THE MATHEMATICS BRIDGING COURSE AT THE UNIVERSITY OF SOUTH AUSTRALIA

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ABSTRACT

The Division of Information Technology, Engineering and the Environment at the University of South Australia runs a Bridging Program with courses in Mathematics, Physics, Chemistry and Communication. The goal is to provide an alternative pathway for prospective students to gain access to a science or engineering degree program. The author has been the coordinator of the mathematics component in the Bridging Program for several years. The innovative methods that have been devised to try and fill some of the gaps in the students' background will be canvassed. Traditionally, computer software in mathematical education has been primarily used for problem solving utilising such packages as Matlab and Maple. However, spreadsheets are a remarkably capable tool for both 'doing' and illustrating mathematics. Their almost realtime graph alteration and their recursive capabilities make them ideal for illustration of mathematical concepts . This capability will be demonstrated using examples from this and other courses for which the author is responsible. I will also present an assessment of how well the bridging course has prepared the successful students for the degree programs they have subsequently undertaken.

Keywords: Bridging Course, Spreadsheet Teaching Tools, Computer Aided Illustration of Mathematics

1 Introduction

The Division of Information Technology, Engineering and the Environment at the University of South Australia runs a Bridging Program with courses in Mathematics, Physics, Chemistry and Communication. The term 'bridging' usually conjures up the concept of a group of students already enrolled in a university degree obtaining some aid in a discipline to fill in the gaps in their background knowledge. At the University of South Australia the goal is to provide an alternative pathway for prospective students to gain access to a science or engineering degree program.

There are various methods of entry into a university degree program in South Australia. The most usual form is through direct entry following secondary school. Under this approach, prospective students list preferences for up to five programs. They undertake a publicly examined set of subjects and are accepted for the highest of their preferences for which their aggregated results reach the cut-off score. This score is calculated through determining how low a score will allow the program to fill its quota of students, inspecting the list of students applying for the program. Alternatively, after a period of two years has elapsed since the student has left secondary school, they may sit an adult entry set of tests to determine if they can qualify to enter university. The level of their results will determine which program they can enter, with the cut-off scores again reflecting the level of demand of the program.

The Bridging Program offers the only method of entry which also provides the students with an opportunity to enhance their skills as well. They study full-time for one semester or part time for two semesters. It is designed for people who either have a gap in their science background or have a comprehensive background but at some time in the past. The author has been the coordinator of the mathematics component in the Bridging Program for several years. The primary goal has not only been to determine the suitability of the students for entry, but also to maximize the chance of success for those who do qualify in this manner.

Innovative teaching methods have been devised to enhance students' understanding of mathematics. These have revolved around the use of spreadsheets to illustrate mathematical concepts. Spreadsheet based design has been chosen because of its what-if capabilities, the virtually instantaneous response to alteration of parameters, its graphical capabilities and its inherent use of recursion which proves eminently suitable for many mathematical applications. Some of these capabilities will be illustrated.

Additionally, it is vital for the successful operation of such a program to evaluate whether or not it is fulfilling its purpose. Thus two measures of the success of the program will be presented. One is a simple measure of how well the graduates of the program perform in their chosen degree program - do they complete the degree or look as though they will (the analysis includes people who will not have had time to fulfill all requirements). There is also a measure which relates specifically to their mathematical performance. Once again, it is a simple measure - is their result in mathematics in the bridging program related to their results in mathematics courses undertaken during their degree?

2 Spreadsheet Tools

Dubinsky [1] outlined six methods to enliven the mathematics curriculum by

- aiding students in visualisation,
- dispensing with much routine symbolic manipulation,
- dealing with larger, more realistic problems,
- providing an environment which encourages exploration,
- making use of animation wherever possible and
- providing an environment for constructive development in mathematics learning.

The author has developed spreadsheet tools over a number of years in order to satisfy at least some of these goals. York and Arganbright [2] contend that 'the spreadsheet provides us with a format that closely parallels the way we think about mathematics. At the same time, it provides students with a creative tool for conducting What-if? explorations.' These explorations can be animated to an extent because of the automatic recalculation of graphs. A number of researchers have used spreadsheets to teach advanced concepts using a problem-based approach. For instance, Mays *et al* [3] developed 'five student-centred projects that examine important problems in the fields of Mechanical Design, Dynamics of Machines, Fluid Dynamics and Thermodynamics.' De Mestre [4] uses Excel to find numerical solutions to differential equations, matrix inversions for solving systems of linear equations and to check integration via numerical integration. Das and Hadi [5] use the Solver option in Excel to solve optimisation problems. York and Arganbright [2] discuss the modeling of growth and harvesting on spreadsheets.

The author began with designing tools to cover a range of topics in the preliminary stages of calculus and linear algebra instruction. Additionally, there is some mathematical modelling, usually also embodying some further explanation of some basic principles. For example, there is some basic predator-prey modelling. Using spreadsheets to develop simple numerical solutions to the equations using Euler's Method results in a powerful tool because of the recursive and graphical features. Stepping forward in time is afforded simply by the dragging of the appropriate formulae. Changes to parameters such as relative initial values of predator versus prey results in the instant graphical visualisation of the effects of the changes. Inherent in this topic is a reinforcement to the student of the formal definition of the derivative as the limiting value of a sequence of slopes of secants.

A summary of the material with a few comments will give an idea of the scope of the practicals. They begin with comprehensive examination of the meaning of parameters of functions. In this exercise, students are presented with a graph of a function and asked to alter one or more of its parameters. The example given in Figures (1) and (2) shows what results when they alter both amplitude and phase of the standard sine function. They are able to see the results of each separate alteration virtually instantaneously and of course repeat it as many times as they feel necessary in order to understand the effect. The graph is designed to retain the original configuration for comparison. In the next class they perform similar tasks in Matlab in order to familiarise themselves with it.

The remaining calculus topics include limits, Euler's Method as stated above, Newton's Method, logarithms and exponentials through exploring pH and Newton's Law of

Cooling, and finish with Riemann Sums. The last one is particularly helpful as the visual effect of increasing the number of sub-intervals is quite dramatic. In the elementary linear algebra presented in the bridging course, spreadsheets are found to be particularly useful in helping the understanding of Gaussian elimination and the algebra of matrices. In the exercise, the students are asked to construct formulae which replicate the standard Gaussian elimination procedures and copy them tableau to tableau until a stage is reached where they can determine the type of solution set possible. This is done for a set of three equations in three unknowns and they can then use this template and substitute in different coefficient matrices to check their results for other example questions. Another exercise has the students performing many examples of matrix addition, multiplication, inversion and so on. They learn about the size of the result of matrix multiplications very quickly since the spreadsheet method of this procedure requires them to highlight the region for the result before performing the operation. Also, they receive error messages if they try to invert a matrix for which there is no inverse, so they learn to check the value of the determinant beforehand.

It is worth mentioning in passing that even though it was not used in this course, a particularly useful example of the spreadsheet utilisation is in introductory infinite series discussions. Students can be sceptical when it is proved that $\sum_{k=1}^{\infty} \frac{1}{k^{\alpha}}$ converges for $\alpha > 1$ and diverges for $\alpha \leq 1$. However, using a spreadsheet, one can quickly calculate partial sums including thousands of terms and graph the sums as a function of the number of terms and easily alter the value of α. This illustrates, rather than proves the result. In essence, this delineates exactly the purpose of this use of spreadsheets. It could be referred to as a re-naming of CAI as computer aided illustration rather than computer aided instruction. It is used not to solve mathematical problems, but rather to illustrate mathematical concepts to improve understanding.

The spreadsheet capabilities have been utilised in various other courses as well to great benefit. A first year course in mathematical modelling uses the population modeling attributes mentioned above, curve fitting using least squares methods and Markov modelling. A time series and forecasting course has utilised the curve fitting capabilities, Markov modelling, spectral analysis (complex analysis is possible in spreadsheets) and the Visual Basic programming module used for constructing autocorrelation and partial-autocorrelation functions and parameter estimation. Some of these obviously are also performed using more time series specific software, but as mentioned above, it is often the visual aspects of a spreadsheet package that are most useful for illustrating concepts. Table 1 gives a concise description of the mathematics concepts that have been illustrated in various courses and the attributes of spreadsheets which have made this medium appropriate.

Concept	Attribute(s) of Spreadsheets
Effects of change of parameters of graphs	Automatic recalculation Dynamic alteration of graphs
Gaussian reduction	Matrix configuration Automatic recalculation
Limits of sequences and functions	Relative referencing Automatic recalculation Recursion
Sums of Series	Recursion Graphics Automatic recalculation
Fundamental Theorem of Calculus	Graphics
Growth Models	Recursion Graphics
Linear programming	Solver
Matrix Analysis	Matrix arithmetic
Spectral Analysis	Complex arithmetic
Time Series	Visual Basic Programming
Optimisation	Solver

Table 1: Mathematical concepts illustrated using spreadsheets

3 Evaluation

There are two aspects to the evaluation that have been performed. One is an evaluation of how the use of the spreadsheet based practicals has been viewed by the students - do they see them as a useful learning tool? The other part of the evaluation is the estimation of the bridging program as an entry vehicle to the university and specifically, is the mathematics component of it helpful to the students in their future mathematical studies?

3.1 The Practicals

The University of South Australia requires staff to elicit an evaluation of every course from students as part of its quality assurance program. There are a set of core questions but also it is possible for lecturers to add questions if they wish to elicit information about particular aspects of a course to ascertain their value to the students. Over the five years that the course has been offered since the adoption of the practicals, the statement 'I found the practical sessions using Excel helped my understanding of mathematical concepts.', rated on a scale of 1 (strongly disagree) to 5 (strongly agree), has been used to test the students' opinion of this aspect of the course. The results have been consistently good, with averages for different groups ranging from 3.3 to 3.7 out of 5. Of significance also is the very low frequency of 'disagree' or 'strongly disagree'. Obviously, the results have to be taken with caution since it is not compulsory to fill in the form. There is another factor which can be viewed in various ways. Since this is an entry program, often a number of students who find that they are not coping will drop out of the program before the end and before they would have filled in the form. So therefore, one might say that the results are skewed by being predominately from those who have a higher probability of passing. On the other hand, they may also be the students who got the most out of the course, being the ones who expended the most effort to avail themselves of the material available. In summary, one is justified in claiming some measure of success for this particular instrument.

3.2 Measures of the Subsequent Success of Graduates of the Program

The program is designed to try and determine if candidates are suitable for coping with a degree program at a university. Thus the ultimate measure of success of the bridging program is the number of graduates who go on to complete a degree program. Obviously, there will be students who would have completed a degree program no matter how they were able to obtain entry. Specifically, there is the set of tests for adult entry alluded to previously. However, there is anecdotal evidence to suggest that at least a certain number of the students believe that having undergone a semester's work, rather than simply passed an entry requirement, has better equipped them for success in a degree program. It should be said that there is a natural lag in the results. Thus, when viewing students' subsequent performance, it was decided to count as a success students who appeared to be well on their road to a degree. Given this criterion, it was determined that of 78 students who have successfully completed the bridging program and gone on to attempt further study at the University of South Australia, 56 can be classified as successful, slightly over 70 per cent. There were actually more than 78 successful in this time, but 10 have not taken up study in this university, so it is possible they have begun studies in another one. Also, no students from 2001 have been included because of course they have not begun their university studies at the time of writing. It is worthy of noting that three of the successful students have completed Honours degrees.

The other measure of success that was investigated is how well the students' results in the Bridging Mathematics Course can be used as an indicator of their subsequent performance in university level mathematics. What has been calculated is the average of their subsequent mathematics results and then these have been regressed on their Bridging Mathematics scores. Figure 3 gives the data and the line of best fit. The correlation between the two sets of results is $r = 0.494, p < 0.01$.

There are a number of features of this regression analysis which are noteworthy. There are a number of outliers, and it is usual to question whether these should be included in the analysis. In this situation though, there is no reason to discard them. They are in the main indicative of students who managed to obtain passing results in the bridging program, but were not up to the task of a degree program. Another aspect is that the slope of the regression line is $m = 0.62$, indicating that if one were using the relationship to predict performance in mathematics courses in a degree program, there would be a systematic reduction from the results in bridging mathematics. Ideally, one would hope that there would be a slope of unity, but there are a couple of reasons why one wouldn't realistically expect that. One is that the assessment procedure for bridging mathematics is designed to favour a learning procedure more than that which would be present in the degree mathematics courses. In this, there is a higher emphasis on assignments, and less on examinations. The other main reason could be that the students in their degree programs are taking mathematics as supplementary to their main focus of study and thus a simple passing grade is sufficient. One would expect them to focus more on their main areas of study. It is encouraging though that there is a significant relationship between the two sets of results.

4 Conclusion

The effectiveness of the Bridging Program in Science and Engineering has been demonstrated through two measures. The success rate of students when they go on to degree programs has been more than 70 per cent. Additionally, the mathematics segment of the bridging program has proven to be a good indicator of success in mathematics courses in the degree program.

It has also been shown that study materials developed for this course involving explaining mathematical concepts using Excel spreadsheets have been rated as successful by the students. The particular aspects of spreadsheets that have been useful have been described, as well as how tools have been also developed for other mathematics courses. As stated previously, the spreadsheet formulations are used primarily to improve understanding of mathematical concepts through illustration, rather than for the solution of problems.

References

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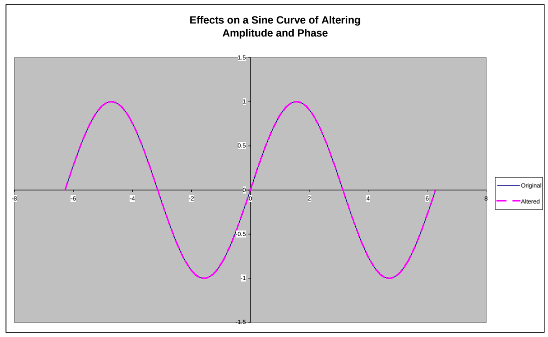

Figure 1: Original Configuration

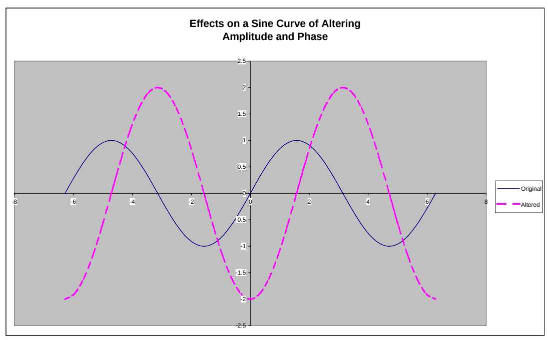

Figure 2: Altered Configuration

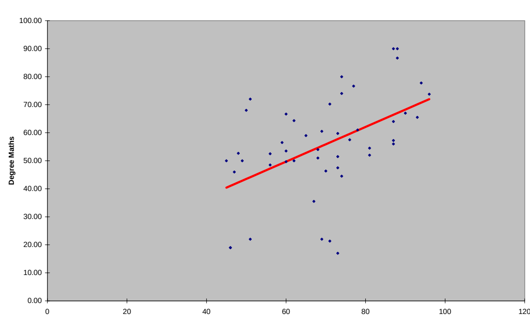

Figure 3: Mathematics Results as a Function of Bridging Mathematics Results