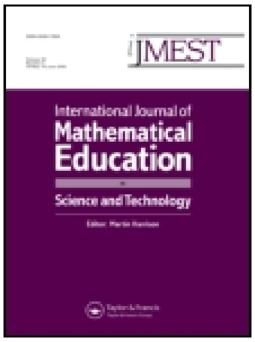

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Learning support and students studying mathematics and statistics

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Learning support in mathematics and statistics has arisen and developed in response to student needs in many universities. After discussing background to such support, this article gives a brief overview of learning support in mathematics and statistics in Australian universities as found in an Australian Learning and Teaching Council project and of the provision in Queensland University of Technology. Qualitative and quantitative data on student usage and student progression are discussed. Analysis of data for students studying mathematics and statistics contributes to growing evidence that such learning support is fulfilling needs across the range of student capabilities, including students choosing mathematics degree programs. The article closes with discussion of the contribution of learning support in the spectrum of learning in mathematics and statistics.

Keywords: learning support; numeracy; mathematics; statistics; student progression

1. Background of learning support in mathematics and statistics

There has been increasing focus over the past 15 years on the roles of numeracy, mathematics and statistics in preparation for, and student learning and achievement in, tertiary study in undergraduate courses across disciplines. The British Cockcroft Report of 1982 first popularized the term 'numeracy' giving an informal definition of:

> 'an ''at-home-ness'' with numbers and an ability to make use of the mathematical skills which enable an individual to cope with the mathematical demands of his everyday life'. [1]

Educational literature sometimes differentiates between the terms 'numeracy' and 'mathematical skill', but Cockcroft's definition brings the terms together. In particular it emphasizes that both familiarity and skills are needed to achieve applicability as well as highlighting the fact that a desired level of competence depends on the specific demands of an individual's circumstances.

In his welcome to the 2005 Association for Academic Language and Learning (AALL) Conference, Professor Malcolm Gillies, then Deputy Vice-Chancellor (Education) at the Australian National University (ANU) made an impassioned plea for greater attention to be given to numeracy at tertiary level. His point [2] was that both literacy and numeracy

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are essential capabilities for life, but, whereas shortfalls in literacy are more readily recognized at the tertiary level and are being addressed to some degree, he expressed great disquiet that there appears to be little knowledge or concern about detecting and preventing stagnation or even decline in numeracy within the mass body of tertiary students. This illustrates one aspect of the role of mathematics in tertiary study – in what could be called citizenship numeracy as a graduate capability.

Other aspects of the focus have been on the importance of mathematics to society and to the individual, both generally and for tertiary study. At the second Australian Bridging Mathematics Network conference in 1992, the then Minister for Education stated [3] that 'mathematics is probably the single most important area of study'. In 1995 [4], a lack of mathematical skills and confidence was identified as a barrier for success for many students. In the Foreword of the Report of the UK Inquiry into Post-14 Mathematics Education [5], Professor Adrian Smith states

> *Mathematics is of central importance to modern society. It provides the language and analytical tools underpinning much of our scientific and industrial research and development. Mathematical concepts, models and techniques are also key to many vital areas of the knowledge economy, including the finance and ICT industries. Mathematics is crucially important, too, for the employment opportunities and achievements of individual citizens.*

The media has tended to focus on the importance of mathematics excellence. A recent article in the New York Times [6] is typical of this. Although the lead sentence states

> *The United States is failing to develop the math skills of both girls and boys, especially among those who could excel at the highest levels*

it is the latter phrase that is the focus of the article. Much as this is welcome, it does little to spread the message that mathematics is important across the complete spectrum of development of abilities.

The comments of [3,4] referred particularly to the circumstances of the broadening of participation in tertiary study. The previous decade saw a 60% increase in the participation rate in tertiary education in Australia [7]. Increasing numbers of mature age, international, alternative entry and equity outreach students have resulted in an enormous increase in the diversity of academic preparedness, prior experience, cultures, learning styles, academic skills and expectations of what and how tertiary learning should take place [8].

There has also been much attention on school mathematics syllabi and their effects on the preparation for tertiary study, and the insufficiencies in supply of mathematics teachers. Again in his Foreword to the Report of the UK Inquiry into Post-14 Mathematics Education [5], Professor Smith highlights curricula, teacher supply and infrastructure as problems, and states

> *The Inquiry has therefore found it deeply disturbing that so many important stakeholders believe there to be a crisis in the teaching and learning of mathematics in England.*

The Australian National Statement for Mathematics was published in 1990. It was not a national syllabus but has significantly influenced curricula across all grades but particularly in grades 1–10. Its form and emphasis embody much of the philosophy and culture of school mathematics education since 1990 and hence is a guide to the driving forces at school level over the past 10–15 years in Australia and other countries. Its emphases include

- maths enjoyment and achievement for everyone;
- hands on approaches with emphasis on what is immediately practical and 'useful';

- 'real life' problem-solving and investigations involving experiments and collecting data and information;
- technology.

Problems arise in the interpretation and understanding of what is 'useful', what maths enjoyment and achievement mean across the diversity of student abilities and future learning, what 'real-life' is, and how technology opens problems to more rather than less mathematical skill and thinking. Like language, mathematical skills and thinking underpin much in other areas, and tertiary study asks for them to be accessed and used confidently and promptly in new and sometimes taxing contexts. Thus any specific mathematical skills requiring use in new contexts in tertiary study must be as familiar to a student as his or her language. It is insufficiency of this familiarity that causes much of students' difficulties. It is also not sufficiently well understood that doing mathematics develops both specific and generic problem-solving skills. Vergnaud [9] commented that psychologists know that doing maths trains the brain; the research challenge is the why and how. Wilson and MacGillivray [10] discuss how statistical reasoning depends on both introductory and intermediate components of numeracy even after other background variables had been allowed for.

Much of the focus on mathematics preparation for tertiary study has been on engineering [11] and physical sciences, but more recently other areas also such as biological sciences [12] and nursing [13]. There is increasing concern about completion rates and retention of students at tertiary level. Difficulty with mathematical skills in engineering has been cited as a major reason why students drop out of engineering degree programs [14]. Tomkinson et al. [15] say of the UK that

> *with wastage rates in science and engineering often in excess of 20%, for many of us the issue of student retention is of future viability. For others the main issue is of the human cost of so many students missing out on an opportunity.*

In the United States colleges of engineering are finding that they loose up to 50% of engineering students during the first two years [16]. In a recent major Australian report [17] on Mathematics Education for 21st century Engineering Students, which involved participation from 32 Australian universities with accredited engineering degree programs, much attention is given to the challenge of student diversity. These universities also participated in another major Australian report [18] on Assessing the Supply and Quality of Engineering Graduates for the New Century, in which the diversity of students entering the programs and the work of engineers featured strongly. In [18] attrition for male Australian engineering students is reported as 48%, and for females, 40%. Although this report includes comments such as 'proficiency in mathematics and statistics are essential and fundamental components of every engineering program', its focus is more on: the structure and curricula of engineering programs; participation in the enabling sciences of mathematics and physics at school; the engineering profession needing to attract both a greater diversity of entrants and more of the most able school leavers; differing views of mathematics across the profession; and improving awareness of engineering in primary and secondary schooling.

In light of the above it is not surprising that learning support in mathematics has become increasingly important over the past decade. Learning support in mathematics and statistics in universities is any facility or program providing extra optional assistance in mathematics and statistics for students *during* their enrolled study in a university degree program, with such assistance being outside the formally scheduled classes and activities of their enrolled course. It can encompass a number of forms, and has tended to emerge and develop in response to the needs and circumstances of different universities. Although much learning support has arisen in response to needs in programs such as engineering, science, nursing or business, students who choose to specialize in mathematics and/or statistics are as likely to access this learning support as much as non-specialists. As stated in [19], the mathematics higher education community has been well aware over the past decade of the challenges in teaching mathematics to both specialist mathematics students and non-specialist 'users'.

After reference to learning support in mathematics and statistics in Australian universities, including the results of a recent major project, this article briefly describes the learning support in mathematics and statistics provided at the Queensland University of Technology. It then considers some qualitative and quantitative data for students who make use of at least some of this support. In particular it investigates data for students who commenced study in mathematics between 2003 and 2007 and who accessed at least one form of learning support. The article briefly discusses why learning support in mathematics and statistics seems to fulfill important needs for students across capability levels and for those who choose to study mathematics/statistics degree programs.

2. Learning support in mathematics and statistics in Australia

2.1. *The Australian Learning and Teaching Council Project*

During 2007, as part of a project funded by the Australian Learning and Teaching Council's (ALTC) Leadership for Excellence in Learning and Teaching Program, the nature and extent of learning support in mathematics and statistics (MSLS) in Australian universities was investigated. The title of the project was *Quantitative diversity: disciplinary and cross-disciplinary mathematics and statistics support in Australian universities*. The report of the full project is available on the ALTC website at http://www.altc.edu.au/carrick/go/home/grants/pid/343. A Guide [20] for the university sector was also produced as part of the project. This is available in booklet form from the author and can also be found on the ALTC website. A national Symposium was held, and Australian and many UK web-based resources for learning support were audited and catalogued. The Symposium report and the catalogue of resources with links and comments are available at http://silmaril.math.sci.qut.edu.au/carrick/. Support for the original work was provided by The Australian Learning and Teaching Council, an initiative of the Australian Government Department of Education, Employment and Workplace Relations.

The aim of the project was to develop national capacity and collaboration in cross-disciplinary mathematics and statistics learning support, to enhance student learning and confidence. The approach and methodology of the project consisted of phases of discovery, collection and collation of information, a national Symposium, dissemination to direct stakeholders, establishment of a website, auditing resources and analysis and synthesis of findings to produce the Guide. The information gathered during the course of the project was obtained by a combination of research, searches, surveys, phone discussions and direct input from delegates to the 2007 national Symposium.

The next section provides a brief overview of learning support in mathematics and statistics in Australia. Fuller and more detailed information, discussion and recommendations are available in the Guide.

2.2. *Some background*

In 1965 the Australian National University (ANU) established the Communication and Study Skills Unit (CSSU) in the University's Counselling Services, and in 1973 the first Counsellor in Mathematics was appointed to this unit. This counsellor reported through the Director of the CSSU and the Director of Counselling to the Dean of Students. The duties of the Counsellor in Mathematics were to provide assistance to any ANU students whose lack of confidence and/or skills in mathematics were causing them difficulties in their university course. The Counsellor was under instructions to refer students with specific queries about assessment tasks in mathematics and statistics back to their lecturers and tutors. Diagnostic tests to assist in evaluating students' areas of weakness were developed, as were resources and workshops on topics of common need.

In 1984, Mathematics Learning Centres were established at the University of Sydney (USyd) and Central Queensland University (CQU). The USyd Centre was initially funded by, and reported directly to, the Vice-Chancellor. The CQU Centre was established as part of the Division of Teaching and Learning Services.

In the past 15 years, in almost every university in Australia, at least some form of learning support in mathematics and statistics has been set up, and in 2007 when this project was mostly conducted, 32 of Australia's 39 universities had at least some form of support. In some universities, the support is associated with a central service, in others it is provided by a mathematics/statistics department, and in others by a combination.

In 2004, it was reported [21] in an update to the 2001 investigation reported in [22], that from a survey of 106 UK universities, 66 (62.3%) offer some form of learning support in mathematics over and above that given by tutorials, personal tutor groups and problem classes. This support ranges from second or third year undergraduates offering drop-in support for first years at specified times to fully staffed and resourced Learning Support Centres. The Mathematics Education Centre of Loughborough University [23] provides a leading example of what can be accomplished by high-level strategic commitment to university-wide support.

Almost all sources of information from learning support facilities in Australia report increasing demand and increasing pressures on them. Such support may include any or all of:

- drop-in assistance
- sessions or classes on specific topics or supporting specific subjects or courses
- appointments for 1-1 assistance
- support facilities in paper or electronic form
- diagnostic testing with associated support assistance on specific topics
- designated space for support
- enabling or remedial programs
- support for postgraduates
- programs with no associated credit towards the student's course
- professional development for support staff
- programs of relevant research or scholarship, sometimes involving collection and analysis of data on students backgrounds and progression.

Bridging programs in mathematics are preparatory programs to enable a prospective student to obtain prerequisite or assumed knowledge in mathematics *before* commencing their degree program. Initially, bridging programs in mathematics commenced in response to policies increasing access to higher education, and the Australian Bridging Mathematics

Network was established in 1991 to provide a support group for those teaching into bridging mathematics. Much of the focus of the BMN was increasingly on preparatory and bridging programs for mature age students. For example, in 2005 the BMN joined with the Australian Council for Adult Literacy in the 12th International Conference of Adults Learning Mathematics (ALM). ALM is an international research forum bringing together researchers and practitioners in adult mathematics/numeracy teaching and learning in order to promote the learning of mathematics by adults. ALM has become a Company and has also obtained the status of a National and Overseas Worldwide Charity by English and Welsh Law, UK, since the beginning of the year 2000.

Papers on learning support in mathematics and statistics can appear at many different conferences. In the past decade, the conference in Australia's region with probably the most delegates with at least some interest in learning support in mathematics and statistics has been Delta, the Southern Hemisphere Symposium on Teaching Undergraduate Mathematics and Statistics. Delta is a biennial conference specifically on the teaching and learning of mathematics at university level. It is therefore similar to the UK's CETL-MSOR conferences. Delta started in 1997 and statistics was included in the titles from 2003. Delta is a community rather than an organization, and there is no formal society. There is an international committee and the convener of each symposium forms a local organizing committee. The name, Delta, came from the concept of change in university mathematics.

2.3. *A snapshot of learning support in mathematics and statistics in Australian universities*

At the time of the investigation in 2007, it was found that 32 of Australia's 39 universities had at least some form of learning support in mathematics and statistics, referred to here as MSLS facilities. For a variety of reasons, seven universities had two MSLS facilities. For example, one university had a different facility on each of two campuses. This is different to facilities with nodes on a number of campuses; these are treated as a single facility, even if there may be some campus-specific differences in services. Three universities had separate facilities for undergraduate and postgraduate MSLS, but in two of these, both facilities were located in mathematics and/or statistics departments. Another two universities had two facilities that developed in response to a range of student needs, and that liaise with each other. Only one university had two MSLS facilities that appeared to be unaware of each other before the project.

In all aspects of the investigation, there appeared to be no pattern with the type of MSLS facilities and services, and type of university. Of the 32 universities, 13 had MSLS facilities based in central services, 14 had MSLS facilities based in mathematics/statistics departments and 5 had both. However, one of the centrally-based facilities was funded by the mathematics department, and half of the mathematics-based facilities were funded by central, combination or special enabling funding. Three of the universities with centrally-based, centrally-funded MSLS facilities did not have a mathematics/statistics department.

The most commonly-offered type of assistance was drop-in, followed by support sessions specific to programs, subjects or courses. Workshops on specific topics and individual appointments were offered by just over one-third of facilities, and a small number offered small group appointments or sessions.

The most common discipline of users of MSLS services was Engineering, followed by Business and Science and then Nursing. Information Technology, Education, Health, Psychology and Arts were all represented. Mathematics was represented as much as

Nursing, but it was not always clear whether a distinction was being made between students doing a Mathematics degree program and students taking mathematics subjects/courses within another degree program or as electives.

The most common disciplines of users are no surprise to those involved with MSLS. Many MSLS facilities are providing lifelines for students in areas with the greatest problems and inner conflicts in perceptions of the roles of mathematics both directly and indirectly in their disciplines. Engineering, Business and Science are all highly dependent both directly and indirectly on mathematical skills and confidence, and these areas have been notable in their reduction of entry requirements and, more importantly, reduction of time in their programs given to developing their students' mathematical skills and confidence. As in the UK and reported in [19,21–23], many MSLS facilities have developed and/or grown because of the needs of engineering students with weaker mathematics backgrounds than in previous generations and in degree programs with less time given to developing mathematics. Also as in the UK, nursing is an area with highly diverse quantitative backgrounds amongst the students but with strict requirements for good skills and familiarity in a very specific area of mathematics, namely dosage calculations.

Aims given by MSLS facilities included:

> To assist first and second year students taking mathematics and statistics and to consolidate their learning in these areas in a 1-to-1 informal setting.
>
> To provide students with the opportunity to seek 1-1 assistance on difficulties that they may have in understanding the content of their lectures or in solving set problems.
>
> To provide a comprehensive range of academic support programs in mathematics and statistics for eligible undergraduate students to address the development of their learning in mathematics and statistics.
>
> To support and enhance the learning experience of students of mathematics and statistics at the University of . . . in achieving their goals.
>
> To develop and provide university-wide learning support for students in any area for which numeracy, mathematical and/or statistical confidence are needed.
>
> To contribute to the learning of mathematics by the provision of support, the creation of opportunities and the undertaking of research to increase positive outcomes in student learning.

Although aims such as the above were often couched in more formal terms than those reported in [22], comments made in surveys or discussions were similar to those of [22] in reflecting the importance of an informal, supportive, non-judgmental environment.

The number of courses/subjects serviced by the facilities varied from 2 to 50. The number of hours of drop-in assistance offered per week varied from 5 to 45. The five universities with facilities offering more than 30 h per week of drop-in assistance were three of Australia's oldest universities, another capital city university and a regional university.

The use of diagnostic testing is not extensive, but if it is used, its aim is to help students identify aspects which they might be advised to consolidate or strengthen. Few MSLS facilities make use of collective results of diagnostic testing in data analysis or research. Qualitative data in the form of solicited or unsolicited student feedback tend to be available, but the quantitative data that are collected and collated tend to be on usage. Only one or two facilities reported more extensive collection and analysis of quantitative data to investigate matters such as student performance and retention. The general reaction to questions or suggestions on the collection and analysis of more extensive quantitative data was that there were insufficient resources and first priority for any new resources had to be student support.

2.4. *The Queensland University of Technology Mathematics Access Centre*

The Queensland University of Technology Mathematics Access Centre (QUTMAC) arose from a project that was established with the support of a university Learning and Teaching Development Grant. The original aim of the grant project was to develop and provide learning support for first year engineering students in mathematics, with extension to other first year mathematics courses where possible. The Grant enabled the development and evaluation of strategies for support sessions and assessment preparation workshops for first year engineering students, and extensions to provide a drop-in centre for general assistance in mathematics courses, support sessions for other first year mathematics and then statistics courses and to develop diagnostic tests and databases and data analysis. Based on the outcomes of the grant project, the QUTMAC commenced operation in 2002. Its aim is to develop and provide university-wide learning support for students in any area for which numeracy, mathematical and/or statistical confidence are needed. With a modest annual budget and extensive in-kind support from the School of Mathematical Sciences, the Centre has provided assistance for approximately 1000 students per year in more than 20 courses. Data analysis such as reported in [24,25] has demonstrated benefits to the students choosing to access this assistance.

General support for undergraduate students consists of collaborative student work-rooms with wireless facilities and drop-in assistance; student-driven support sessions for a range of specific first and second year courses across disciplines; paper and web-based resources; and special assessment-preparation workshops for some areas. Support sessions are course-specific optional sessions that may be on specific topics, or may start on specific questions and then range freely as desired by the participants, or may be completely student-driven. Worksheets covering many topics have been developed for science and engineering, networking in IT and clinical practice in Nursing. These worksheets have been designed to supplement the extensive resources such as those developed in the UK and available at http://www.sigma-cetl.ac.uk/ and are designed to provide students with help in filling in 'holes' or consolidating understanding and confidence in a wide range of necessary basic mathematical topics and skills.

The QUTMAC has designed, conducted and analysed diagnostic tests for first year engineering students, for nursing students and has assisted with diagnostic tests for other first year courses in mathematics and statistics. Diagnostic tests are voluntary and students receive their individual results. The QUTMAC collaborates with staff in mathematics and in other disciplines to devise strategies and diagnostics to help students identify their areas of weakness or low confidence and to plan support sessions and resources to address these. Special projects of this type have been carried out in IT, Nursing and Electrical Engineering, with significant success in improving students' confidence and results. As reported for universities in general in Section 2.3, data tend to be in the form of student feedback and usage, with quantitative data on student performance and progression requiring considerable resources in terms of staff time and collaboration with other disciplines. When possible, such quantitative data are collected and analysed; an example for Nursing students is given in Section 3.2.

A scheme was commenced in 2004 of selecting and mentoring volunteer drop-in duty tutors from talented mathematics/statistics undergraduates or postgraduates with the potential and desire to train as tutors. It has proved to be an excellent way of providing and overseeing peer assistance as part of the QUTMAC programs, and of assisting in the development of communication skills in mathematics and statistics. It provides a foundation for the subsequent tutor training and practice which now extends over two days. A number of sessional tutors continue as volunteer drop-in duty tutors because they find it valuable in informing their tutoring work, as well as personally enriching.

Since 2006, a series of symposia in Statistical Thinking, Data Investigations and Statistical Analysis has been conducted for postgraduates across all disciplines, with an accompanying statistical thinking diagnostic questionnaire. The questionnaire aimed to combine interest with self-assessment on foundational statistical methods and thinking oriented to use in research investigations. The objectives of the symposia are to help postgraduates learn more about their statistical thinking; planning a statistics-friendly data investigation; turning research questions into statistical questions; and choosing, using and interpreting statistical procedures. Across 2006 and 2007, over 200 research students and staff from all faculties registered.

3. Data on student progress and learning support in mathematics and statistics at QUT

3.1. *Qualitative data*

Students are asked to provide written feedback on the QUTMAC programs. Very few negative comments are received, and are mostly requesting more and/or different times for support sessions or drop-in duty hours. The positive comments tend to be similar over time and student programs. Some are included here (verbatim) to capture the main messages

I have avoided this stuff for the last 20 years, but it really is easy and fun.

The MAC sessions have been excellent and have improved my understanding and my marks.

I arrived being 'scared of numbers' and left the session feeling empowered.

Helpful staff very approachable worth coming to

excellent support provided, used this service regularly.

MAC sessions are great. It really helps a lot. Really helps clear things out.

Help sessions were run in a democratic manner.

Another fantastic maths lecturer. His brutal honesty and light humour makes the subject a bit easier to deal with.

Willing to help the student. Whenever the student approched showed a positive attitude to help them. Make sure that the students understand. Very patience. Really knows what the students need. His teaching method also enhance the understanding of the students.

very friendly & approachable.

MAC SESSIONS are extremely VITAL to success.

The above student comments illustrate the key aspects of MSLS valued and perceived of value by students, namely

- helping their achievement;
- improving their confidence and comfort;
- providing supportive, positive, informal environments.

3.2. *Some quantitative data for engineering and nursing students*

The QUTMAC endeavours to collect quantitative data and maintain a database of usage of services, and when resources permit, analyse these and data on student performance and progression. Data on visits to the drop-in room are through students signing in and out by course and time but anonymously. Data on assistance given to students in the drop-in room are provided by duty tutor records, in which they are asked to record course and general topic of enquiry. Data on attendance at support sessions and exam/test workshops are obtained by the staff member conducting the session, by means of students voluntarily recording their names and date of participation. Hence because all records are voluntary, they tend to underestimate usage. Also, because support sessions are informal and friendly and sometimes lively, staff often forget to keep a roll; this includes the Director of the QUTMAC (the author), to the annoyance of the keeper of the database. However this collection of data and maintenance of a database is invaluable, as illustrated by the following examples.

The number of visits to the drop-in room over each semester in 2007 was between 500 and 600, with average time spent in the room between 80 and 90 min. The number of episodes of assistance provided by the duty tutors was between 300 and 400, with requests for assistance coming from between 20 and 30 different courses.

In the Nursing degree program, a diagnostic test has been developed in collaboration with Nursing staff and administered in the first Clinical Practice course in which dosage calculation learning starts. The support sessions for this course are in the form of specific topic workshops, facilitating student choice of attendance. In 2006, a specifically-designed follow-up test was administered later in the semester, after both the workshops and work in the course. In a class in which 217 students took the first diagnostic test, 30 scored less than 50% on the test and 77 less than 67%. Thirty students chose to attend at least one of the workshops. In the follow-up test, the increase in score for these students was just over 20% (and statistically significant), while the increase in score for those not attending the workshops (many of whom had no need to) was approximately 2% and not statistically significant.

Engineering students in first year at QUT are streamed according to their mathematics background being core algebra and calculus from school level, or core + advanced. Support sessions and exam/test workshops are very popular with engineering students, and indeed, these were the original focus of the Maths Access Centre under its original university grant. In 2004–2005, approximately 25% of both streams attended at least one support session. In 2006, this was 20% for the cohort with the lesser maths preparation, but 50% for the cohort with the core + advanced background. This worrying information was an incentive for increased publicity. In semester 1 of 2007, approximately one-third of both cohorts attended at least one support session, and in semester 2 of 2007, this was approximately 50% of both cohorts. The participation in at least one of the exam/test preparation workshops had been fairly consistent over 2004–2006 at approximately 50% for both cohorts; in 2007 it was approximately 33% for the cohort with the lesser maths background, and 45% for the cohort with the core + advanced background. It is of interest to consider if the increase in attendance at weekly support sessions resulted in students' feeling less need to attend exam/test workshops.

It is generally easier to track students in professional degree programs such as engineering than degree programs in mathematics and statistics themselves. Research reported in [24] for the 2002 entry cohort showed not only that students who attended at least some of support sessions and/or exam/test workshops had significantly higher overall marks in the course, but that for the cohort with the lesser maths background the number of sessions attended was statistically significant and the size of the beneficial effect of the core + advanced school background extended into the following semester and was both significant and considerable. Analysis of data over 2004–2005 showed this effect to be increasing, leading to curriculum design changes. Research reported in [25] investigated completion and attrition amongst engineering students, and included finding that students who use the QUTMAC either in the support sessions or the exam workshops are nearly twice as likely to complete the course as the whole cohort and half as likely to discontinue engineering. Again it was found that students with the better maths background of core + advanced were more likely to make use of the QUTMAC.

It is important to emphasize that because MSLS programs are voluntary, the students self-select. That is they made an effort to use available services to fill gaps, consolidate skills and improve confidence. Such students are more likely to complete the course than those who had gaps and could not see them and/or did not bother to use the resources that were available to them.

However it is of interest that the QUTMAC data over a number of years shows consistent findings with those of [26] – that engineering students across all capabilities and backgrounds use MSLS services, desiring to improve their skills and confidence and achievement.

3.3. *Learning support, performance and progression for students in mathematics and statistics*

There is increasing attention in higher education on transition, first year experience, attrition, learning spaces and group learning strategies. As in [27], mathematics/statistics students at QUT had also 'colonized' the original Maths Access Centre physical space so that by 2006, a students' workroom was created as a separate space to the drop-in room and the room where support sessions are held. Mathematics and statistics students have always, as was intended, used the drop-in services, but they also quickly requested course-specific support sessions and in some courses, exam/test workshops 'like the engineering students'. Course-specific support sessions have been provided in core mathematics and statistics courses since 2002. In other mathematics degree courses and for exam/test workshops, arrangements are discussed and made with each cohort.

For this section, data have been researched and analysed for students commencing the first year mathematics and statistics courses of QUT's mathematics degree programs between 2003 and 2007. These programs are the BMaths and a number of double degree programs with the BMaths. The topics of interest relate to comparisons between students who had been recorded as using at least 1 h of QUTMAC support sessions, or exam/test workshops if these had been provided, and students never recorded as such.

The figures over show the 95% confidence intervals for the means of the final results in each course in each year that has records sufficient for such presentation, for the students who are recorded as having participated in at least one QUTMAC support session in that course (upper interval of each pair of intervals), and for the students who did not chose to participate in any support session (lower interval of each pair). Students entering with just a core mathematics background start with the first mathematics course, while those with core + advanced start with the second mathematics course. All courses shown are first year courses except for the second year linear algebra course. Students other than those in mathematics degree programs take these courses, particularly the first mathematics course and the first statistics course.

The widths of the intervals depend on both variability within the group and on numbers in the group, with higher numbers decreasing the width of the interval. Hence the statistics course tends to have the narrowest intervals. However in many cases, the widths of the intervals, particularly the upper ones for students who have attended at least one support session, are due to the diversity of capabilities amongst students who choose to use MSLS services (Figures 1–6).

In every case, the mean overall mark is greater for those who have attended at least one session. In some years the difference is very great while in others it is not, reflecting the variability from cohort to cohort in students who choose to attend support sessions. The differences are most marked in the first statistics course, likely reflecting both the larger numbers in that class and that, in a first statistics course, commitment to doing the work is a great precursor of success. As usual, the trap of inferring causality needs to be avoided because participation in MSLS is a voluntary, optional 'extra'. However, it is clear that there are students in the 'mainstream' mathematics and statistics courses with a diversity of capabilities for whom MSLS is meeting a need.

Attention was then turned to data for the students who enrolled in either the first or the second mathematics courses above in 2004–2007 and who were also officially enrolled in a mathematics degree program in that period. For these students, the data on attendance at support sessions in their mathematics/statistics courses showed that of these students who had attended at least one support session, 61% had done so in just one course, 23% had done so in two courses, 12% had done so in three courses and 2% had done so in each of four and five courses. Figure 7 shows the average number of sessions (each session is an hour) attended per course per student.

The progression of the students who enrolled in either the first or the second mathematics courses above in 2004–2007 and who were also officially enrolled in a mathematics degree program in that period, was then considered. The students were classified at the end of the period as: still enrolled or completed a mathematics degree (Maths); enrolled or completed another degree in QUT (Other); or discontinued study at QUT (Discontin). Students often change between types of degree programs in

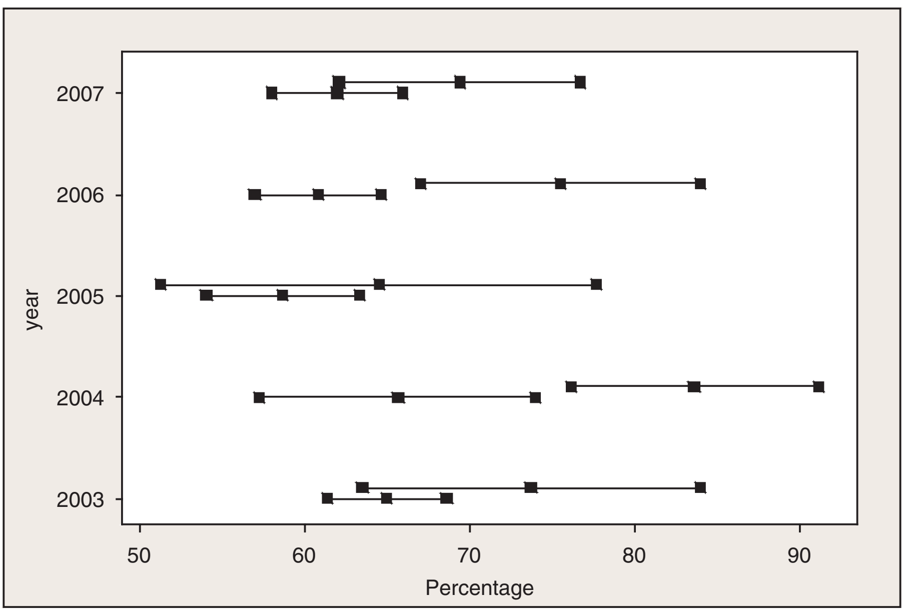

Figure 1. Confidence intervals for mean result in first mathematics course by year, with upper interval in each year for those who attended at least one support session, and lower for those who attended none.

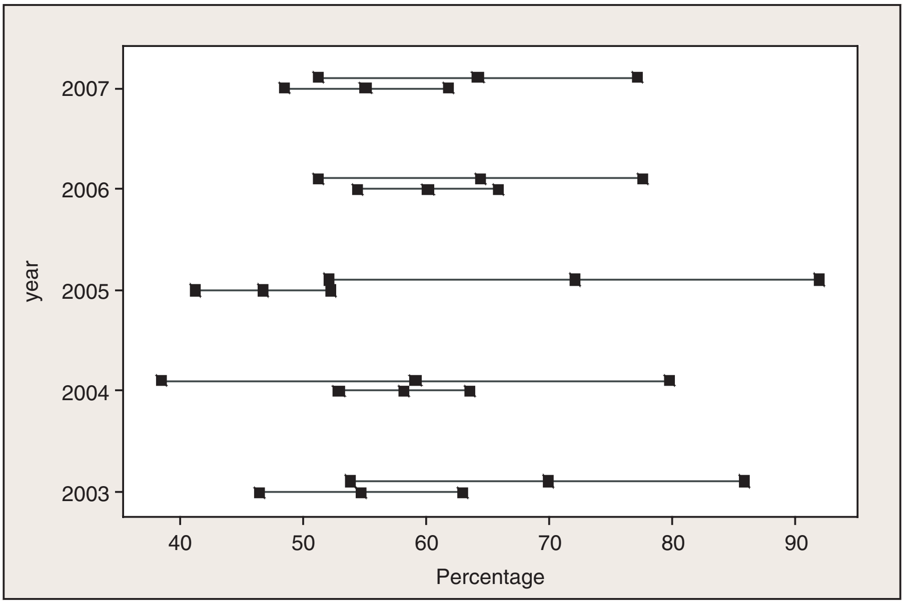

Figure 2. Confidence intervals for mean result in second mathematics course by year, with upper interval in each year for those who attended at least one support session, and lower for those who attended none.

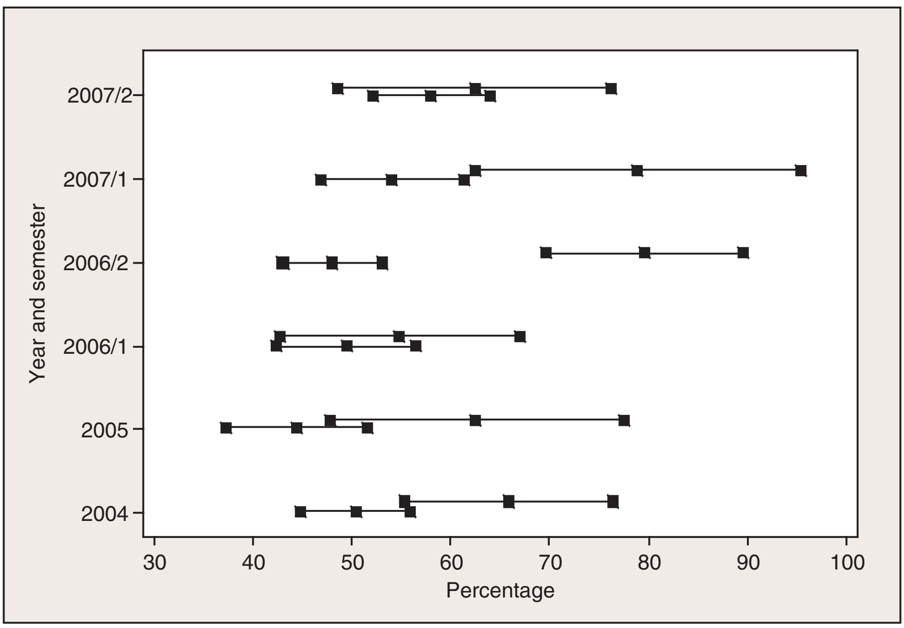

Figure 3. Confidence intervals for mean result in third mathematics course by year and semester where applicable, with upper interval in each pair for those who attended at least one support session, and lower for those who attended none.

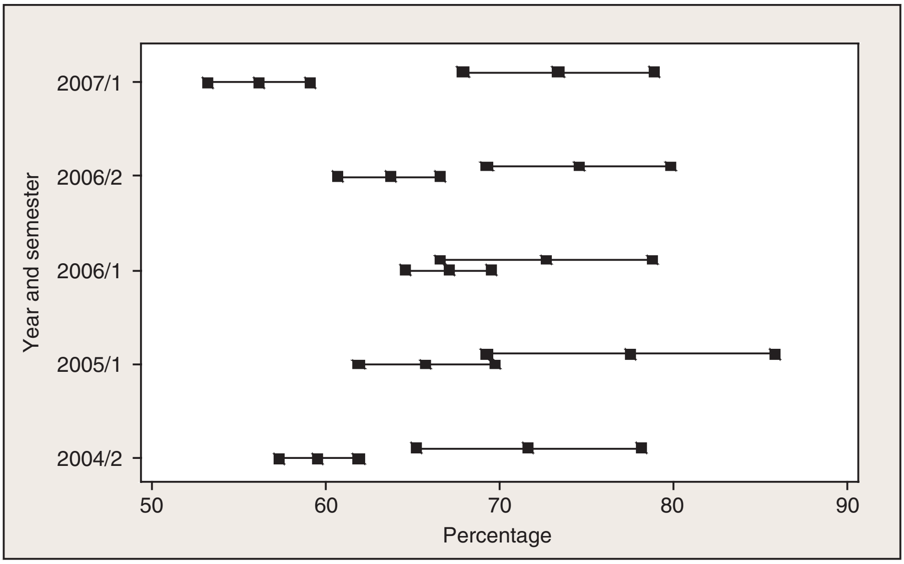

Figure 4. Confidence intervals for mean result in first statistics course by year and semester where applicable, with upper interval in each pair for those who attended at least one support session, and lower for those who attended none.

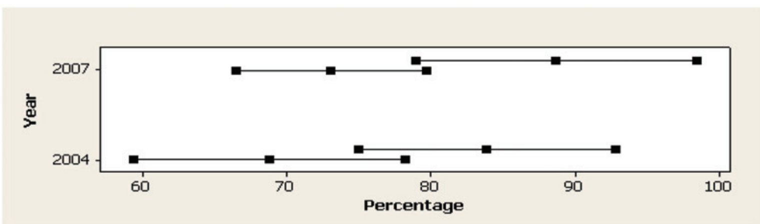

Figure 5. Confidence intervals for mean result in first computational mathematics course by year, with upper interval in each pair for those who attended at least one support session, and lower for those who attended none.

mathematics, particularly between double and single degree programs. These programs are all classified as Maths and care was taken to ensure the data are per student not per enrolment. Table 1 shows the percentages of those who ever attended at least one support session in any mathematics/statistics course (Attend) and of those who did not (Not attend), in each of these three categories. The association between ever attending at least one support session and progression classification is highly statistically significant (p for chi-square $= 0.000$).

A 95% confidence interval for the difference between Grade Point Averages (GPA) between the two groups at the completion of the period or completion of degree, is (0.4, 1.05) which is statistically significant with a p-value of 0.000.

As stated above, and as with the engineering students, causality cannot be inferred. As stated in [23], cause and effect are difficult to establish. However it is again clear that the support sessions are fulfilling a need for many students in mathematics/statistics degree programs across capability levels. There is also strong association between even minimal

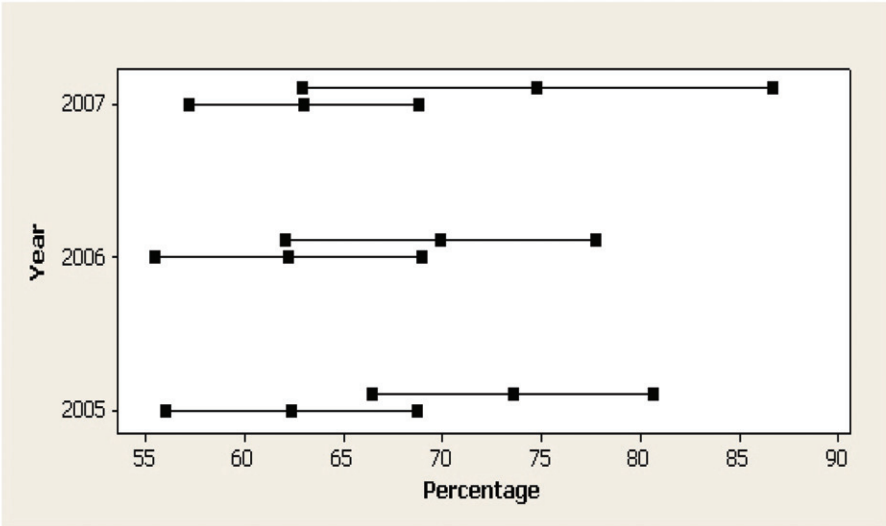

Figure 6. Confidence intervals for mean result in second level linear algebra course by year, with upper interval in each pair for those who attended at least one support session, and lower for those who attended none.

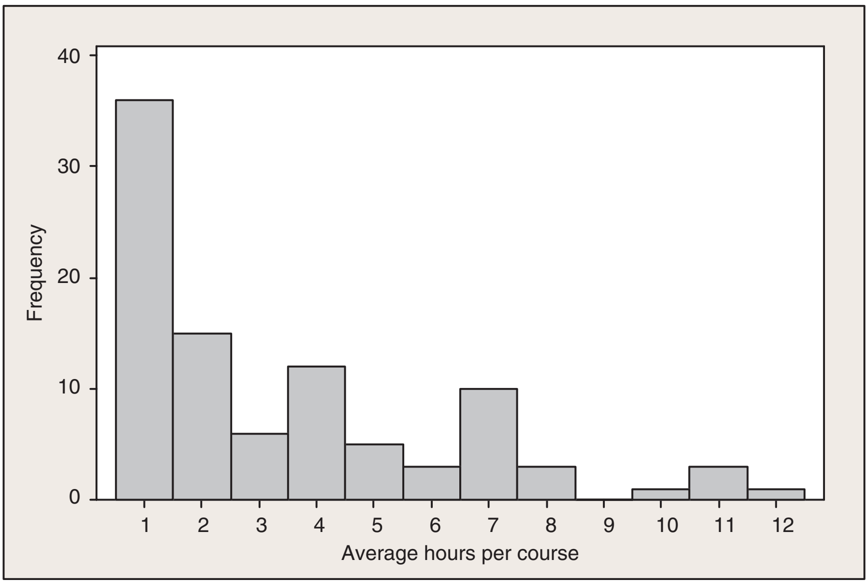

Figure 7. Average number of hours of support sessions attended per student per course.

Table 1. Percentages of MSLS users and non-users in progression categories.

	Discontin. (%)	Maths (%)	Other (%)
Attend	10.5	77	12.5
Not attend	30	52	18
All	24.5	59	16.5

usage of MSLS and progression in mathematics/statistics programs. Records of courses in which assistance is provided in the drop-in room are also consistent with this, indicating that MSLS facilities in general are fulfilling a need of students in mathematics/statistics degree programs.

4. Discussion

The mathematics higher education community is well aware that those students who take advantage of learning support in mathematics and statistics range over all levels of abilities in mathematics. Data previously and recently published demonstrate this for engineering students, and the above demonstrates this also for students choosing to study mathematics/statistics. Indeed, the above data indicate that the range of capabilities amongst the latter group for whom MSLS is fulfilling a need is wider than amongst engineering students.

Mathematics is a natural human activity, as fundamental and important as language. And, similar to physical fitness, mathematical fitness is a prerequisite for the achievement of skills and confidence in specific fields of endeavour. Modern sport science is very aware of the importance of general physical fitness in enabling the development of talent in specific sports. It is the lack of awareness of the parallels with mathematical fitness underpinning academic development across many disciplines that has significantly increased the importance of learning support over the past one to two decades.

The provision and practicalities of learning support are as complex and subtle as are the mathematical needs to be met. Like language and physical fitness, mathematical skills and confidence need time to develop, they need to become a part of the person and they need maintenance. Whether we are considering mathematics or statistics majors, engineering, business or nursing students, learning support in mathematics and statistics is part of a multifaceted composite of contributions to students' progress, achievement and retention in university programs. Sound tools to enable students to identify their weaknesses are important components of this learning support. An essential aspect of research in learning support is measurement of its effects on student progress, but the demands of data collection and analysis required for such research are often submerged by the day-to-day demands of servicing needs.

An important point is that the type of student work that is used in the data analysis of this article is best described as individual work within a collegial, supportive environment where the collegiality is both with peers and with staff. As discussed in [27], social learning spaces are of great importance to mathematics students, but this is another contribution in addition to the actual MSLS support to individuals. The collegiality with staff is also mentioned in [27]. What is important is that an integrated balanced combination of all strategies is provided. All components, from lectures, whose role is discussed in [28], tutorials, practicals, materials, assessment, collegiality with staff and peers, learning spaces and MSLS, play their part.

Key challenges for MSLS are similar to those for all providers of teaching in mathematics and statistics in higher education, whether as disciplines in themselves or within contexts of other disciplines. Mathematical and statistical skills, both specific and generic, are acquired through *doing* mathematics and statistics. In mathematics and statistics, passive learning is in actuality no learning. A significant component of the power of mathematics and statistics is transferability. For students in other disciplines this is chiefly transfer of skills and tools into new contexts. For students in mathematics and statistics themselves, this is the essence of problem-solving and developing further problem-tackling techniques. Learning support contributes to the overall fabric of mathematical and statistical learning through helping students become more mathematically fit to continue and progress in their university program of study.

Hence it is not surprising that learning support in mathematics and statistics is as important for students majoring in these disciplines as it is for those needing quantitative skills for others. Nor that the pedagogies, scholarship and research of such support are, and must be, part of those for the learning and teaching of mathematics and statistics.

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