

Students' mathematical preparation Part A: Lecturers' perceptions

LINDA GALLIGAN^a, ANDREW WANDEL^b, ROBYN PIGOZZO^c, ANITA FREDERIKS^{d*}, CLARE ROBINSON^c, SHAHAB ABDULLA^c, TIM DALBY^c

^a*School of Agricultural, Computational and Environmental Sciences*, ^b*School of Mechanical and Electrical Engineering*, ^c*Open Access College*, ^d*Learning and Teaching Support, University of Southern Queensland, Toowoomba, Australia*

*Corresponding author: anita.frederiks.usq.edu.au

This paper analyses first year lecturers' perceptions of mathematics topics and skills needed in the respective courses that they teach and their perceptions of students' preparedness for these topics. Surveys and interviews with lecturers were conducted at a regional university in Australia and showed many lecturers regarded that little mathematics was needed in their courses and that mathematics was compartmentalised into specific courses. However, when mathematics was evidenced, lecturers often perceived their students having poor skills and some have adjusted their courses accordingly.

Keywords: tertiary mathematics education; mathematical under-preparedness; diversity of student population

1. Introduction

The last fifteen years has seen Australian universities' student population become more diverse than ever before [1]. The federal government's acceptance of the Bradley Review [2] and the resulting policy changes including uncapped places and more graduates from low socio-economic areas is heightening this diversity. As a consequence, difficulties in addressing this diversity are being faced by students, lecturers and university policy designers [3]. This diversity covers not just cultural or socio-economic diversity but also academic background, experiences, and views [1].

The situation is compounded by multiple entry pathways into first year. For example students may enter directly from school, from Technical and Further Education (TAFE), complete a preparatory program for Australian students, or an English language program for international students. Many students may also have a considerable time gap between finishing school and beginning university. Some of these gain entry with dated qualifications, and enter on their prior experience. For each pathway there are issues around the level and coverage of academic skills required.

Of particular interest to this study is students' preparation in mathematics and statistics, because a smooth transition to tertiary education can be hindered by an unsatisfactory mathematical background. This lack of preparation is evident in quantitative programs such as engineering and science [4-7] but also other programs such as business and education [8-10]. It has been argued that all students need to have some level of numeracy to be successful at university [11, 12].

At the University of Southern Queensland (USQ) the majority of students are not recent school leavers (median age 28 years) [13] and many are from a low socio-economic status background. In 1997, a USQ study found that the mathematics knowledge expected by lecturers did not always match quantitative aspects of the course material ("course" being one quarter of a full-time load in one semester), degree program "recommendations" or "assumed knowledge" [14]. This current study replicates the previous study completed 16 years ago and

extends it to include the students' perspective of their mathematical background. There were three aims in this project. The first aim was to determine lecturers' perceptions of students' mathematical preparedness. The second aim was to examine first year students' perception of their mathematical preparedness for tertiary study. The final aim was to discover lecturers' perceptions of the mathematical topics needed for study in their respective first year courses. This information was obtained by student and staff questionnaires and interviews. This paper (Part A) will report on the first and last aim. A companion paper (Part B) reports on the student perspective.

The outcomes of this study will assist planning in all programs, particularly in the enabling programs, first year mathematics service courses, and academic learning support retention and progression.

2. Literature Review

This section provides a background to the paper discussing the nature of student diversity, mathematics diversity at university, and responses to this diversity from universities.

2.1. Diversity of students

Students entering university present with a diversity of academic abilities [15] as well as expectations and experience [1]. Many students also manage study with other commitments such as paid work and family obligations [16]. This diversity has been recognised as an issue in Australia with the commission of a series of reports from 1994 [1]. Students also have a variety of mathematical preparation which can result in a range of academic issues that universities and students need to address. For example, should universities provide free support to underprepared students that they have accepted via multiple entry pathways? What starting point in mathematics is suitable in a university undergraduate degree? To address this diversity there is a range of support and preparation that can be given to students from one-on-one to embedded support in courses or programs [12].

Diversity and university preparation issues were highlighted in the Australian university transition reports. In the 2009 report [1], while it was found that about half the respondents felt that school prepared them well for university:

This was not the case for students from rural areas and those from lower socioeconomic backgrounds. There continues to be a disparity in the level of university preparedness of students from certain demographic subgroups. Enhancing the quality of targeted pre-enrolment support and information continues to be a challenge for universities. [p. 33]

These concerns are prevalent in a range of subject areas but mentioned particularly are students' abilities to write and perform mathematics [17, 18].

2.2. Diversity of necessary mathematics

Research into the mathematics needed in university is critically under-researched [19, 20], despite a need for numeracy as an explicit graduate skill. The seven generic capabilities that appear common in higher education [21] do have some reference to numeracy. This is sometimes specifically highlighted at individual universities. For example Murdoch University has numeracy as an explicit sub-section of Communication Skills in their Graduate Attributes [22] and is part of their Foundation program. James Cook University [23] has developed a Post-Entry Numeracy Assessments (PENAs) with follow-up support for people with identified numeracy needs. A report from the University of Tasmania recommended in 2010 that "numeracy be included as a graduate attribute by explicit

incorporation within one of the existing UTAS graduate attributes or academic standards” [11], but currently only has “numerical and graphic communication” under their communication section. In response, a call has been made for a national approach “in cross-disciplinary mathematics and statistics learning support to enhance student learning and confidence” (p. i). [24]

Currently, each discipline at university has its own mathematics prerequisites, culture, expectations and characteristics. There appears to be little debate that basic mathematics such as fractions, decimals, percentages, data representation, analysis, and interpretation is needed across all disciplines [25]. For anything more, there is some debate around the level of mathematics needed. In a recent Wall St Journal article it was argued that “For many young people who aspire to be scientists, the great bugbear is mathematics. Without advanced math, how can you do serious work in the sciences? Many of the most successful scientists in the world today are mathematically no more than semiliterate.” [26] Along a similar vein, some in the engineering profession argued that: “their courses did not reflect what the workplace required and this was an issue for them in the workplace (p.8) ” [27]. They believed that “that much of the mathematics included in their courses was never required in the workplace and that the time could have been better spent on other areas”. More broadly, a 2008 National Numeracy review panel concluded “that at all levels of education up to and including university, many students (and their parents) are not persuaded that the mathematics education they are receiving will serve them well in their future workplaces.” [27]

However, at many universities there is a belief that a problem exists in students’ understanding of mathematics, even a crisis. In a Western Australian study [28] researchers found that coordinators of scientific and quantitative courses noted that their students were nervous and lacked confidence about the mathematical content, often withdrew early in the semester, were mathematically poorly prepared and reluctant to enrol in their quantitative courses. Similarly, UTAS [11] described a “mismatch between the numeracy requirements of UTAS courses and the students’ ability to meet those demands” and concluded that “numeracy is required in every area of study” (p. 1). There is a concern that this lack of participation in mathematics (and science) disciplines may lead to problems with sustained economic and productivity growth and development [29, 30]. This concern is shared by others around the world [31, 32].

In engineering, evidence suggests that mathematics is still considered to be a core skill for a student enrolling in engineering, while the targeted level of mathematics within university can be too high for many graduates entering industry, but too low for those pursuing research-intensive careers. A 2008 engineering report concluded that data analysis and statistics were grossly under-taught for all graduates [33]. The results of a survey of 31 engineering staff covering 63 courses identified nineteen broad mathematical topics in engineering programs [34]. This paper and others suggested that deep basic mathematical knowledge is essential as it underpins much of the engineering curriculum [35]. Other programs including chemistry, computer science, economics, business and finance, suggest that, for some, mathematics is still an important part of many degrees [36]. In addition, it has been shown that students who face difficulties with their first year mathematics may not continue or may fail some courses [5].

It is not just the content but the expectations and culture around university learning that influence students’ behaviour and performance. Matthews, Adam and Goos [5] suggest that students bring strong beliefs about science and mathematics from high school in which they are treated as two different subjects. When they reach university, mathematics is often embedded in other courses, and in this interdisciplinary approach, students with weak

mathematical skills are more likely to disengage from learning than those students who have a stronger mathematics foundation.

For staff in academic support or service programs, there is a crucial need to understand this meta-knowledge around the different mathematics skills. However, it is also important to have an institutional structure around development of such knowledge [12] and a shared knowledge of what that knowledge is. For example, in science:

it is crucial for mathematicians to better understand the skills, interests and requirements of the student audience, who are generally not studying mathematics for its own sake. It is equally crucial for scientists to recognize and understand the scope, relevance and usage of mathematics in science. [5]

2.3. University response to diversity

Universities have strategies to address diversity issues of expectation, experience and preparation. In particular, a variety of support, particularly for under-represented groups in the community, is available to students in most universities. While a national approach to this issue has not been developed [12], support does include a mix of upfront bridging courses, parallel support in courses where it is integrated into the teaching [12] and one-on-one support [25]. Often this support includes testing students on specific mathematics skills where early detection may bridge perceived deficiencies [20]. While those in mathematics support or in mathematics related disciplines recognise students' quantitative under-preparedness, those outside are often unaware of the extent of the problem.

3. Method

Ethics clearance was obtained to survey both students and lecturers with permission given to communicate with students and staff by the Faculties of Arts, Sciences and Business and Law. Similar information from Engineering and Surveying lecturers had already been obtained and some results have been published [34] (permission was not granted from the Faculty of Education).

All first year lecturers were asked to fill in a survey and if they would consent to a brief interview. The Queensland Junior and Senior Mathematics Syllabi for Mathematics A, B and C were used to develop questionnaires detailing mathematics topics studied in Years 10, 11 and 12 Queensland Secondary Schools. Questionnaires were designed to ascertain academics' perceptions of mathematics topics expected for study in their respective courses and their perceptions of on- and off-campus students' performance in these topics. An open-ended question allowed academics to make personalised comments. This survey is a partial replication of a survey conducted at USQ in 1997 [14]. This replication was to allow comparisons to be made and changes in perceptions analysed (not part of this paper).

4. Results

Results of the quantitative data from survey, open-ended comments from surveys and staff interviews are now outlined.

A total of 131 questionnaires were sent. The response rate is shown in Table 1. There were thirty-six responses with a total of 17 lecturers who responded to open-ended questions. Of these, only four indicated that mathematics was not required in their courses, with two of the four stating that mathematics would be required at higher levels of their subject area. Six lecturers commented that a portion of their students did not have the assumed prerequisite mathematics skills and another four lecturers acknowledged that many of their students showed an aversion to mathematics. To be noted is that four lecturers stated that they had

altered their course or teaching of their course to accommodate for the lack of mathematical skills.

Table 1. Number of surveys returned by Faculty **Error! Reference source not found.**

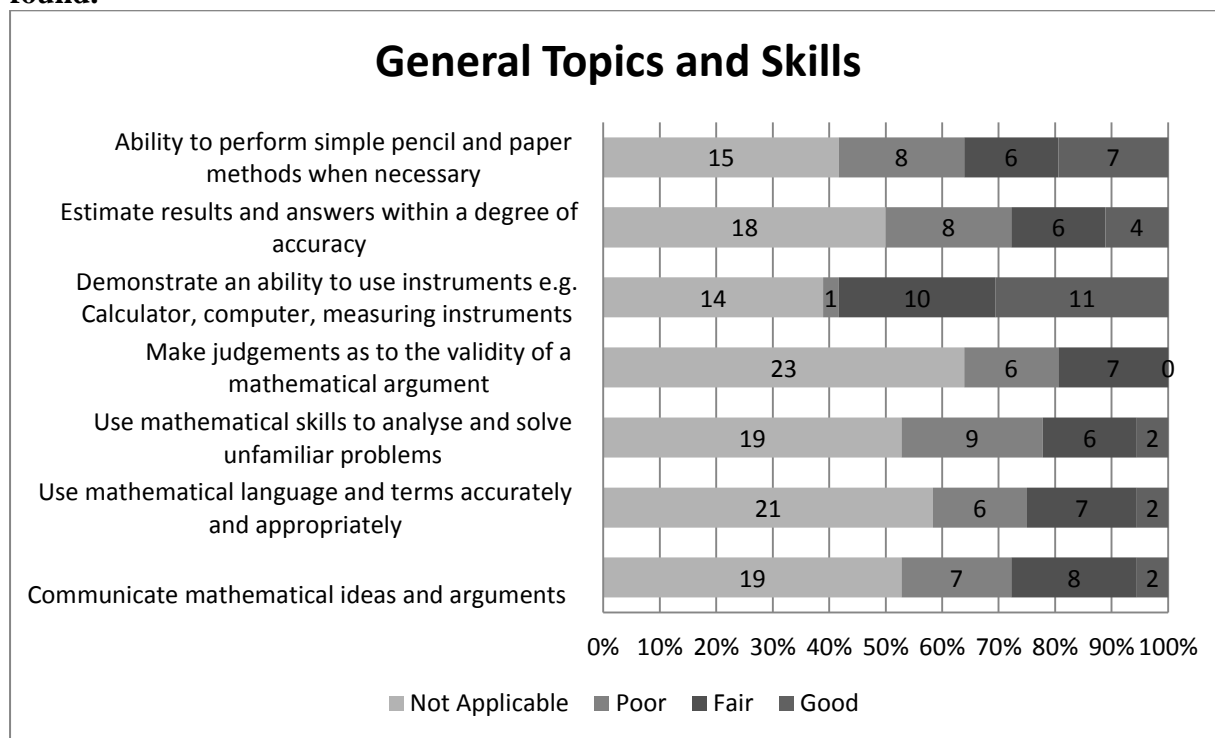


Figure 1. Lecturers' responses to "perceived student proficiency" in general topics and skills. The bars show the fraction of responses and numbers within bars show a count.

Figure 1 shows the lecturer's response to the perceived level of proficiency for general topics and skills that students require in order to complete their course. Of significance in these results is the high response that is recorded as "not applicable". This indicates that lecturers perceive that these general topics and skills are not necessary for their course. Given that lecturers were surveyed across three faculties, Business, Science and Arts this is a result of interest. In addition, some of the respondents from the open-ended comments explicitly stated that mathematics was not required in their course, but was necessary in other courses. Despite this, seven of those respondents who stated that mathematics was unnecessary rated their students' capabilities in a significant number of topics or skills in at least the Year 10 proficiencies. While one hypothesis may be that the lecturers are largely unaware of how pervasive mathematics is in their courses, from the corresponding open-ended comments it seems more likely that the lecturers have low expectations of the students' abilities and the course content is appropriately targeted as a consequence:

Respondent 3 (Psychology, No expected background, Some skills rated): Maths only explicitly relevant to one module. This requires understanding (not calculating) of, central tendency, variability, and inferential statistics. Later courses in the program require more advanced stats. Students sometimes change major due to concerns about these skills, pre-emptively before they even try to understand.

Respondent 12 (Arts, No expected background, No skills rated): Because of a lack of competency in students in general, there has been a shift away from teaching history

students statistics. This trend is long-term though, and no historian (from this university) would be willing to teach a "statistics for history" course.

Despite all of this negativity, there are some lecturers who are acting positively to address the issue for the benefit of their students:

Respondent 17 (Arts): students tell me they hate, don't understand or can't do maths. Knowledge of basic maths is as important to a good journalism as having news sense, knowing the rules of grammar, and write clear, accurate and interesting stories. ...in their first year, students in my course will learn that if they know their way around numbers they will be in a much better position to tell their readers what's going on.

Looking into the results, the first four statements are similar in that they are assessing mastery of concepts, which is fundamental for enabling synthesis and analysis. This higher level of thought capability is where students struggle the most, which causes difficulties in terms of introducing newer, more advanced concepts that require mastery. Unsurprisingly, in this modern age of pervasive gadgets, the students' ability to use gadgets is their strongest asset; this does not necessarily mean that the students are competent overall:

Respondent 9 (Science): Students can sometimes solve a problem because they know how but they don't know why. Without a calculator they can't calculate, can't roughly estimate and can't even tell the order of the result.

Finally, investigating the last two statements, there is a similar proportion of students who struggle with basic skills as those who struggle with more advanced skills, which has a causal link: basic skills scaffold advanced skills. However, there is a higher proportion of students with mastery over the basic skills, so this means that a substantial proportion of the cohorts are able to learn the new content that they will face.

The remainder of the survey focussed on the capabilities taught at the various year levels of high school. **Error! Reference source not found.** shows the results for expectations of students who have completed Year 10, where a total of 25 specific topics and skills were examined, with the data agglomerated based on a categorisation of the skill, so each bar shows data for a number of statements. Again, the content not required (Not Applicable) response rate is surprisingly high, particularly when the "Graphs" category includes interpreting graphs and "Statistics" includes data collection. The "Finance" statements were very specific to the field and so it is to be expected that these were restricted to a small sample. Assessing the actual responses, the overall good results for "Numbers", "Graphs" and "Unit comparison/conversion" correspond to the reasonable level of basic abilities that were shown in **Error! Reference source not found.** The moderate capabilities in "Statistics" are to be expected because many people find these concepts difficult to master. The poor abilities in "Trigonometry" and "Solving Equations" have been experienced by the authors regularly and are of considerable concern because mastery of these fundamental areas leads to capability in the more advanced concepts.

Lecturers who indicated some mathematics in their courses, commented on students' lack of skills, for example

Respondent 30 (Chemistry): Basic numeric skills are lacking. I dread times when I introduce logarithmic & exponential functions... much of my time is spent teaching maths, it gets very frustrating especially when it is yr 8 level!

The extra teaching that these students receive mean that the fundamental mathematical knowledge in Geometry, Trigonometry, Solving Equations and Graphs is improved overall in terms of a reduced fraction demonstrating *Poor capability*. Nonetheless, as an absolute measure, these results are substandard. By contrast, the capability in statistics

appears to remain largely unchanged. That integration is considered to be weaker than differentiation is consistent with long experience of this phenomenon, but the capability in differentiation is insufficient:

Respondent 34 (Science): My class has a mix of student maths backgrounds, with many it seems being uncomfortable with any aspect of calculus. I may to have resort to returning to an algebra-based physics textbook.

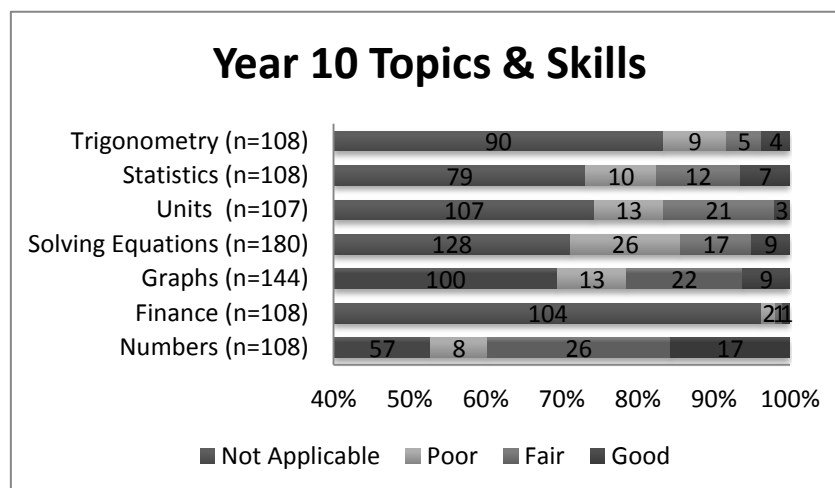


Figure 2. Lecturers' responses to perceived student proficiency in topics and skills from the Year 10 curriculum. The bars show the fraction of responses and numbers within bars show a count. Note that each bar is an agglomeration of a number of statements, so the total number of responses (n) for each category is listed.

For Year 11/12 (Figure 3), the most alarming result is the overwhelming majority of Poor responses for Functions. This is indicative of mathematics not being a field that is understood, rather one where steps must be followed in a particular order to produce an answer. With this lack of mastery comes the inability to attempt any problem that falls outside these strict protocols.

Only two respondents considered that their courses contained material pertaining to Mathematics C capabilities and so there is limited value in the data other than the overall capabilities were below standard, with no topic considered to have "Good" capability.

Individual interviews were held with some of the survey respondents. The three science lecturers voiced a strong opinion from their colleagues that they were not satisfied with some students' mathematics preparedness and that students have the impression that they can do mathematically-based courses without basic mathematics, as one lecturer stated; "Students need to realise they cannot do statistics in 5 minute grabs... Students can't do the building blocks." Other lecturers' opinions were that students are unaware of their own lack of mathematics skills and enrol in higher level courses because they are unable to recognise that their set of skills is deficient compared with those required. The students are then unprepared because they do not understand their lack of skills and therefore unsuccessfully try to cram what they do not know instead of building upon a foundation. Furthermore, responses indicated that students have an acceptance that they cannot do mathematics because Australian society is quite happy to accept the catch phrase "I am no good at maths."

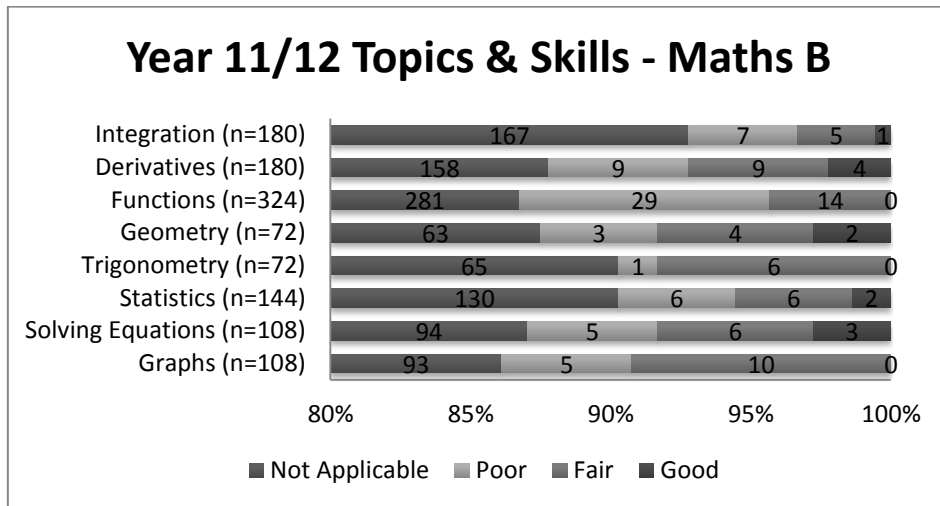


Figure 3. Lecturers’ responses to perceived student proficiency in topics and skills from the Mathematics B curriculum. (as per Figure 2).

5. Discussion and Conclusion

Diversity is an issue in most universities, however at USQ the multiple facets of diversity, i.e. in abilities, expectations, experience, commitments, and mathematical preparation, creates challenges that need a range of solutions at the institutional, faculty, program, and course level [12]. While the response rate to this survey was less than 30%, it does represent data about numeracy aspects across a whole university. A full report is currently being written. The investigation reported in this and the complimentary paper (Part B) and our other investigations [34] provides evidence to inform program planners, particularly in the enabling programs, first year mathematics service courses, and academic learning support at USQ and in tertiary institutions with similarly diverse cohorts of students. Further analysis is being undertaken to compare this data to the 1997 and analyse changes in perceptions. Further research would need to be undertaken to see if the results are replicated in more traditional universities.

Specifically, this paper found many academics saw little need for students to have any level of mathematics in their courses. For those that did, there is a perception of lack of capabilities in the fundamental skills shown by students entering university, which translates into a difficulty in scaffolding advanced knowledge. This problem is partly due to a compartmentalisation of knowledge that mathematical skills are only required when studying a course titled “Mathematics” and a lack of awareness that mathematics permeates into many aspects of life. We conjecture that this compartmentalisation translates internally in terms of strategic learning, whereby a student might target specific topics to achieve a passing grade and thereby not devote the requisite energy to understand the breadth of mathematics.

Coincidentally, while the current data was being collected, a number of changes occurred. A new statistics for social science course was introduced in the Business, Education, Sciences and Arts disciplines to provide students with basic concepts on how data is evaluated. Unfortunately, as it is only an optional course in programs, much of the numeracy requirements are still going to have to be taught within courses, (like journalism) or expectations reduced (like history). Another approach is to address the issue at entry level. Engineering instigated a reorganisation of the engineering mathematics courses, citing a lack of competency in the topics described here when undertaking fundamental engineering courses. The approach taken has been to increase the entry-level requirements for the two-

year degree program and simultaneously include introductory material for higher-end topics. With the implementation of these changes commencing in 2013, it remains to be seen what influence this will have on the engineering programs.

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