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Managing diversity in first year service mathematics course: integration of effective numeracy teaching principles and management theory.

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ABSTRACT

First year service courses in mathematics are faced with numerous challenges as a result of the increasing diversity of student populations and the hierarchical nature of knowledge within mathematics. These challenges are even more extreme when such courses are offered in multi-mode format (on campus and by distance education). This paper describes the evolution of a foundation mathematics course, which currently integrates self-paced skill based materials, authentic problem solving activities and generic study skills into a unified curriculum which is underpinned by a 12 step scale for effective numeracy teaching (Marr and Helme 1991) and traditional management theory. The course is characterized by its ability manage groups of students with uneven preparation.

There is little doubt that few universities have escaped the influences and pressures produced by the move from elite to mass higher education. In just close to three decades there has been a substantial increase in the number of students accessing university education and a substantial change in the student profile. This changing student population has placed increasing pressures on the university sector to find ways to address the learning needs of students in an equitable manner. In institutions, which provide the same course in on-campus and distance education modes, the challenge is even greater. Compounding this situation is the predicament of service courses, particularly the mathematics service course. In these cases a single course is often expected to address the needs of students immersed in diverse disciplines, from different educational backgrounds and with a diversity of beliefs and attitudes towards mathematics. The occurrence of this type of uneven preparedness is reported widely within commencing engineering students (Molyneux-Hodgson 1999; Taylor and Morgan 1996a,b and 1999; Mustoe 1996; Kurz and Holoch 1996; Gardner and Broadus 1990; Pickard and Cosk 1996; Clark 1996; Crowther, Thompson and Cullingford 1997; Shaw and Shaw 1999). Further, like all other first year students, students enrolled in foundation service courses are novices to the tertiary learning culture. The challenges facing service mathematics courses include:

- developing mathematics skills that are transferable to diverse disciplines;
- catering for uneven preparedness in a subject in which knowledge is hierarchical;
- developing self management skills for success in university study; and
- addressing generic skills, especially those associated with problems solving and communication, that are transferable to diverse disciplines.

This paper proposes a series of solutions to the above challenges, which have been developed and trialed in a self-paced mathematics service course for on campus and distance education students in a large regional multi-mode Australian university.

Background

The University of Southern Queensland (USQ) is a large regional Australian university which offers courses across 5 faculties in on-campus, distance education and online modes. It currently enrolls approximately 20 000 students, 75% of whom study off campus from every state in Australia and overseas. The Foundation Mathematics service course has a long history at USQ. It was initially designed in the mid eighties to provide refreshment mathematics for first year students in mathematically focused courses (Bachelor of Engineering, Applied Mathematics, Computer Science). In the late eighties with the changing student profile and expansion of discipline based programs, Foundation Mathematics changed to being a core program for a number of general programs such as Biology, Bachelor of Technology, Education (maths/science specializations), Associate Degrees of Engineering and Surveying. This situation was drastically changed in the late nineties by the downgrading of the mathematical entry requirements for a number of programs. This meant that students could now be enrolled in Foundation Mathematics after having studied little mathematics in the senior school or equivalent. To manage this diversity in mathematical background the course was merged with a bridging course in 1997. The new course could be taken by students over one or two semesters depending on their mathematics experience on entry to the course. The entry point of each student was assigned to one of three alternatives on the basis of an entry test. Entry point 1 required the student to complete all the preparatory material before continuing on to the pre-existing Foundation Mathematics content. Entry Point 2 required the student to begin halfway through the preparatory material, while Entry Point 3 students began at the start of the pre-existing Foundation Mathematics material. Very able students were encouraged to take up the offer of testing out of the course in the first weeks. Students proceeded through the course at their own pace being assessed by regular mastery quizzes and an examination for distance education students. No lectures were offered and all students (on campus and distance education) acquired information from a set of print-based study materials. This approach aimed to:

- seamlessly integrate the philosophy and materials of a bridging program into the core mathematics program;
- provide flexible assessment which allowed for different entry and completion points; and
- allow all students to be able to study at their own pace in their own time.

Although successful from a number of aspects, the problems of student procrastination and a lack of community within the course, were a concern (Mander, 1998). Commencing in 2002 the course curriculum was further changed to include the following four components.

1. A series of mastery based modules that focused of the basic mathematical content required for the above.
2. An overlay of self management and study strategies to assist students make the transition to university studies and to manage the flexibility embedded within this course.

3. A series of problem based group sessions/discussions that addressed
 - the development of mathematics skills, including mathematical communication and problem solving skills under authentic situations;
 - the nature of mathematical inquiry;
 - the usefulness and value of mathematics; and
 - the attitudes of students to mathematics.
4. A series of assessment strategies which included
 - production and maintenance of an action plan for study;
 - a series of mastery tests to assess basic mathematical skills; and
 - a series of written assignments to assess problem solving in authentic situations and mathematical communication skills.

The implementation was staged, with full implementation taking place in S1 2002. At this time the program enrolls 711 students (344 on campus and 367 off campus). Traditionally approximately 30% of students would have studied (not necessarily successfully) the lowest level of mathematics or equivalent at senior school with 70% having studied levels of mathematics which contain some calculus. On average students have been away from study for 5 years (range = 1- 20 years) and have tertiary entrance scores of 70 (standard deviation of 20) on a scale for 0 to 100, where 100 is the highest level. Table 1 displays the distribution of students within different programs of study.

Table 1: Percentage of students in different programs in 2001 and 2002.

Program of origin	2001 (456 students)	2002 (711 students)
Engineering and Surveying	72 %	55 %
B. Engineering.	0%	17%
B. Technology	36%	18%
Associate Degree	36%	20%
Sciences	16 %	9 %
Information technology	0 %	20 %
Assorted programs (Arts, Education, General Studies, Psychology, Business)	12 %	16 %

Design: The Mathematics Course Content

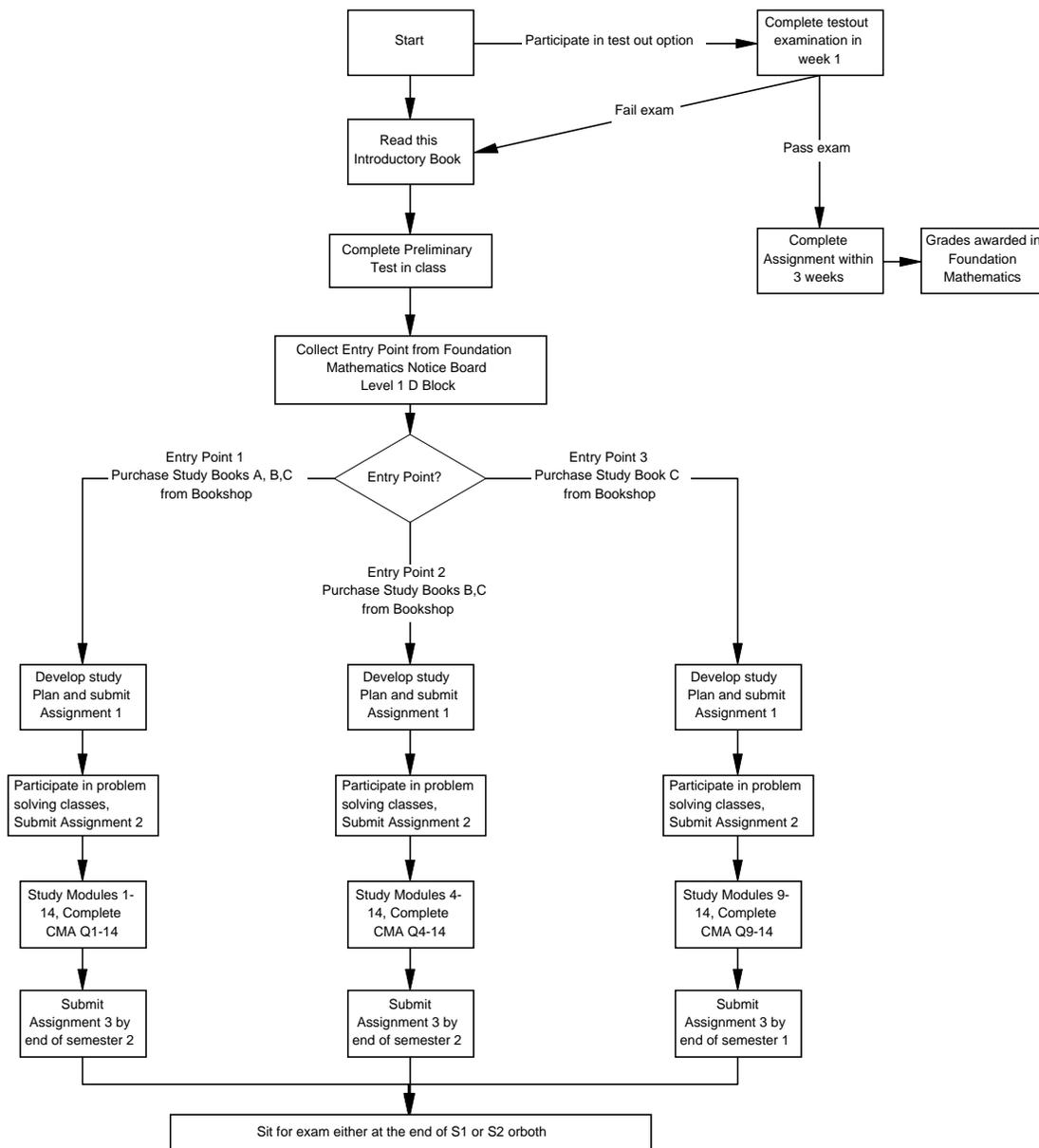
The course design was based on two interconnected frameworks. One was developed for numeracy teachers by Marr and Helme (1991) and enunciated the principles of effective instruction within numeracy courses, particularly those which enrolled students with maths anxiety or poor attitudes and experiences of mathematics. Within the context of the first framework a management structure, which focuses on a cycle of planning, organizing, leading and controlling (Stoner, Freeman & Gilbert, 1995), was also utilized. These two frameworks were combined to guide students through a carefully sequenced series of topics which provided the foundation for mathematics that would be encountered in a range of tertiary programs. The self-paced structure and the flexibility of three alternative pathways through the course allowed

students to work at their own pace developing confidence with mathematics and general problem solving appropriate to this level of mathematics. Figure 1 displays the sequence of events.

On successful completion of this course the student should be able to:

- demonstrate an understanding of a number of mathematical topics essential for tertiary study;
- demonstrate the skills necessary to extend mathematical knowledge beyond this course;
- interpret and solve a range of authentic problems involving mathematical concepts relevant to this course;
- effectively communicate mathematical concepts and arguments.

Figure 1: Summary of stages of Foundation Mathematics course in 2002.



Using the framework described above the following strategies were implemented to facilitate the achievement of the objectives:

Preliminary Test

This is a simple skills based test to allow staff and students to determine the students' level of mathematical knowledge and thus the appropriate entry point for the course

Introductory module.

This module contains discussions of past students' experiences of mathematics and mathematics learning with suggestions about general study strategies and specific instructions on how to develop a study plan for this course. The module encourages students to reflect on their personal experiences with mathematics and to include these in the first assessment with suggestions as to how these experiences will affect their future learning in Foundation Mathematics.

Embedded study skills

Generic study skills are introduced within the introductory module along with information on specific study strategies for mathematics. This information is reinforced throughout the print materials, where small study skills tips called 'Hints for success' are included as needed. Planning for study is developed early within the first assignment, in which students prepare a study plan for the next one or two semesters. Students are encouraged to modify the plan when difficulties arise and are required to formally report on their progress in the 8th week of the semester, when the second assignment is due.

Text materials.

Students are not given lectures, but provided with study materials which they are expected to study in their own time at their own pace. The text materials are characterized by:

- The presence of informal language. All text materials are written in informal language with little mathematical jargon making them more accessible to novice students. Formal mathematical language is introduced at a slow pace.
- Content is presented in context and applied to events that many students may be expected to have encountered previously. Sections entitled "A taste of" are included throughout each module to include applications modified from their possible future university studies. At the end of each module is a section entitled "Putting it all together..." in which a number of sections within a module are linked in an authentic problem based setting.
- Content and activities are presented in manageable chunks grouped in small bursts to allow students to experience early success and to build confidence, knowledge and skills gradually. All activities have fully worked solutions with problem solving prompts to guide students through the steps as appropriate.

Quizzes.

The content of the study material is self assessed by students using a series of computer marked quizzes. Students have access to multiple alternative quizzes so that they can achieve 80% mastery before progressing to the next module.

Problem solving sessions.

Each week students are required to participate in a problem solving session. The aims of these sessions are to:

- provide students with authentic mathematical problems solving experiences;
- develop communication skills; and
- build team spirit and facilitate peer support.

These sessions are presented in traditional classroom settings for on campus students and through synchronous online tutorials and asynchronous online discussion groups for off campus students. The problems presented are typically solvable by numerous methods allowing entry point 1 students to participate at the same levels as entry point 3.

Assessment.

Three assignments are designed to ensure that students face and reflect upon their past mathematical experiences, prepare a plan for study, develop mathematical communication and problem solving skills.

Support

Students are supported in traditional ways through face-to-face consultations and classes for on campus students and by phone, email and through online asynchronous discussion groups for external students. By the 8th week of S1 2002, 921 postings have occurred on the discussion groups and approximately 580 email queries have been addressed.

Discussion

The multiplicity of needs of the first year foundation service course is not simply solved by traditional instructional models. The course design presented here is rooted deeply in the processes originally developed in basic education. We have found however that they are equally applicable to the higher education sector as can be seen in Table 2. It is the strategies developed within this framework, that allow this course to develop transferable mathematical skills in an unevenly prepared population. For students to be able to self-manage this complex course along with other courses and life activities, they need to follow the steps of planning, organizing, leading and controlling as enunciated in basic management theory. Within the context of this course, planning and organization involves development of a study plan, identification of resources required and available, and identification of barriers to study. In the “leading” phase students are encouraged to self-assess their progress through reflection on their study plan and to self-assess their mathematical skills through the completion of the quizzes. They are required to demonstrate these skills in the assignment work. The control phase is developed through the integration of self-assessment and planning in the assessment work particularly assignment 2. The application of each of these four management phases requires the demonstration of generic study skills which are hoped to be transferable to other studies. The experience of staff with

bridging programs in which these strategies have been used for some years suggest that this will be the case (Bedford, 2001).

Solutions to problems caused by increasing diversity within service courses are not simple. This paper presents one alternative that has proven practical in a multi-mode situation.

Table 2: Implementation of principles of effective numeracy teaching (Marr and Helme 1991) into Foundation Mathematics.

Strategy for face-to-face teaching	Strategy for Foundation Mathematics
Acknowledge and discuss student feelings about math	<ul style="list-style-type: none"> • Quotations from previous students maths histories are presented for comparisons • Students are asked to write own maths history as an activity and assessment • Students are asked to reflect on past experiences at the beginning, during and at the end of the course
Use activities that provide early experience of success	<ul style="list-style-type: none"> • Students are directed into an entry point which best suits their chance of experiencing early success. • Modules are partitioned into small achievable sections including fully worked examples followed by activities • Early sections cover acknowledged skills • Detailed solutions to all activities including problem solving steps are included as part of the study strategy • Frequent self assessment quizzes
Encourage risk taking	<ul style="list-style-type: none"> • Personal quotations at beginning describe students' risks • Feedback from tutors in assignment, phone consultation and problem solving sessions applaud risk taking
Value a range of approaches to problem solving	<ul style="list-style-type: none"> • Alternative solutions to questions sometimes provided in text materials • Open acknowledgement in materials that there are other acceptable ways to solve the same problem, reinforced by tutors' responses • Alternative solutions always encouraged in problem solving sessions
Include different teaching strategies	<ul style="list-style-type: none"> • Cooperative learning encouraged through problem solving sessions and electronic discussion groups • Instructional design of the material includes a range of instructional methods from a didactic approach to problem based discovery
Teach in appropriate context	<ul style="list-style-type: none"> • Materials initially developed in context to reach beginning students • Materials are written in the first person with little to no jargon or formal mathematical language. • Real life examples included in the materials • Examples from tertiary contexts included
Help students to develop own strategies for overcoming math anxiety	<ul style="list-style-type: none"> • Students are asked to reflect after assignments 1 and 2 on their progress and study strategies

Teach relevant to adult students and use gender and culturally inclusive teaching strategies	<ul style="list-style-type: none"> • Students are presented with an overview of the course and its objectives early. • Language and examples are directed at adults and is critically assessed to ensure that it is gender and culturally inclusive.
Responsive to student needs	<ul style="list-style-type: none"> • The frequent use phone and email contact and the problem solving sessions (face-to-face and online) give a good mechanism for tutors to be responsive. • Tutors are encouraged to return assessments within 1 week and to respond to phone calls and email the same day.
Encourage learning through interaction and cooperation	<ul style="list-style-type: none"> • Students are required to participate in on campus problem solving sessions or discussion groups.
Acknowledge difference between students in backgrounds and mathematical skills	<ul style="list-style-type: none"> • Addressed in the introductory book
Make learning an enjoyable experience	<ul style="list-style-type: none"> • Modules designed to allow for students to be successful early in the course. • Light relief is included in the form of occasional jokes and cartoons and in responses by tutors. • Students are also encouraged to share jokes in the discussion groups

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