Skilling up: Three bridging courses preparing students for the mathematical demands of tertiary study

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Providing effective learning support for students in the mathematical demands of tertiary study is a goal of many universities. This paper reports on three pre-semester bridging courses developed, delivered and evaluated by mathematics skills lecturers at the University of Western Sydney. These courses prepare students for specific mathematics content in nursing, statistics and engineering units. The goal is to develop students' concepts and skills before they apply them in their mainstream unit, rather than administering 'band-aid' solutions after students experience difficulties. Findings suggest that bridging students are highly satisfied with the preparation they receive and that tailoring the content of the courses to student needs contributes to their readiness. More assessment is required into the long-term benefit to students of attending such bridging courses.

The provision of mathematical support to university students, especially in their first year of study, forms an important part of the learning support services which many students use to develop their academic skills. At the University of Western Sydney (UWS) in Australia free mathematical support is provided before and during semester on six campuses by a small team of three permanent mathematics skills lecturers (one full-time and two half-time) in the university's Learning Skills Unit.

This paper reports on the development and effectiveness of three short pre-semester bridging courses at UWS – *Numeracy for Nurses* winter workshops*, UniStep Basic Statistics* and *UniStep Maths Bridging for Engineering Students*. These courses have been designed to a high standard to address the mathematical needs of students prior to commencing a mainstream unit. They are tailored in their content in that they not only teach the assumed mathematical knowledge for the unit, but they also introduce students to some of the content and skills they will encounter in those units. As such they provide an excellent opportunity for students to prepare themselves and gain confidence, thereby facilitating their transition to a particular unit of study. Such an approach is not only likely to be more cost effective, but is considered to be more educationally sound than the alternative of waiting until students experience difficulty, and possibly failure, and then attempting to provide mathematics assistance.

Literature Review: Students' Mathematical Needs at University

Students coming into Australian universities have a 'broad range of abilities, attitudes and personal and educational experiences' (Taylor, 1999, p. 212). According to McInnis et al. (2000), one third of students going directly from school to university feel unready to choose a course and two thirds do not feel well-prepared for university study. Lack of mathematical preparedness of students can be a strong barrier to their success in the first year of study at university (McInnis & James, 1995 cited by Taylor, 1999, p. 212). Godden and Pegg (1993) note three reasons for un-preparedness in students: lack of mathematics skills, inadequate exposure to various mathematical topics and an increasing reliance on mathematics in courses not traditionally mathematically orientated. Also, the mathematical needs of mature-aged students may be greater than those of recent school leavers due to greater gaps in their mathematics education (McLoughlin & Marshall, 2000). Some students – often older ones – coming into university are already aware of their un-preparedness and actively seek ways to overcome it, while others need to be alerted to their needs (Stewart et al., 2001; Egea, 2004).

Strategies to address lack of mathematical preparedness include foundation courses, pre-semester bridging courses, drop-in centres, integrated curriculum support and on-line support (Taylor, 1999; Godden & Pegg, 1993; Nicholls & Robertson, 2004). Taylor (1999) notes that these strategies have developed from concerns, not only in respect of students in traditional mathematical areas, but also in respect of students in non-mathematical courses. These strategies have goals of fostering success and independence in learning for disadvantaged or under-prepared students (Taylor, 1999; Godden & Pegg, 1993).

For the strategy of bridging courses, Collins (1993) notes they are a way to ensure that students who have been offered a place can be brought up to 'a standard quickly and without major expense' and are 'aimed at "topping up" or at addressing small discrete gaps' in student's preparation (p. 102). These bridging courses also address the affective domain in under-prepared students who 'tend to underestimate their mathematical abilities, have low self-esteem and in general are very anxious' (Egea, 2004, p. 390). In the statistics bridging area, students often approach upcoming studies with dread, terror and an apparent lack of skills, yet subsequently succeed (Ormond, 1997).

The outcomes of bridging courses can be measured in terms of the course itself and/or in terms of subsequent student success in mainstream studies (Golden & Pegg, 1993). It is essential therefore to define the aims of a bridging course so that its success can be determined. If the course is shown to be successful then this can provide justification for continuing to offer the course (Godden & Pegg, 1993). Bridging courses may provide social, as well as academic, benefits (Troskie-de Bruin, 1999), while sometimes a successful outcome can be that students decide to delay or avoid taking a particular subject (Collins, 1993). It has been suggested that bridging courses should be tailored towards meeting the needs of particular groups of students rather than 'aiming too wide' (Troskie-de Bruin, 1999). Measuring the subsequent effect of bridging courses on students' academic performance in mainstream studies can be difficult to do (Troskie-de Bruin, 1999). Unfortunately it is often not even attempted due to the lack of prestige and funding of bridging courses (Godden & Pegg, 1993).

In this paper, the evolution and aims of the three UWS bridging courses will be described; the profile and needs of participants will be outlined followed by the methods used to evaluate course effectiveness and the results obtained. Outcomes of the courses are discussed, similarities and differences are highlighted, and outcomes are related to the relevant literature. Future directions are discussed, particularly those aimed at better gauging the effectiveness of such courses as a means of preparing students for particular areas of tertiary mathematics study.

Numeracy for Nurses Winter Workshops

The Course and its Evolution

The Bachelor of Nursing degree program is offered at four of the university's six campuses and has an annual first-year intake of well over 600 students coming from 'diverse social and educational backgrounds' (Stewart et al., 2001, p. 209). Mathematical competency is of particular importance to nurses in order to minimise calculation errors when they calculate drug dosages for administration to patients. Knowledge of Year 10 mathematics (end of junior high school) is sufficient for these calculations (Hutton, 1998; Clarkson, 1990). However, deficits in the mathematical skills of nurses and difficulties experienced by nursing students have been reported in the literature over several decades (for example, Gillies, 2004; Hutton, 1998; Gillham & Chu, 1995).

Mathematical support has been offered to nursing students at UWS for over ten years but a more systematic approach to this support was adopted in 1999 when a collaborative 'Teaching Incentive Grant' project involving nursing lecturers and a mathematics skills lecturer was set up to improve numeracy outcomes (Nicholls & Stewart, 2000; Stewart et al., 2001). Outcomes of this project include all first-year students completing a basic numeracy diagnostic test and compulsory follow-up tutorial to help them determine if they should attend the voluntary pre-semester numeracy bridging course where they can develop the concepts and skills needed for dosage calculations.

The current *Numeracy for Nurses* winter workshop course is a ten-hour course over two consecutive days, scheduled to occur immediately prior to the initial introduction of dosage calculation and administration to first-year students. Course content has been influenced over the years by a number of factors such as teacher observations – by both nursing staff and mathematics skills lecturers – of common difficulties in dosage calculations experienced by students, skills deficits amongst nurses reported in the literature, and the reflections of staff teaching after each delivery of the course. The content includes concepts and skills considered fundamental to success in dosage calculation such as fractions, decimals and conversions between them, the metric system of measurement and unit conversions, weight and volume, mathematical problem solving skills, and estimation and checking skills. Content and activities are set in appropriate nursing contexts, where possible, providing relevance for students.

Profile of Participants

Over the last three years, attendance has more than doubled to the point where approximately one quarter of all first-year students choose to attend, indicating an

increasing awareness of the course. Participants are characterized by the following (figures in brackets are for the 2004 course):

- a high proportion of females (92% of registrations in 2004 – slightly higher than the overall 86% female enrolment in nursing at UWS)

- a high proportion of mature-age students (51% attending were at least 21 years of age; 33% were at least 26 years of age)

- a long gap since last studying mathematics (80% had had a break of more than five years; 66% – more than 10 years)

- a tendency not to have studied high levels of mathematics at school (60% had achieved the relatively low level of General Mathematics at the NSW Higher School Certificate or had not studied mathematics at HSC level at all)

- a broad range of attitudes to the mathematics needed for drug calculations, with a few students expressing fear or terror – evident in the written reflections of students sought at various points during the course.

Effectiveness of Course and Implications for the Future

The effectiveness of the course is gauged in several ways including comparison of pre- and post-test scores, feedback, both formal and informal, from participants and teaching staff, as well as feedback from nursing staff as they monitor student progress in drug calculations. Overall the evidence suggests that the course serves a valuable role in preparing students in the key mathematical skills they will require for medication calculation and administration. For the 42% of students who completed the post-test in 2004, scores ranged from 50% to 100% with a mean of 80% (s.d. 15). This suggests that by the end of the course, students had a good grasp of the concepts covered. Other indications of the extent to which the course met its goals included generally very positive comments from participants, a rating of 4.4 (standard deviation: 0.89) on a scale of 0–5 in respect of the usefulness of the course in 2004, and acknowledgement from the *Nursing Therapeutics 2* unit coordinator that, in 2003, no student failed *Nursing Therapeutics 2* because they had failed the drug calculation component of the unit.

Analysis of the 2004 course evaluations returned by 53% of participants revealed that what students valued most in the course was the opportunity to go back to basics and refresh their mathematical skills. Aspects of the course noted by students as being particularly useful included:

- fractions and decimals and conversions between them

- ‘developing understanding’, particularly in respect of what the ‘old rules’ were and ‘why they work’

- being able to put concepts into practice and seeing how mathematics is applied to nursing contexts, especially in relation to measurement concepts (for example, metric units and conversions, and weight per volume), and through doing hands-on activities involving scales, syringes and liquids

- knowing/confirming that there are ‘many ways to solve maths problems’ and that sometimes there is an easier/other way

- building/restoring confidence

- being taught by friendly, approachable teachers who gave ‘good explanations’, showed working out on the board, presented material in ways that were ‘easy to follow’, answered queries/uncertainties, and ‘let us ask silly questions’ without making us ‘feel stupid or dumb’.

Based on student feedback, the annual *Numeracy for Nurses* winter workshop course continues to be an efficient and effective strategy aimed at preparing students for the mathematical demands of dosage calculation in the B. Nursing course. However, a number of challenges remain for the future. These include questions of how to attract into the course those students who are least well-prepared, and how best to cater for large numbers of participants and the diversity of their mathematical backgrounds and needs, particularly given the limitations of available resources, the continuing requests from a significant proportion of participants for an expanded program, and the fact that four campuses are involved.

UniStep Basic Statistics

The Course and its Evolution

The *UniStep Basic Statistics* bridging course is a recent addition to the suite of bridging courses which form the university’s current enabling program called *UniStep*. The aim of *UniStep* is to ‘provide new UWS undergraduates, especially those from disadvantaged backgrounds, with opportunities to develop academic skills that will enhance their capacity to succeed in higher education’ (Parker & Nicholls, 2004, p. 1). *UniStep Basic Statistics* is a 21-hour course run over seven evening workshop sessions in February. It commenced in 2004 as a result of requests from students for a specific preparation for statistics.

When the course was initially designed, several key considerations were kept in mind when tailoring the content to the needs of students. The primary goals were to develop in students the fundamental concepts and skills they would need for the successful study of statistics, and to aid students’ transition into introductory statistics units in a range of discipline areas such as psychology, business, science, and health sciences. More specifically, the content needed to introduce students systematically to preliminary areas of statistical thinking which are often taught very quickly in mainstream statistics units. Another goal was to introduce key statistical concepts and skills in a context-rich and practical way that fostered understanding.

Profile of Participants

UniStep Basic Statistics is promoted to all newly-enrolled students and is conducted annually in February with an additional mid-year course commencing in 2005. Participants in the course have been enrolled in a variety of degrees, many of which are non-mathematical. In particular, 64% of participants for 2004 and 2005 who returned evaluations (n=70) were enrolled in an undergraduate business degree. Attendance figures of 56 and 46 respectively for 2004 and 2005 indicate that only a

very small percentage of the estimated 1500 students who enrol in mainstream statistics units each semester attend the bridging course. This raises the question of why other students who might benefit do not attend.

Course evaluations reveal students attend because they are concerned about their level of preparedness and believe that doing a bridging course may therefore be beneficial. There was little explicit mention by students of anxiety or fear of statistics in their course evaluations (see Ormond, 1997); however it was nevertheless apparent that some students were not feeling ready to face statistics without obtaining some preparation. In terms of mathematical background, about 80% of students who have attended the two courses (n=70) had completed mathematics to the end of high school, suggesting no general lack of basic mathematical knowledge amongst participants. The perception of under-preparedness may be linked to the time away from the study of maths and the associated need to regain familiarity. For example, in 2004 48% of students returning end-of-course evaluations (n=31) had not studied mathematics in the previous 2 years, while in 2005, for those returning first-day evaluations (n=39) the proportion was more than 70%. These figures also suggest a relatively high proportion of participants were non-recent school leavers. Lack of recent mathematics study may also have been a motivating factor for the 25% of students (n=70) who attended in 2004 or 2005 because they needed to refresh their statistical/mathematical knowledge.

Effectiveness of Course and Implications for the Future

Effectiveness of the course has been evaluated in various formal ways, including end of course student evaluations in 2004 and 2005, a first-day evaluation in 2005, a casual teacher's end-of-course evaluation in 2004, and an analysis of student performance on the course's final assessment task in 2005. End of course evaluations (n=31 in 2004 and n=28 in 2005) reveal that about 80% of respondents found the course was 'very helpful' or 'extremely helpful'. About 70% felt the course was 'challenging but achievable' while every participant felt the presentation of the course was 'suitable' or better. In 2005, the teaching quality was 'satisfactory', 'good' or 'excellent' for all respondents. Unfortunately, however, not all students complete the course. For example, in 2005, only 65% of participants completed the course. Anecdotal evidence suggests work commitments, transport problems and the lateness of the evening workshops cause drop-offs in attendance to occur, but better data is needed on why students discontinue.

Those students who do complete the course report that its most useful aspects have been: gaining a greater insight into and understanding of statistics, revision of the 'basics', the course study notes, learning about graphing techniques and statistical terms, learning how to use calculators for statistical calculations, understanding of statistical measures and learning how to apply formulas. Some students felt the course's main benefit was to be able to walk into their semester subject with some confidence to apply the concepts learned. In 2005, students were given a take-home final assessment on the content of the first five days of the course. An analysis of 23 assessment papers was carried out to gauge student performance and understanding. The mean score was 29 out of 35 (82%) with a standard deviation of 2.8 marks indicating a high level of student achievement and a good understanding of many of the course concepts.

In 2004, the casual teacher's observations were that the course was pitched at the right level but suggested that adding the normal distribution and z-scores to the content would be beneficial. After inclusion of these topics in 2005, about 28% of students listed standard deviation, z-scores or the normal distribution as being the most useful aspects of the course. This suggests that students value content which connects very clearly with mainstream statistics units.

The above findings suggest that the course is pitched at the right level for most students, there is a high level of satisfaction with the course, students understand and can correctly apply many of the course's basic concepts and skills, and student expectations of having their under-preparedness addressed by the course are being met. This can all be viewed as confirmation that the course content has been tailored appropriately to meet students' needs, taught and understood well, and that the course achieves its aim of improving students' skills and knowledge, although pre-testing would help to further substantiate this claim.

Some students' evaluation comments confirm that the course is meeting the goal of aiding their transition into an introductory statistics unit, although additional follow-up evaluation would more clearly determine the impact of the bridging course on student transition. In particular, retention rates in statistics subjects for bridging course participants versus a similar control group of non-participants could be studied. Also, follow-up work on why some students do not complete the bridging course would be helpful.

Given the large numbers of students who enrol in mainstream statistics units, there are probably many other students who might benefit from attending the bridging course. Work needs to be done to find out more about these students, why they do not attend and how to improve promotion methods to attract more of them into the course. Another area for further investigation is that of students who attend the bridging course after failing a mainstream statistics unit.

UniStep Maths Bridging for Engineering Students

The Course and its Evolution

For the last ten years the Learning Skills Unit has run a pre-semester bridging course in February designed to prepare students for the mathematics component of the UWS engineering degree. The assumed knowledge in mathematics for engineering has decreased over the years from a relatively high level to an intermediate level of calculus and trigonometry. However, there is no formal requirement for students to have achieved this assumed knowledge to gain a place. Also, students who have been taught this assumed knowledge may not have fully mastered it. So the course has two roles: to expose students to this assumed knowledge and secondly to provide an opportunity for greater mastery of it.

In 2004 the engineering bridging course became part of the *UniStep* program (mentioned in the previous section) and was broadened to accommodate any student enrolling in a degree with an assumed knowledge of calculus. These students now also attend the engineering bridging course. However close to 90% of the students attending continue to be engineering students.

In 2005 the bridging course was extended considerably from what was a five-day course taught only through lectures to a twelve-day course of morning lectures and afternoon tutorials. This was done to accommodate changes to the first year engineering degree program. One effect of these changes was that the bridging course needed to now include preparation in statistics as well as the usual topics of algebra, number plane and graphing, trigonometry, relations and functions, series, logarithms, and both differential and integral calculus. This expansion of the bridging course is a clear example of the tailoring of content based on consultation with relevant academic staff. Over the ten years of the bridging course, content and pacing of the course have continually been modified in response to staff and student feedback.

In general, course content is aimed at giving students a transition from secondary to tertiary mathematics. Particular emphasis is placed on content considered to be of greatest importance in the engineering course as well as content known to cause students difficulty. The course also aims to enable students to: determine their readiness for studying a mainstream mathematics unit, inform them about available mathematics assistance, and provide them with opportunities to familiarise themselves with the campus and to interact at a social level.

Profile of Participants

Between 1996 and 2005, attendance at the course has varied between 130 and 180 students. For the engineering students, this has represented approximately 30% of all first-year enrolments. Students are predominantly male and recent school leavers. For example, in 2005, 79% of those returning evaluations (n=96) had left school in the previous two years. Students' mathematical backgrounds have changed considerably over the ten years of the course. In earlier years, nearly all students had studied calculus. For example, in 1996, 52% of students (n=65) had studied substantial calculus, 46%, some calculus and 2% possibly no calculus. By 2005, only 22% of participants (n=96) had studied substantial calculus, 50% some calculus, and a very high 26% had no previous calculus knowledge (2% undetermined).

The reason for attending for two-thirds of participants is to refresh and/or improve their maths. Most of the remaining one third attends because the bridging course content teaches the assumed knowledge for their first semester mathematics unit.

Effectiveness of Course and Implications for the Future

First-day and end-of-course evaluations are used to gauge students' impressions of the effectiveness of the course. Less formal methods of evaluation include observation by teaching staff of students' performance on exercises and quizzes. There is no final test in this course; however introduction of an end-of-course on-line self-assessment is planned for future courses. In 2005, a staff survey was administered and an additional student survey was administered at the end of first semester, aimed at exploring engineering students' perceptions of the contribution of the bridging course to their progress and performance in their first semester mathematics unit.

End-of-course evaluations consistently show that students value the course. For example, in 2004 65% of students (n=62) found the course 'helpful' or 'very helpful' (on a five-point scale); the corresponding proportion in 2005 was 69% (n=58). In terms of difficulty of content, in 2004 and 2005 an average of 58% of students considered that the content was 'challenging but achievable'. The spread of opinions

on the pace of the course remained virtually unchanged over the last two years, despite the fact that in 2005 the length of the course had been more than doubled. In 2004, 50% (48% in 2005) indicated the pace was 'suitable', 28% (26%) indicated it was 'fast' or 'very fast' and 20% (24%) responded that the pace was 'slow' or 'very slow'. A further analysis relating to pace revealed that 46% of those who had not previously studied calculus found the pace to be 'fast' or 'very fast', and 33% of those who had previously studied considerable calculus found the pace to be 'slow' or 'very slow'. Thus it appears that the course is pitched roughly in the middle of the group and is appropriate for the majority of students. However in terms of suitability of the pace the broad range of responses illustrates the difficulty of meeting the needs of such a large number of participants, especially when their backgrounds and needs are so diverse. Of particular concern is whether the needs of the least prepared students are being adequately met.

Some of the greatest benefits of the course stated by students are that it provides opportunities to: review and better understand high school mathematics, experience new topics, and learn different methods of approaching problems. Other benefits include: giving students their first experience of university and how it works, learning at a more mature pace, and experience in taking lecture notes.

In May 2005, an end-of-semester questionnaire was completed by 72 students who attended the final lecture in their first-year engineering mathematics unit. It revealed that of the 43 students who did not attend the bridging course, 93% had previously studied calculus (51% substantial calculus, 42% some calculus) and 7% had not previously studied calculus. By contrast, for the 29 students who did attend the bridging course, only 69% had previously studied calculus (24% substantial calculus, 45% some calculus) and 31% had not previously studied calculus. These results suggest that the bridging course is successful in attracting students who do not have the assumed knowledge for the engineering mathematics unit. Responses from those students who attended the bridging course (n=28) indicate that 50% consider that their performance would have been worse without the bridging course, whilst the other 50% indicated that their performance would have been the same. This finding suggests that at least half the participants surveyed anticipated their marks would be higher as a direct result of attending the course.

In 2005, staff evaluations were returned by four course teachers. Staff members were generally satisfied with the course. Two major concerns emerged: the poor behaviour of a few students in lectures, and the difficulty of adequately preparing students who have no background in calculus over such a short period of time.

Discussion and Future Directions

Analysis of the three bridging courses, the participants, and how well they meet their goals reveals a number of similarities, but also some notable differences. A common theme emerging from all three bridging courses was that students – both mature-age and recent school leavers – attend because they perceive a need to gain or regain basic mathematical knowledge and skills in preparation for an upcoming unit of study. The opportunity to prepare by learning or refreshing basic knowledge was an aspect of the courses that students valued highly, suggesting that the goal of preparing students is being met. As suggested by Stewart et al. (2001) and Egea (2004), self-awareness may be an important motivator influencing students to attend a bridging course.

Students also appreciate encountering some of the content of their mainstream unit, as indicated in their feedback, and some familiarisation with targeted content may contribute to their feelings of readiness to tackle the unit, thus assisting transition.

Broad-ranging ability levels and educational backgrounds were themes common across all three groups of bridging students, reflecting a similar diversity amongst students entering Australian universities (Taylor, 1999). The need to prepare students for mathematical content in non-mathematical courses was a characteristic of both the nursing and statistics courses, as was the relatively high proportion of mature-age participants (Godden & Pegg, 1993; Taylor, 1999). By contrast, students attending the engineering bridging course included a much higher proportion of recent school leavers Differing levels of mathematical knowledge was particularly marked amongst the engineering bridging course participants. This lack of homogeneity amongst participants in the three courses poses particular challenges in the teaching and management of the courses.

The degree of success in attracting target students to the bridging courses is variable and warrants further investigation. The reasons why under-prepared students do not attend, how to alert them to their needs (Stewart et al., 2001; Egea, 2004) and encourage them to attend are questions of particular concern in relation to the statistics bridging course which currently attracts only a small percentage of target students. Possible explanations for this include the fact that it is still a relatively new course, and unlike the nursing and engineering courses, it does not have a single discipline area from which participants are drawn, making promotion more difficult. It is also likely that high attendance rates occur in both engineering and nursing because the bridging course has gained a high profile amongst School staff, and the high level of acceptance and value placed on the course by staff results in more effective promotion of it by them to students.

While the evaluation format did not specifically set out to explore the affective domain, students who expressed anxiety, fear or terror were fewer in number that might be expected, given the prevalence of negative attitudes amongst under-prepared students suggested by authors such as Egea (2004) and Ormond (1997). In many cases, students' awareness of the need to be prepared translated into feelings of concern, firstly because they perceived themselves to be inadequately prepared, and secondly because they anticipated their under-preparedness might result in them not coping with their mainstream unit. Further investigation needs to be done in this area, particularly in relation to the extent of anxiety amongst bridging course participants, and whether the most anxious students choose to attend or alternatively, whether they avoid the experience because they find it too confronting.

Fostering success and independence in learning is the underlying purpose of many mathematics support programs (Taylor, 1999; Godden & Pegg, 1993) and appears to have been achieved, to some extent at least, in each of the three bridging courses. For example, in respect of *Numeracy for Nurses*, many students clearly indicated that the bridging course had led to a growth in their knowledge, increased their confidence, and increased their ability to tackle mathematical problems. Targeting a particular group, expert knowledge of needs and careful tailoring to meet them, and continual monitoring and adjustment of courses in response to changing needs appear to be some of the key factors of student success in the bridging courses.

More research is needed to determine the extent to which students' transition to study in particular discipline areas is enhanced by attending bridging courses, and also the impact of bridging courses on student retention and failure rates. Only in respect of *Maths Bridging for Engineering Students* was any attempt made to measure the longer-term effects on students of attending the course. Ideally the evaluation process for each bridging course should similarly include follow-up after students near the end of their mainstream unit in order to determine the impact of the bridging course on their performance.

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