

Academic numeracy and first year undergraduate studies across six regional universities

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This paper is a preliminary investigation into first year undergraduate students' progress in academic numeracy studies across six Australian regional universities. The paper analyses a survey of university teachers, follow-up interviews and secondary academic numeracy data. Initial findings are presented in terms of the nature of academic numeracy required in the subjects offered and support strategies provided. The study suggests that support services are not contributing well to attrition in subjects requiring academic numeracy. Some effects are due to the diversity of the student body and further research is needed on both localised and cross-university approaches that focus on student's goals and personal agency.

Students' engagement in first-year academic numeracy programs is generally in undergraduate mathematics and statistics subjects, but also as components of other subjects. Numeracy, or mathematical literacy, for this study was defined similarly to Geiger, Goos and Forgasz (2015) as the ability to identify the knowledge and capabilities required to accommodate the mathematical demands of private and public life. Numeracy is not equivalent to number or mathematics, but embraces a broader conceptualisation; however, academic numeracy programs are generally dedicated to introductory mathematics and statistics or contain an element of introductory mathematics as an essential component (Whannell & Allen, 2012).

A collaborative study, *Bite size maths: Building mathematics capability of low SES students in regional/remote Australia* (BSM), was dedicated to providing online resources to support academic numeracy in regional (non-urban) universities. As part of the broader BSM study, this paper presents a summary of the first-year programs in academic numeracy and strategies to support students within them, at the six regional Australian universities of the Regional Universities Network. These universities all have a substantial proportion of students enrolled with little or no mathematics or numeracy background or who have completed schooling more than 10 years ago, with large numbers of these students also from low- to mid-socioeconomic (SES) backgrounds (Australian Academy of Science, 2016; Lyons et al., 2006).

Academic Numeracy in an Australian University Context

In Australian universities many students enter mathematics or other numeracy-allied programs with suitable Australian Tertiary Admission Ranks or equivalent entry qualifications across a range of different subjects, but with minimal or limited background in numeracy (Smith, Ladewig, & Prinsley, 2018). Typically, the educational background of students enrolling in professional degrees such as business, nursing and education, show a lack of preparedness for the level of numeracy required (Australian Academy of Science, 2016). This limited numeracy background may lead to students holding perceptions of a 2019. In G. Hine, S. Blackley, & A. Cooke (Eds.). *Mathematics Education Research: Impacting Practice (Proceedings of the 42nd annual conference of the Mathematics Education Research Group of Australasia)* pp. 779-786. Perth: MERGA.

reduced capability to study numeracy, specifically mathematics, and further contribute to student anxiety and self-fulfilling failure (Lake et al., 2017). The current Chief Scientist of Australia highlights the critical nature of this issue (Finkel, 2018) in relation to the economic and social costs of not dealing adequately with academic numeracy.

Higher education institutions have responded to the high attrition rates in academic numeracy programs by providing resources that identify and support students with less than adequate skills and who may be vulnerable to withdrawing (Galligan & Hobohm, 2015). Retention and attrition within these programs are also related to students' engagement with enabling and support services at appropriate times (Stone et al., 2016). Academic numeracy support can take different forms, but many universities lack a systematic approach, with support found in pockets within individual subjects, learning centres, enabling programs and university departments (Galligan, 2013).

Academic Numeracy in a Regional University Context

Regional Australian universities have first-year undergraduate programs that offer subjects involving academic numeracy. A science student, for example, may need to understand a logarithmic graph in a first-year biology subject, or a nursing student may need to calculate dosage (proportional reasoning). While these two examples only require basic numeracy, there is usually no prerequisite 'recommended' or 'assumed' mathematics knowledge for entry. Where numeracy entry requirements are defined, they are often poorly understood by students. Programs, such as engineering, some sciences, and secondary mathematics teacher education, do require higher level prerequisite mathematics. Lecturers thus assume that students entering these subjects have the requisite knowledge and skills and are often ill-equipped to assist these students when they do not (Galligan & Hobohm, 2015; Wandel et al., 2015).

Fewer students go on to enrol in and complete higher-level mathematics subjects in regional universities compared to larger urban universities and problems with retention and progression are more acute due to the disadvantaged nature of the student population (Lyons et al., 2006). Some regional universities do not have mathematics departments or sufficient enrolments for higher-level mathematics. Therefore, the unified voice of mathematics is often lost and along with it any coordination of academic numeracy learning.

There appears to be four issues for these universities, compared with their urban counterparts, that disproportionately affect students: high attrition rates, especially from numeracy-allied first-year subjects; appropriate access to resourcing of support services (both financial and pedagogical); students' understanding of the culture of the university, particularly their critical literacy (see Lawrence, 2013); and students' willingness and ability to accept support offered (Woolcott et al., 2018). Regional universities, however, do have some commonalities with peri-urban and urban universities in the need for collection and use of evidence to plan for the support of at-risk students (MacGillivray & Wilson, 2008).

Academic Numeracy at the Participating Regional Universities

The six participating universities are headquartered in regional Australia and have strong track records in supporting their significantly diverse student cohorts, including support for the high proportions of regional, disadvantaged and other under-represented students (Woolcott et al., 2018). All six are actively engaged with industries within the community that employ students with numeracy competencies. Four of the universities have a school or department of mathematics and statistics and the other two have mathematics subjects and programs within other schools or departments, such as education or science.

Despite these universities being at the forefront of distance and online education and community outreach, all six have experienced some of the highest attrition rates of any Australian university (e.g., between 2001 to 2014, Department of Education and Training, 2017). This reflects current challenges in regional education—many of the students come from high schools in regional and peri-urban areas that have high proportions of disadvantaged students, including many who live in low SES environments with problematic access to schools, suitable curricula, and higher education and training programs (Lyons et al., 2006; Quinn & Lyons, 2016). Students at these regional and rural schools remain under-represented in mathematics programs at both secondary school and university (Australian Academy of Science, 2016) with schools struggling to maintain equivalent educational standards in numeracy compared with metropolitan areas (Quinn & Lyons, 2016).

As with most universities, subjects targeting academic numeracy offered at preparatory and first-year level have adapted to cater for increased student diversity and breadth of the mathematics or quantitative competencies that these students bring to their tertiary studies (Galligan & Hobohm, 2015; King & Cattlin, 2015). Students may also require an increasing level of understanding of statistics to meet their professional or accreditation requirements, however some professional degrees, such as teaching and nursing, have until recently offered only a narrow range of knowledge and skills in numeracy, if at all.

Fewer students taking intermediate and advanced high school mathematics and the dropping of specific mathematics prerequisites for university entry has reduced numeracy levels. The Australian Academy of Science (2016, p. 30) expressed the following concern in relation to mathematics education:

... has led to a reduction in the content taught and in the achievement levels needed to pass a subject...the availability of undergraduate majors in the mathematical sciences...is inadequate in regional universities.

The current study provides a preliminary analysis of a survey of university teachers and follow-up interviews and an examination of secondary data related to academic numeracy at these universities. Initial findings are presented to address the following research questions, with a discussion included as to how this information can be used to jointly address the challenges of providing appropriate academic numeracy support at regional universities:

1. *What are students' engagement/experiences with academic numeracy in subjects taught in the first year of regional universities?*
2. *What strategies have universities investigated and/or enacted in order to deal with the broad range of mathematics and numeracy competencies of students undertaking first-year academic numeracy programs?*

Methods

The study employed both quantitative and qualitative methods involving multiple embedded case studies, using six cases (each from a different university) within the overall BSM project. This approach was preferred to a multi-case approach, since all cases occurred under the influence of the BSM project and this influence cannot be separated from the cases (Yin, 2013). The variation between cases (e.g., whether or not there was a dedicated mathematics department, number of first-year students from rural and remote areas, or number of full-time staff teaching academic numeracy) provided an opportunity to examine the research questions in relation to academic numeracy programs in these regional university contexts. The longitudinal mixed methods approach drew from both primary and secondary data. Primary data included results from a qualitative survey of nine teachers at the six study universities who were involved in first-year programs (2014 to 2016) that included introductory academic numeracy. Questions were based around identification and

support for students at risk at each university, including locally conducted research on retention and attrition in academic numeracy. Seven of the nine respondents also participated in follow-up semi-structured interviews (in person or on Skype by one of the study authors) designed to elaborate on institution-specific or regional issues raised in the survey.

Secondary data from 2014 to 2016 were obtained from publicly accessible databases or were supplied by each university: first-year subjects that offered academic numeracy in part (e.g., biology or business subjects), or as an entire subject (e.g., introductory mathematics); the rationale behind these subject offerings; research that had been conducted on the development or implementation of support structures or interventions for students within these subject offerings; and whether or not these support structures or interventions had been taken up by students.

The primary and secondary data were combined and analysed thematically using NVivo and assessed against the research questions. The study followed university ethical protocols, with the names have been de-identified. Secondary data were used also to determine how and when academic numeracy was provided in first-year programs, including in service subjects (e.g., see Woolcott et al., 2018), and whether or not students undertook support or interventions offered.

Results and Discussion

First-year academic numeracy programs

Each university offered mathematics and statistics subjects as well as enabling or bridging programs (preparatory programs), and academic numeracy within other programs. The six universities offer a range of numeracy knowledge and skills in both online and blended learning formats: students may be able to complete a first-year mathematics subject either online, as a combination of online and face-to-face or in an exclusively face-to-face setting at a number of campus locations.

Analysis of the surveys and in-depth interviews supported the view that many students are mathematically ill prepared when they enter preparatory and introductory mathematics units. Many of the respondents commented on the challenges with the pre-requisite content of the quantitative skills in their subjects. As one interviewee noted:

They're not very comfortable doing it because they haven't spent enough time, (so maybe) not enough practice at school... I think it is a lack of practice. (Interviewee A)

Interviewees reported that students experience particular difficulties with algebra, fractions, graphs, logarithms and unit conversions, with more specific difficulties related to operations with fractions, connecting graphs to formulas, finding patterns and relating them to mathematical formulas, and accurately using line intervals (Many of these concepts are addressed in junior secondary mathematics curriculum and should be well developed by Years 11 and 12).

Students found letters in formulae problematic. Algebra is a great problem and again they are afraid of letters and they are not able to connect the formula, (with) letters a and b with the actual expression, so if you ask, 'What is a, what is b?', they're sometimes lost. (Interviewee D)

Interviewees also reported that many students were not *au fait* with the language and conventions of mathematics, impeding learning in introductory undergraduate numeracy.

I had a problem (explaining) to the students what are rational numbers or real numbers...for example, if we have a question about the intersection of two intervals, I explain what an interval is. I explain the wording. I explain the symbols. I think I have explained everything and at the end they understand what an intersection is, but they just list the integers which are in this interval...They really do not understand this continuity across [of] numbers. (Interviewee E)

Other issues identified that contributed to high rates of attrition or academic failure clustered around institutional processes and personal factors (including critical literacy). Students had trouble adapting to the university culture, with its own requirements, expectations and discourse. The interviewees expressed frustration at both the failure of pre-enrolment processes to identify students at risk, and the lack of preparation courses for these students once they had been identified, as well as the lack of uptake of available support by at-risk students. Personal factors reported included students' anxiety and lack of confidence with mathematics, and their lack of cognitive preparedness for tertiary mathematics study.

One interviewee also bemoaned the fact that "There is nothing to prepare them for it (university numeracy programs)". There was consensus among the study participants that the current approaches were not providing the necessary upskilling for students in need. While bridging and additional support and enabling programs are available in mathematics and numeracy at the participating institutions, their use is not appropriately targeted and institutions appear to leave it to students to self-select involvement and to navigate the processes involved; something many appear unwilling or unable to do.

...administration cannot seem to cope with excluding students who already have the skills or including students who need to do the subject before taking on a higher-level subject. (Interviewee H)

Processes to identify students at risk of attrition or academic failure in introductory academic numeracy programs vary widely between and within the study universities, and even within programs. The processes used to gather this data range from diagnostic tests and formal assessments, to informal observation of students in tutorials. While the ideal might be to conduct pre-enrolment diagnostic testing, most at-risk students are only identified within the first three weeks of semester. This variation in identification of at-risk students echoes the unsophisticated approach mentioned earlier—one interviewee highlighted the issue as "what is said to be done, compared to what is done". Analysis of the survey showed that, when data are gathered about student performance, it may, or may not, be analysed and feedback may, or may not, be provided to the students in question.

Resource issues impact the capacities of mathematics staff to identify and support at-risk students. Interviewee responses, in fact, raised the question of who should be doing this sort of thing and how their efforts should be evaluated in terms of success and accountability—some support programs were well-funded, but there appeared to be no accounting process to establish whether or not funds were well spent and how effective the support was. Additionally, the separation between the academics teaching in numeracy programs and those meant to be supporting them (and students) indicated that there was a clear divide between the core academic pursuits and support practices and needs.

Strategies for Student Support and First-Year Academic Numeracy Programs

All survey and interview respondents reported that the study universities are acutely aware of the problems (both institutional and personal) of early attrition and academic failure, including in academic numeracy, with a number of initiatives in place to identify and support students at risk. Respondents agreed that institution-wide research into such support mechanisms had been patchy and not always effective. Several of the project team undertook a meta-analysis of research on first year undergraduate mathematics attrition and the mechanisms through which this problem is being addressed at one of the study universities (Lake et al., 2017). They determined that the most helpful research identified gaps in student mathematical knowledge, providing insights into how to best identify at-risk students, and suggested ways to assist these students. However, there were very few instances of implementation and evaluation of interventions or updating of university processes.

Interventions to support students struggling with introductory mathematics might be loosely grouped under two categories—those that involve mentoring and building student motivation, and those that focus on learning content itself. These approaches are not mutually exclusive, and many successful interventions drew on both (see also Stone et al., 2016; Woolcott et al., 2019). All respondents interviewed indicated that they were undertaking multi-university research into student attrition or academic failure, and how to best address this problem as it pertains to academic numeracy, with the BSM project a recent example. The respondents supported the view that in all cases, whether within or across universities, research in this area suffered from a lack of dedicated funding and a failure in many instances to transfer findings into actual institutional practices and processes. As one interviewee commented:

My experience is that once the research is done, there is no commitment to implementation... academics operate with the view that it's the research that gets you promoted, not doing something about the problem that prompted the research in the first place. (Interviewee C)

This failure suggests using the principles of design-based implementation research may be more successful. These principles take up the issue of collaborative research and practice that involves multiple stakeholders, in a process that aims to design, test and implement innovations through iterative functionality (Woolcott, Mason, & Seton, 2018).

The survey identified a range of institutional support practices for students 'at risk', including enabling units (Tertiary Preparation Program and Learning Centre initiatives) and support services such as mentoring programs, drop-in centres and study groups. The uptake of both enabling units and support services by first-year students was considered very low (5% of the cohort), although drop-in centres showed more promising usage patterns. Respondents were concerned that there were no evidence-based support programs available for at-risk students in academic numeracy, and specifically in mathematics subjects. Several respondents argued that universities often operated with anecdotal evidence of the effectiveness of the diverse support services on offer. Of particular concern was that students did not access support in a timely manner. One interviewee indicated that staff working on the subject made themselves available to students, but noted:

We encourage students to come to us and we're really happy to help them and we have office hours, but unfortunately they do not use this very much. Somehow they are afraid of this. (Interviewee G)

Some institutions offered additional classes or mentoring programs where previously successful students helped new mathematics students. Acting as a mentor was reported by successful students as a useful initiative, but mentees did not always report their experiences as useful, and there were some reports of mentors/class teachers not offering the required level of assistance. When mentoring or extra classes were offered online, students did not always take up the opportunity, citing difficulties in attending online tutorials and preferring instead to look at pre-recorded materials or request one-on-one tutoring.

Staff working on introductory undergraduate mathematics units suggested that institutional strategies to support students at risk of attrition or academic failure were not always in place across academic numeracy programs. The lack of involvement of academics in support programs was felt to contribute to a reported over-dependence on casual tutors with insufficient skills and experience to aid students who were underprepared and were struggling. Study interviewees also commented on the lack of funding for, and the failure to integrate, a well-targeted support network at the institutional level.

Despite such difficulties, the interviewees were positive about embedding opportunities for students to keep practicing until they had mastery of a particular concept. Interviewees, however, stressed the importance of ensuring that such mastery be based on interaction with

existing subject structures, be complementary to those structures, and keep students on-task until completion of any such modules attempted. As one interviewee noted:

A lot of students that are struggling... that are having trouble with the course... if it's too long they would probably get bored with it, and they would just leave it half way and then they wouldn't progress through the whole thing, whereas the benefit they'd actually have (would be) to finish the whole thing. (Interviewee H)

Conclusion and Ways Forward

Academic numeracy is arguably a critical component of many programs that university undergraduates appear to have entrained as a part of their overall educational and social goals (Galligan & Hobohn, 2015; Smith et al., 2018). While students in regional centres are enrolling in programs that require academic numeracy, they are often at a disadvantage above that of their urban counterparts if they come from regional schooling. Survey and interview analysis as well as secondary data analysis conducted here suggest that, where support services were offered, students at risk were not necessarily taking up that offer and further research needs to be undertaken to examine motivational aspects of regional disadvantage that may underpin this issue. This view was explored in Whannell and Allen (2012) who suggested that strategies are needed to improve the preparedness of first-year regional mathematics students, in part to overcome the broad spectrum of competencies that they present with at university. Interviewees in the current study further suggest that any progress on the issue may require longitudinal approaches and continuing and sufficient resourcing.

It is apparent from this study that considerable research has been carried out at each institution, but findings have been applied only at the local university level. The current study begins a discussion on how such findings can be shared and adapted in a regional setting. The approach used in the embedded case study supports the view of Woolcott et al. (2018) that a localised approach using data analytics that combines multiple factors may be useful in refining statistical research in order to make analyses more efficient and effective through a person-centre and place-based rationale (see also Woolcott et al., 2017). This suggestion aligns with the view that the current limited level of sophistication in approaching the issue of academic numeracy may warrant design-based implementation research approaches. Such approaches should address the problem in a more coherent way while providing feedforward and feedback interactions that would bridge the gap between research and practice in this area.

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