer aided teaching is that the computer should allow teaching to be taken beyond what can be done by a human lecturer without modern information technology. The above study with MyMathLab Global illustrates this point. As mentioned above 11 thirty question quizzes were given to the students during the semester, i.e. 330 questions per student. Each student did the quizzes at least once, over half the class did the quizzes twice and some students did them three or four times. (The reason the students were motivated to repeat the quizzes was that if they did the quiz more than once their highest mark would count towards their course mark for the subject.)

On average each student did each quiz twice so that in a class of 21 students a total of 13 860 questions were done by the students. It would be very difficult for a lecturer to mark this amount of material during a semester and provide the necessary feedback to each individual student. Therefore what this online package allows is for the teaching to go beyond what a human lecturer without computer assistance can do. Much of the computer assisted teaching used currently merely replicates what a human lecturer can do and at best allows greater access by large numbers of students to conventional teaching. This is obviously beneficial but it does not make full use of the potential of modern technology. What we as educators should be investigating is ways of using modern technology to go beyond what human lecturers can do.

This approach to student practice could be more widely applied in engineering because in the author's opinion it would be particularly suited to subjects such as electrical circuit theory, engineering mechanics, electronics, etc.

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Appendix 1

The following is a summary to the statistical analysis of the students' mathematics results. The full analysis is given in the previous paper.

	Diagnostic Test (%)	Examination (%)
Assessment average	40.2	59.9
Assessment std. dev.	25.0	27.8
Maximum Mark	94.9	100.0
Minimum Mark	2.6	5.8
Median	35.9	59.4
Combined std. dev.	28.1	
Overall effect size	0.70	
Number of students	43	
95% tolerance on mean	7.86	8.75
Upper/Lower 95% limit	48.1	51.1
Student-t Test	0.000003	
Difference between test and estimate	12.4	
Maximum effect size	2.52	

Appendix 2

All the end of course student responses to the question: "What have you really liked about your study at MIT?"

Responses
1 The way of teaching and format of study.
2 Deez nutz (sic)
3 The maths
4 The venue campus close to my place
5 Learnings
6 Good lecturer
8 Learning materials eg (sic), past exams papers.
9 Learning new and effective things
10 Classes are taught easily and are manageble (sic)
11 decentish (sic) pace
12 The personal feeling, like im (sic) not a number. M
13 Everything is so far good and would like to have two quizzes like mymathglobal (sic) to all the other subjects
14 Best lecturer
15 Lecturer is awesome - work is easy to follow.

All the end of course student responses to the question: "What could we have improved?"

Responses
1 Everything is good about staff
2 None
3 Nothing
4 Timetable, teaching materials need to verify before course start.
5 Need field trips.
6 Facilities and classrooms.
7 Splitting the course schedule
8 The pace of this course.
9 The time schedule is too long
10 Engineering classes should be 3 days a week only. More time for self study (sic).
11 The timetable.
12 Engineering class would be 3 full days in a week so students can have a (sic) opportunity (sic) do hard work on assignments
More (sic).
13 Class times. Too late into the day for maths don't you think?
14 Longer break in between 3 hour lecture

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