AN ENGINEERING BRIDGING COURSE - SUCCESS OR FAILURE ?

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ABSTRACT

The aim of the study was to evaluate the success of a one-year undergraduate bridging course in Engineering (PBS) offered to educationally disadvantaged students, with special emphasis on the role of mathematics in addressing and overcoming some of the problems encountered by Engineering students. These problems include the inability of relating classroom examples to the real world, and the impotence of students of making approximations and estimates in the absence of calculators.

The study briefly describes the aims and structure of the course which has a two fold purpose: to teach students how to think, how to use common sense, to guess, estimate and approximate, and how to translate real-life problems into mathematics, and to provide the framework and basics of the first year Engineering mathematics course. Examples of first year university mathematics problems that teach students how to think clearly and creatively are cited

The mathematical performance of this group was compared with the performance of a large control group of Engineering students in each of the three years of study. This was replicated for four groups of PBS students A statistical comparison of the groups show that there is a significance difference in the average mark and the pass rate at first year level. In the second and third year, there are no significant differences in the groups, implying that the advantage of the bridging class has been carried through to further other years of study.

Details of the subsequent career of a number of highly successful graduates have been included as well as comments and reflections of some of the students who have graduated since the inception of this program in 1986 .Universally they consider this was the best year of their lives where they learned many skills which were never taught again in their studies.

Introduction

This is an empirical study on teaching mathematics to educationally disadvantaged students who are selected for a one year undergraduate bridging course The course was designed to prepare these students for a career in Engineering. From a theoretical point of view, it addresses the issue that all students, particularly at university level, should be taught how to guess, to estimate, approximate and how to construct mathematical models of the real world. The study aims to evaluate the success in mathematics of these bridging students, by statistically comparing their results during their undergraduate years with the results of those engineering students in the same class who were not privileged to be exposed to the special attention the bridging students received in their pre-university year. The initial hypothesis is that exposure to thinking and problem solving skills offered in this one year bridging course impacts on future mathematics success.

Background

The University of the Witwatersrand Pre University Bursary Scheme (PBS) is a one year course offered to students who wish to pursue a degree in engineering. The programme was initiated in 1986, and since its inception 32 companies have sponsored more than 700 PBS students. More than 60 % of these have graduated with a degree in Engineering. In exchange for five years of free tuition and residence fees , the students are obliged to work for their sponsoring company after they graduate.

Students are offered lectures and tutorials in Mechanics, Graphics, Chemistry, Physics, Mathematics and Computing. There is also a course in Communication, where students are tutored in written and spoken skills An important facet of the programme is the personal development of the students. Students are given a Toastmasters course and have public speaking nights for the first part of the year. In addition there are life and study skills workshops, afternoon field trips to factories, laboratories and mines. Students are also required to spend three weeks per year on site work with their sponsoring companies where they are exposed to the engineering environment. Due to space logistics, the maximum number of students that can be accommodated is 60, but the numbers fluctuate dependent on the number of students selected by various large South African corporations such as Eskom, Sasol, Anglo Gold, Anglo Platinum, etc.

I have been lecturing the mathematics component to these students since 1996. Thus the contents have been more or less stable since that date. The slight variation in content each year

is dependent on time constraints and the calibre of the students. Since class participation is encouraged, the interaction may initiate extra topics.

Records have been kept of their progress throughout their undergraduate years , and if possible after graduation. The statistical analysis of their results in mathematics has been done from 1997 (1996 PBS group) to the end of 2001.

Mathematics

The syllabus was not only designed to address some of the academic problems that students experience in mathematics but also to teach students to relate classroom examples to real life problems, to approximate and estimate in the absence of computers, to use common sense and previous experience to solve new problems.

Mathematics can be used to develop certain skills such as how to think, by translating real life problems into mathematics . This can be done very successfully by studying functions and their applications. In the first week of lectures, students are exposed to with word problems based on piece-wise defined functions.

Here is an example:

The monthly water tariffs of the Durban Metro for household use are calculated as follows:

There is no charge for the first 6 kilo litres; for the next 24 kl, the charge is R2.53 per kl. If a household exceeds 30 kl in a month, each additional kilo litre is charged at R5.06. Express this information as a mathematical function, and sketch the graph.

An area of mathematics which is glossed over or completely neglected at first year level is the Bolzano Theorem and the Interval Bisection Method, which unlike Newton's Approximation do not require calculus. At a later stage these two methods are compared. The students are often intimidated by the choice of an initial estimate of a root, and also by knowing how many iterations to perform. This is a very good exercise in estimation and approximation.

Linear Interpolation is no longer needed at school since calculators have replaced tables, but this is a simple technique which can be included, at any level, in the study of straight lines The process can be easily explained graphically, and trains the mind to explore different ways of tackling problems.

Another technique I use to encourage mathematical insight is "guesstimation", i.e guessing the answer before starting a problem. There are many situations where this can be successfully applied, sometimes with a great deal of fun.. Students find guessing the answer extremely intimidating, and they take some time to appreciate the value this has in promoting precision and accuracy of calculation. I think this is an important skill that has been lost over the years due to the ready availability of calculators. But this is especially pertinent for calculations using calculators. Guessing beforehand, even if it is a ball park figure, trains a student in the importance of accuracy and precision. The recognition and identification of errors when they occur is an important skill for everyone, but especially for engineers

A universal problem area for most students is the introduction of radians. Being able to anticipate the answer to a trigonometric calculation on a calculator guides them in knowing when they are in the incorrect mode. They need a yardstick (such as $\sin 30^0 = 0.5$) with which to compare the value they obtained

An oft neglected area is checking results when the problem is solved. I ask students to examine the solution to a problem and decide if it is feasible A simple example is to sketch a polynomial curve and compare its shape with the sign of the leading coefficient.. It is very easy to check solutions of simultaneous equations and also trigonometric equations by substitution.

Syllabus

The framework of first year mathematics is presented by exposing the students to radians, to new trigonometric identities and their use in solving trigonometric equations. The students are drilled in basic differentiation and integration skills and if time permits, we study the Binomial Theorem and Pascal's Triangle and some matrix algebra with special reference to applications. The spade work for the first year mathematics course is done so that the students in the following year can concentrate on the harder applications. The purpose is not to complete the whole first year course; there must still be enough in the following year to challenge and excite them mathematically. Hopefully this exposure to thinking and problem solving skills impacts on their future mathematics education

Statistical Analysis

I started teaching mathematics to the PBS students in July, 1996, so this study is based only on those students with whom I have had personal contact. The engineering degree extends over 4 years and a mathematics is studied for the first three years only..

The study was based on the following groups of students:

PBS year	1st year Maths MATH 180	2nd year Maths MATH 280	3rd year Maths MATH 380	Graduation
1996	1997	1998	1999	2000
1997	1998	1999	2000	2001
1998	1999	2000	2001	
1999	2000	2001		
2000	2001			

In each year, a comparison is made between the mathematics marks of the PBS students and the marks of the whole group (WG) excluding the PBS students. Two-sample z-tests are used to determine whether there are any significant differences in the average final mark of the two groups, and two-sample tests on proportions are used to investigate whether there are any differences in the pass rate of the two groups.

The Results

From the tables (Appendix I) and the bar charts (Appendix 2) , the following conclusions can be reached.:

At first year level, the mean mark and the pass rate in all years was higher for the PBS students then for the whole group

the differences in pass rates are significant in every year at the 5 % level

the differences in mean marks are significant at the 1 % level in 1998 and 2001, and significant at the 5 % level in 1997 and 1999.

there is no significant difference in the groups in 2000.

At second year level, the pass rate for PBS was higher in 1999 and 2000, and the mean mark was higher in 1998

there is no significant difference between PBS and WG for either mean mark or pass rate

At third year level, the PBS pass rate and mean mark was higher in 1999 and 2001

the difference in mean mark is significantly different at the 5 % level in 2000

there is no significant difference in the mean mark nor in the pass rate in the other years

Conclusions

As would be expected, the mathematics marks of PBS students are better than the marks of the other students in their first year. PBS students have a distinct advantage as much of the work is familiar to them. The pass rates are also significantly higher.

In the second and third year, the mean mark and pass rate are not significantly different. From this we can conclude that although these students were academically disadvantaged when started the PBS course, by the second year there is no difference between the PBS students group and the mainstream students. The pre-university year has enabled these students to overcome their deficiencies and their academic achievement could be favourably compared with the remaining students who had been accepted directly from school based as a result of their matriculation success.

Success stories

Of the 313 PBS alumni who could by now have graduated, 150 have done so in Engineering and 51 have done so in other disciplines, many at other universities. A study at the University has shown that about 60 % of students who have completed the PBS course have graduated in contrast to about 28 % of previously disadvantaged students directly entering the mainstream courses. All the students interviewed have unanimously said that the programme was the best thing that happened to them.

To quote one successful student, who did the PBS course in 1988: "....The programme did a lot more than teach us about engineering.; it taught us how to think, it taught us to be problem solvers and to be creative at the same time.... We didn't just learn facts, we learnt how to learn. "

After graduating this student completed an MBA at the Sloan School of Management in the USA , and is presently employed at Rio Tinto in London, in charge of its world wide coal mining investments.

Four university engineering graduates have established a black empowerment engineering consultancy firm. Three of these students are PBS alumni. Two of them graduated with degrees in mechanical engineering, and the other has a degree in electrical engineering. In addition, two of these three PBS alumni have completed graduate diplomas in industrial engineering and the other is presently studying technology management.

There are many other successful alumni amongst whom are :

a Metallurgist at De Beers, a Senior Inspector for the Department of Mineral & Energy Affairs

the Chief Director at the Department of Mineral and Energy

In addition, a heart-warming success story is that of Jacob Modise, Chief Operating Officer of Johnnic Holdings who was a graduate of the Anglo American Corporation's Cadet scheme, a precursor of the Pre-University Bursary Scheme, which was offered to both Commerce and Engineering students in the early days of the programme. He was orphaned at nine years of age, was one of 10 Matric students selected for the cadet scheme, and qualified as a chartered accountant at 22 years of age. When asked in an interview what was the biggest ever opportunity he was offered in his life, he said it was his selection for the cadet scheme.

Further information about the PBS course will be found at the following websites

http://www.wits.ac.za/pbs/companies.htm

http://www.asec.org/prism/mayjune/html/global.html

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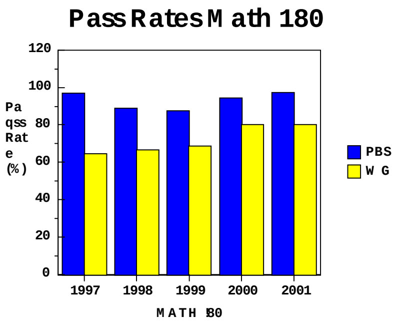
Appendix I

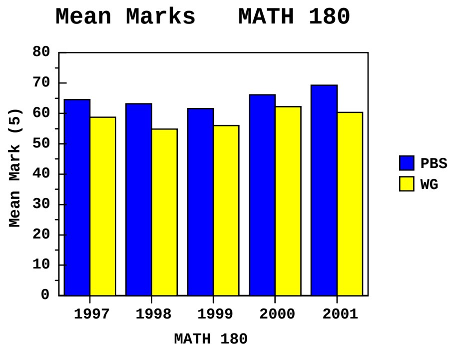
Tests on difference of PBS and Whole Group

PBS Year			$p - value$	Significant ?
1996		Math 180	p = 0.00269<0.01 **	****Sig at 1 % level**
	Proportions	Math 280	p = 0.38	Not Sig. at 5% level
		Math 380	p = 0.567	Not Sig. at 5% level
		Math 180	$p = 0.0378 < 0.05$ *	**Sig. at 5% level**
	Means	Math 280	p = 0.17	Not Sig. at 5% level
		Math 380	P = 0.11	Not Sig. at 5% level
1997		Math 180	$p = 0169 < 0.05$ *	**Sig. at 5 % level**
	Proportions	Math 280	p = 0.47	Not Sig. at 5% level
		Math 380	p = 0.21	Not Sig. at 5% level
		Math 180	p = 0.0097 < 0.01 **	**Sig. at 1 % level**
	Means	Math 280	p = 0.7698	Not Sig. at 5% level
		Math 380	$p = 0.02 < 0.05$ *	**Sig. at 5 % level**
1998		Math 180	$p = 0.0149 < 0.05$ *	**Sig. at 5 % level**
	Proportions	Math 280	p = 0.23	Not Sig. at 5% level
		Math 380	$p = 0.1032$	Not Sig at 5 % level
		Math 180	$p = 0.0459 < 0.05$ *	**Sig. at 5% level**
	Means	Math 280	p = 0.66	Not Sig. at 5% level
		Math 380	p = 0.1559	Not Sig at 5 % level
1999		Math 180	$p = 0.0332 < 0.05$ *	**Sig. at 5% level**
	Proportions	Math 280	p = 0.8107	Not Sig at 5 % level
		Math 380		
		Math 180	p = 0.08	Not Sig. at 5% level
	Means	Math 280	$p = 0.534$	Not Sig at 5 % level
		Math 380		
2000		Math 180	p = 0.010 < 0.01 **	**Sig. at 1 % level**
	Proportions	Math 280		
		Math 380		
		Math 180	p = 0.0016 < 0.01 **	**Sig. at 1% level**
	Means	Math 280		
		Math 380		

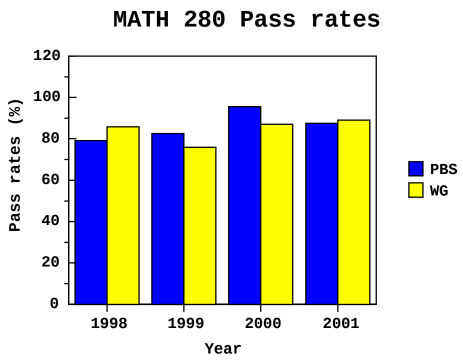
Appendix II

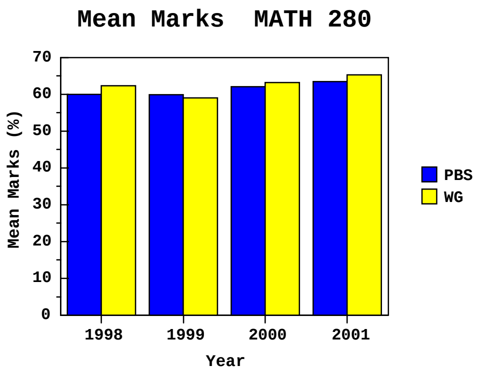
MATH 180 1997 - 2001





MATH 280 1998 - 2001





MATH 380 1999 - 2001