An undergraduate technology-based applied mathematics program at Universiti Sains Malaysia

Rosihan M. Ali
School of Mathematical Sciences
Universiti Sains Malaysia
rosihan@cs.usm.my

Ahmad Izani Md. Ismail
School of Mathematical Sciences
Universiti Sains Malaysia
izani@cs.usm.my

Abstract

The rapid industrialization of Malaysia has resulted in a high demand for applied mathematicians, scientists and engineers who are skilled in the mathematical and computer modeling of problems arising in business and industry. It is very desirable that both symbolic and numerical computing become an integral part of the undergraduate degree program. The objective is not the study of technological devices (graphic calculators and computers), but rather to use them to facilitate and promote the study of mathematics. The precise manner of using such technology within the undergraduate program is not yet thoroughly established. In addition, departments have to operate with inadequate computational facilities and a lack of technical support to maintain equipment. In this article we describe an undergraduate mathematics program which has been designed to produce graduates reasonably trained in mathematical and computer modeling. Further plans to improve this program, in particular with regard to the use of hand-held technology, are also described.

Introduction

The Malaysian economy has undergone tremendous changes over the past forty years. In the 1950's and 1960's the economy was highly dependent on the primary

commodities sector; in particular, the production of rubber and tin. In the mid-60's the Malaysian government embarked on an industrialization program in an effort to diversify and modernize the economy. This strategy has borne fruit. Manufacturing now accounts for over 30% of the GDP compared with 11% in 1965 [1,2]. In the early 1990's the manufacturing sector grew at well over 10% per annum. With the increasing modernization and sophistication of the economy has come a great demand for engineers, computer scientists, applied mathematicians and other scientific personnel.

Malaysia is now undergoing a transformation from the Industrial Age to the Information Age. This is a global phenomenon characterized by the electronic transmission of information. It brings with it new challenges and opportunities for higher education [3]. At the forefront will be the innovative use of technology in teaching and learning, as well as in research and development.

This paper will describe how Universiti Sains Malaysia (USM) has responded to the demand for applied mathematicians who are well-trained in mathematics as well as in using computing technology to analyze and solve problems arising in business and industry. The paper begins with an overview of the conventional B. Sc. mathematics program before concentrating on the new B. Appl. Sc. mathematics program and the opportunities technology has to offer.

The B. Sc. program in mathematics

The Universiti Sains Malaysia was set up in 1969 with one of the objectives being to increase the number of science graduates in Malaysia. The B.Sc. (*Bachelor of Science*) degree was one of the first undergraduate degrees offered. A student who wishes to major in mathematics within the B.Sc. program will typically take 15 mathematics courses. The courses offered in the late 1970's and early 80's were the usual courses in calculus, linear and modern algebra, differential equations, complex analysis, FORTRAN programming, and basic numerical methods. The B.Sc. program then also included a significant number of courses in statistics and operations research [5].

In the main these courses were very much theory-based and somewhat traditional. There was not much scope to introduce real-life mathematical problems and the associated modeling and computer solution within many of the above-mentioned courses. The use of computing techniques to solve mathematical problems were limited to the programming and the numerical methods courses. There were no courses on mathematical modeling of engineering and scientific phenomena, no (extensive and compulsory) final year project whereby the students can be trained in the fundamentals of conducting research and in the use of computers to model real-life problems. Given these shortcomings and limitations, it was felt that a new program was required to cater to the needs of the expanding manufacturing and services industry.

The B. Appl. Sc. program in mathematics

The B. Appl. Sc. (*Bachelor of Applied Science*) program in mathematics, introduced in 1987, was formulated to overcome some of the perceived inadequacies of the B.Sc. program. It is essentially an applied mathematics program with a bias towards the use of computers and an emphasis on problem-solving abilities.

There are four areas of specialization: CAGD (Computer Aided Geometric Design), Mathematical Modeling, Applied Statistics and Operations Research. Students take common core courses in the early years and specialized/optional courses in later years according to their area of specializations.

The common core courses aims to provide students with a strong foundation in mathematics and a computer programming language. Topics covered include calculus, linear algebra, statistics, C programming, and differential equations.

The specialized and optional courses aims at imparting to students important specialist knowledge.

Students in the CAGD and Mathematical Modeling streams take further courses in analysis, vector calculus, differential equations, numerical methods, finite difference methods, and mathematical algorithms for computer graphics.

Students intending to major in CAGD take specialized courses in computer graphics and computational geometry, while those in Mathematical Modeling take courses in modeling and fluid mechanics.

Students in the Applied Statistics and Operations Research streams take courses in statistical methods, probability, operations research, and statistical inference. They each have the following set of optional courses:

Applied Statistics	Operations Research
Quality control	Linear & integer programming
Design & analysis of experiments	Queuing systems & simulation
Multivariate analysis	Network flows
Sample surveys & sampling techniques	Inventory control
Time series analysis	Mathematical Programming

Students from all specializations are also required to participate in a software laboratory and must complete a major project.

The software laboratory courses expose the students to standard software used in industry such as AutoCad and 3D Studio (for CAGD/Mathematical Modeling) and SAS, SPSS, Statgraphics, SAS/OR, GPSS (for Applied Statistics/Operations Research). New software will be introduced as they become available to provide students with practical skills required in industry.

The language used in the programming course has been changed to C since C has become the systems language of choice in industry and is also expressive and versatile as a general purpose programming language. FORTRAN, the dominant science and engineering programming language, is introduced in the Basic Numerical Methods course. The solution of differential equations may require the evaluation of complicated integrals, matrix inversion and the solution of algebraic equations. We have included an introduction to MathCad in the syllabus of the Differential Equations I course. MathCad was preferred over other well-known packages because it is relatively simple to use. In many of the above-mentioned courses, real-life problems are often introduced and course assignments often include the modeling and computer solution of typical mathematical problems arising in business and industry.

The compulsory major project in the final year which involves the mathematical or statistical modeling of a scientific or engineering problem, a literature survey, and the use of a computer for modeling and solution purposes. Recent student project titles have included traffic flow simulation, modeling flow in an estuary, process analysis of lamp standard design, money market statistical analysis, data envelopment analysis, and shape preserving curve interpolation. It is hoped that through the project students would acquire other skills such as communication, presentation, and participation in teamwork. Further details on the B. Appl. Sc. program can be found in [7].

Prior to their final year, many B. Appl. Sc. students spend their vacations on industrial placements and in quite a number of cases their final year project is a continuation of problems they were dealing with whilst on industrial training.

It should be noted that most B. Appl. Sc. students majoring in CAGD/Mathematical Modeling choose to minor in Computer Science and most of those majoring in Applied Statistics/Operations Research choose to minor in Management. These choices of minors complement the major component of the program in terms of areas of applications and additional quantitative/computing (including software engineering) techniques.

A survey conducted in 1996 [4] by the School of Mathematical Sciences USM indicated that the B. Appl. Sc. graduates have no difficulty obtaining employment in business and industry with quite a number getting job offers before their final exams. A high percentage of employers also expressed satisfaction with the performance of B. Appl. Sc. graduates in mathematics.

The School of Mathematical Sciences regularly invites distinguished applied mathematicians from overseas to act as external examiners for the B. Appl. Sc. program in mathematics. The role of an external examiner is to ensure the quality of the program by reviewing the curriculum, vetting the examination papers, reviewing the answer scripts, and meeting with student representatives The external examiners have found [6] the B. Appl. Sc. program to be of an acceptable international standard and have provided valuable feedback on how the program could be further improved. In particular, a number of external examiners have suggested the incorporation of technology and modeling into some of the core courses.

The USM experience

The traditional lecture or tutorial is not the only approach to the teaching and learning experience. The rapid advancement of computer and related technologies over the last few decades has placed demands on the integration of technological devices into the undergraduate programs as rapidly as permitted by available resources. As students become more computer literate, the use of computers has taken an increasingly important role in education.

The computing facilities at the School of Mathematical Sciences consists of two personal computer (PC) laboratories, with 386 in the first year lab and 486 in the advanced lab. It therefore comes as no surprise when many External Examiners [6] noted that the computational facilities are considerably inadequate both in terms of quantity and of quality. The facilities need to be upgraded or replaced, to include networking, central file server, Intel-based PCs, and workstations. Additional provisions must also be made to procure appropriate and more sophisticated software.

There is also an urgent need for technical support to help maintain the equipment. Both students and staff have voiced complaints about excess down-time of equipment due to hardware failures. It is certainly wasted academic time when capable faculty are used to maintain computer systems and to install software.

Additional support staff must also be made available so that all computational laboratories can be made available to students in the evenings, on weekends, and even over holidays. Students expressed frustrations stemming from the short hours that these facilities are available, most of which is dedicated to actual lectures or scheduled laboratories.

With the growing number of students, it has become an expensive investment for the school to buy and maintain PCs as well as buy the necessary software. The school has found that the costs of replacing equipment in order to keep in step with technological developments impossible to sustain. Recent cuts in funding have compounded these problems. USM now has to cater for an increasing student numbers while trying to reduce cost.

Given this scenario, there is therefore a need to explore all reasonable alternatives for the delivery of quality teaching. New technologies have stimulated a surge of new approaches that reach out to students. New visualisation tools are now available for the teaching and learning of mathematics. One such tool is the hand-held mathematical computer (graphic calculator), whose technology and levels of sophistication have grown significantly over the last few years. Hand-held computers have now become powerful enough to cater to the needs of many mathematics courses, and are cheaper alternatives to PCs at only a fraction of the costs. Learning is also carried out fully in the classroom without students having to move from the classroom to the computer laboratory, and hence provides a hands-on experience. In view of increasing student enrolment and the inability to provide PCs to all students, the school sees graphic calculators as useful tools to facilitate and promote the study of mathematics.

Future plans

The school has begun introducing graphic calculators into the calculus and software laboratory courses so that students develop familiarity with these devices. Plans are now being made to extend the usage of graphic calculators in all relevant courses. An additional laboratory equipped with these devices will also be made available.

However incorporating the use of hand-held computers will also involve a revision of the school's teaching, learning, and assessment practices. There is a need to study current teaching methods so that these devices are used effectively. Staff need to gain more experience and to fully understand the potential of the technology before such infusion of technology can be more widely adopted. For this purpose, several staff have undergone training in the use of the appropriate technology.

Existing computing facilities will be upgraded and more powerful computers will be purchased. This is to cope with the expected increase in the number of students as well as the need to install new and more sophisticated software. Regular reviews of the curriculum are also planned to keep the curriculum in line with trends in business and industry. In this regard, more regular surveys of employers of the B. Appl. Sc. graduates are planned.

Multi-media is also evolving as a very powerful tool for meeting the demand for more flexible learning. The capability to mix text, diagrams and images with video and sound greatly enhances the ability to transmit information meaningfully. Efforts are being made to develop well designed multi-media courseware, which would allow a student to learn at his own pace and level.

As students pay an increasingly larger percentage of the costs of their education, we must find ways to make our programs relate directly to their career opportunities and earnings potential. We have to prepare our students by incorporating into our curricula appropriate training in the technologies, and we must strive to make more

innovative use of technology that would enhance efficiency, effectiveness, and quality of the teaching and learning process.

Acknowledgement. The authors are grateful to Prof. Peter Jones for his many helpful comments and suggestions in preparing this paper.

References

1. Economic Planning Unit, *First Malaysia Plan*, Prime Minister Department, Kuala Lumpur, 1965.

2. Economic Planning Unit , *Seventh Malaysia Plan*, National Printers, Kuala Lumpur, 1996.

3. *National Information Technology Agenda*, National Information Technology Council, 1996.

4. S.H. Quah et al., *Laporan Prestasi Kerjaya dan Graduan*, School of Mathematical Sciences, Universiti Sains Malaysia, 1996.

5. Universiti Sains Malaysia, *B. Sc. Handbook*, 1980.

6. Universiti Sains Malaysia, *External Examiner's Report: Collection of reports from 1988/89 through 1995/96 on the undergraduate programs at the School of Mathematical Sciences*.

7. Universiti Sains Malaysia, *B. Appl. Sc Handbook*, 1997.