# ON-LINE LEARNING FOR BRIDGING MATHEMATICS STUDENTS

**GEERT MARIUS SPYKER**
Department of Mathematics and Statistics, Curtin University of Technology, Bentley 6102, Australia. E-mail: geert@maths.curtin.edu.au

## Introduction

One of the descriptions in the Concise Oxford Dictionary for education is: systematic instruction. To make this instruction effective, teachers and students are required, while appropriate tools are needed to make this instruction efficient. An important aim of education is to prepare students to be active for the benefit of others in a complicated world. This benefit should be most apparent in their particular field of study.

As mentioned above, this instruction should be systematic. Teachers should provide a methodical plan of subject material and activities to enable students to reach their educational goal. For that reason, a proper curriculum with attached syllabus must be developed in every subject area while appropriate educational tools must be specified as well.

In the subject area of mathematics, these tools have become more and more powerful. In the 1950s, each student possessed a trigonometric and logarithmic tables book while some even used the slide rule. At the start of the 21st century, most students, in particular at tertiary institutions, use computers and graphics calculators that enable them not to 'get bogged down' in arithmetic errors but to develop a more investigative approach to mathematics.

## Some historical notes

In the state of Western Australia (WA), with a population of approximately two million, the mathematics curriculum in secondary schools has changed considerably over the last fifteen years. In the late 1980s, most upper school students were not exposed to the topic calculus. Only about 15% of Year 11 and 12 students took the subjects *Mathematics II* – functions and statistics/probability – and *Mathematics III* – differential and integral calculus – which were taken together. This implied that only those who aimed to study Science or Engineering at university were willing to dedicate one third of the total study time in these years to mathematics. To enable a larger student cohort to learn the basics of calculus, new mathematics courses were developed for the upper school, which meant a complete overhaul of the mathematics curriculum.

One of the results was that a new subject called *Introductory Calculus* was offered to Year 11 students. This meant that approximately 40% of the student cohort, which would prepare themselves for a university study after Year 12, would have been exposed to one year of studying the basics of functions, differentiation and integration. Together with the Year 12 subject *Applicable Mathematics*, with topics such as basic matrix algebra, time series, probability and statistics, these students would be better prepared for Applied Science courses at a tertiary level.

When a new curriculum is introduced, there is often a vast difference between the stage of planning and the practical results during and after the implementation stage. With the introduction of the new upper school mathematics subjects in WA schools in the early 1990s, universities decided upon prerequisite mathematical knowledge of the students before accepting them in various courses of study. However, it soon became apparent that either the entrance prerequisite requirements should be changed or that new first year units at tertiary institutions should be developed. At Curtin University of Technology in Perth, WA, it was decided not to lower the existing academic standard but to develop new units so that a larger cohort of students would benefit. Reasons for this decision were:

- Too many students opted for the 'easier' mathematics courses at high school and, thus, were mathematically under-prepared when entering university.
- The percentage of secondary students applying for a university place is rapidly increasing.
- Many mature-age students applied for and received a university place.

## Bridging Mathematics

With the introduction of the new units, the aim was to bridge the gap between what is taught at secondary schools and what is required at tertiary institutions. Hence, the name Bridging Mathematics is used. It became clear that specific attention should be paid to the following topics:

- A thorough revision of algebra: factorisation, problem solving, and applying the index and logarithm laws.
- An overview of functions, in particular linear, quadratic and cubic, while minor attention is being paid to hyperbolic and root functions, and their graphical representation.

- The use of trigonometry in practical examples and a few major trigonometric identities.
- Some basic matrix algebra and its use in solving equations.
- Differential calculus and its application in maximum/minimum problems.
- Integral calculus and its application in determining areas and volumes.
- Basic vector geometry and its use in practical situations.

Initially, the units were intended for Applied Science and Spatial Science students who were unable to cope with their first year mathematics unit. Soon other departments on campus heard of the existence of these bridging mathematics units and directed some of their students to enrol in these units. It means that their period of study will be longer but, ultimately, they greatly benefit from this thorough revision of high school mathematics.

The units are spread out over two semesters. Not all students are required to complete both units. Environmental Biology students, for instance, only must successfully complete the first semester unit. The enrolment figures for these units are increasing. This year, a total of 270 students enrolled and the pass rate was approximately 75%. Those who failed either did not complete the unit or the material was still too difficult for them.

## Assessment

The first semester bridging unit is divided into four modules, viz. Algebra, Functions and Trigonometry, Matrices, and Differentiation used in curve sketching and in growth/decay exercises. For each module, students are required to complete a few worksheets, an assignment and a final test. There is no final semester examination, which is quite a relief for most students who already struggle with the wide variety of mathematical concepts they are exposed to. Each module has the same weighting and the final unit result consists of the average of the modules.

Soon, it became apparent that an alternative assessment tool should be found to replace the assignments. One of the reasons for this change was that the problem of collusion was to be alleviated as much as possible. It was fortunate that at that time the Department of Mathematics and Statistics at Curtin received a financial incentive for an On-line Learning Development (OLLD) Project to further develop a web tool with the aim to foster flexible learning and to facilitate self-assessment by the students [1]. The web tool used by the department was the AIM system described below.

## ALICE Interactive Mathematics

The AIM system was introduced to the department by the author of article [1]. He refers to the International Workshop on Advanced Learning Technologies (IWALT) in 2000 where this system was introduced [2]. In the above-mentioned article we read the following brief description of the AIM system:

> "AIM uses the symbolic package Maple as its computational engine to assess solutions submitted by students to unique and individualised quiz questions that are provided via the web. ALICE stands for Active Learning In a Computer Environment. AIM allows the user to frame questions, which may have structured parts, and to provide immediate feedback and detailed solutions to students using it. It can supply students with a wide range of randomised input questions and then check the students' responses using a symbolic package handle. For example, if the correct solution to a question is cos ($2x$), the answer given as $\cos^2 x - \sin^2 x$, or $2 \cos^2 x - 1$ or any of the many other equivalent forms, are all acceptable as being the same or equivalent answer."

The flexibility of entering material into the web-tool is described as follows:

> "The ability to accept algebraic objects, as understood by Maple, is a very useful enhancement to the capability of the web-tool. Since the web-tool uses the randomisation facility within Maple, we have the option of two levels of randomness in the framing of questions: one is the randomisation of variables, algebraic expressions, or numerical values in a particular question, and the second is the randomisation of a set of questions to be used."

The department was fortunate to be able to appoint an administrator who familiarised himself with the AIM system and adapted it to the requirements at Curtin. The tests were compiled by the lecturer-in-charge and the administrator entered these tests on the web and kept track of the students' performance in close liaison with the lecturer.

## AIM for Bridging Mathematics unit

As was mentioned before, it was decided to replace the existing assignments by a new assessment tool. The choice of the AIM system was the first step in using the internet to promote interactivity between students and administrator within the confines of the web-site and between student and lecturer by means of email. AIM also promoted a self-paced learning environment with the opportunity to rectify errors to the questions without 'heavy penalties'. This method of reflecting upon one's errors directly after they have been made promoted an improved understanding of the concepts.

At the start of first semester this year, each student received a written outline that explained the OLLD Project and introduced some specific syntax requirements when using Maple. After entering the web site [3], students were invited to complete an Introductory Tutorial that introduced them to the syntax of AIM and how to enter answers. This tutorial was set up in practice mode because the students had access to a 'solutions' button. The marks obtained for this tutorial were not kept for assessment purposes. Using the solutions button, the students obtained a new quiz and were enabled to familiarise themselves even better with AIM.

In the second week of semester, students could start with the first quiz that dealt with basic algebra concepts. A total of eleven quizzes were compiled which served to consolidate the concepts presented to them during the previous lecture. Three quizzes were presented on algebra and two each on functions, trigonometry, matrices, and differentiation. Each quiz consisted of seven questions so that students could complete them within the set time limit. These quizzes were set up in assessment mode without access to the solutions button. The quizzes were available on Monday morning and had to be completed by Friday midnight. The following week this quiz was available in practice mode with different values for the variables due to the randomisation facility within Maple. Thus, students were enabled to prepare themselves in various ways for the final test of each module of work.

## Survey

During the second last lecture for the semester, students were asked to complete a survey so that the lecturer and the administrator could receive appropriate feedback on the use of AIM in the bridging mathematics unit. Verbal feedback had indicated already that for many students it was the first time that they had been exposed to this mode of assessment.

The 'Survey OLLD Online Tests 2003' aimed to obtain information on the mathematical background of the students involved, their experience with the syntax of the quizzes, the amount of time spent on completing them, and the level of helpfulness of the feedback they received when doing the quizzes. Finally, the students' input was requested on how to improve these quizzes and their best and worst features.

## Feedback

A total of 158 students – 54% male and 46% female – responded by completing the survey. Of these students, 49% had completed their secondary education in the year 2002 while 21% had completed high school more than five years before. This means that a relatively large group were mature-age students who had not studied the subject of mathematics for quite some time.

When students were asked about their mathematical background, it became apparent that 69% had not studied the prerequisite subjects in high school as preparation for their tertiary studies. Those who had completed the subject *Introductory Calculus* in Year 11 and *Applicable Mathematics* in Year 12 had either obtained a poor result or had failed the final examination.

The syntax requirements by Maple caused many initial difficulties. 53% of the students indicated that "initially they had problems with the syntax but after a few on-line tests everything was fine", while 32% indicated that "the syntax had been a continuing problem" for them. Although the students had been reminded during lecture to enter the product $(x – 2)(x + 3)$ as $(x - 2)*(x + 3)$, many forgot and often showed exasperation in their email messages. Many wrote that the syntax was the worst feature of the on-line quizzes.

In the next survey question, students were asked in how far the regularity of the quizzes had improved their study habits for the subject. 18% indicated that the influence was significant, 39% said that the influence was reasonable, while the remainder mentioned that the influence on their study habits was insignificant or non-existent.

It was disappointing to note that 42% of the students mentioned that they rarely made use of the revision quizzes for self-learning purposes while 39% indicated that they never looked at completed quizzes anymore or used them to prepare for the final test of each module of work.

An important key when entering an answer to one of the questions of a quiz was the 'validation' key. After pressing this key, syntax errors were pointed out so that the student received the opportunity to rectify their input and receive only a minor penalty. The survey showed that 16% of the students indicated that by correcting their mistakes their understanding of the subject material had improved significantly. Another 16% mentioned that their algebraic and arithmetic skills had greatly improved, while 40% were of the opinion that the process of correcting their mistakes had occasionally helped their understanding. It was disappointing that 20% of the students felt that the opportunity to correct their mistakes when completing a quiz had no impact on their understanding of the subject.

It was heartening to note that 87% of the students indicated that the feedback they received after they had completed a quiz was helpful. It also became apparent that the quizzes dealing with Algebra and Trigonometry were rated as being the most helpful in learning and understanding the required concepts.

## Conclusion

During the first few weeks that the on-line quizzes were running, a number of students were quite upset and even pleaded that the quizzes should be abolished. One of the students wrote in an email: "I have serious concerns and objections to this new web test system. I believe this system will not give true results for myself and other students but may actually cause some failures especially for borderline students…I believe this system will make it difficult for students with a poor background in mathematics such as myself where every mark counts. I understand that technology must advance to save time and money but surely there must be room for improvement over this." Thankfully, this dedicated mature-age student finished with a distinction for this unit. Upon completion of the unit, it became clear that alls students who had faithfully completed their quizzes benefited by obtaining a good final result.

A major benefit from the lecturer's and tutors' perspective was that the marking load was much lighter because the computer kept track of the results for each quiz. The employment of an administrator greatly benefited the lecturer-in-charge and solid ground work has been done for following years. Without the support of the administrator the lecturer would have been much busier.

A major didactical benefit of the on-line quizzes was that students must understand their subject material properly before they can enter meaningful solutions. They are also helped into rectifying misconceptions. One specific misconception many students had was that the solution for $y^2 = 290$ is y = sqrt(290) while there are two solutions. Another multiple choice question asked to simplify $(\sin x + \cos x)^2 + (\sin x - \cos x)^2$. Some students were adamant that the answer was $2 \sin^2 x + 2 \cos^2 x$ while they failed to recognise that the answer was 2.

For following years, it will be necessary to introduce students to the syntax of AIM in a more thorough manner with extra tutorials in between the regular quizzes. Certain questions in various quizzes should be changed or simplified so that students have a better understanding of what is asked. Overall, students have obtained a better insight in the mathematical concepts they encounter because during lectures reference could be made to questions and problems asked in completed quizzes. Students live in a world where the computer takes a prominent position and they should be prepared to use them efficiently and effectively.

## References

[1] Siew, P.-F., 2003, *Int. J. Math. Edu. Sci. Technol.*, **34**, 43-51.
[2] http://allserve.rug.ac.be/~nvdbergh/aim/docs
[3] http://olld.maths.curtin.edu.au/