DEVELOPING STUDENTS' ACADEMIC NUMERACY SKILLS: TAKING A WHOLE-OF-INSTITUTION APPROACH

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ABSTRACT

The broad diversity of students commencing at university is now a well-documented feature of higher education in Australia. The literature also reveals that the many commencing students lack the mathematical preparedness to meet the academic numeracy demands of their programs. Whilst it may be well understood that students need a certain level of mathematics to study, for example, engineering, the numeracy demands in many other disciplines are not made so evident or explicit. Recent research has found low numeracy to be more problematic than low literacy with regards to successfully undertaking higher education studies, with resultant implications for student retention. This paper describes the journey undertaken at one university in adopting an institution-wide approach to developing their students' academic numeracy skills. A key component of the initiative presented is the development of a credit-bearing Academic and Professional Numeracy topic [2] as a means to enable students' from across all of the disciplines to better manage the numeracy requirements of their courses.

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INTRODUCTION AND BACKGROUND

Numeracy in the tertiary domain places an emphasis on the application of mathematics and quantitative concepts within academic disciplinary contexts (Skalicky, Adam & Brown, 2010). In the Australian context, Taylor and Galligan (2002) were the first to describe the quantitative skills necessary for success in the university context as *academic numeracy*, a term that has now been broadly adopted. Drawing on Galligan's recent work (2013a; 2103b), academic numeracy will be defined in this paper as the capacity to confidently and competently use mathematics at university level, and to be able to apply, interpret, critique and communicate mathematical concepts in particular disciplinary contexts.

An increasingly diverse student cohort is now attending university as a result of the widening participation agenda. The lack of mathematical skills and understandings in many of these commencing students has been discussed broadly in Australian literature (Wilkes, 2010; Taylor & Galligan, 2009; Jennings, 2009; Jourdan, Cretchely, & Passmore, 2007). Many students commence university lacking even the most basic of mathematics skills. An extensive study conducted in the UK (Parsons & Bynner, 2005) has revealed the serious implications that arise from students' inability to manage their academic numeracy demands. This study found *low numeracy* to be *more problematic* than low literacy with regards to successfully undertaking tertiary studies, with resultant implications for student retention. In regard to this, what is more worrying is that the literature indicates that the students with the poorest skills, who most need support with numeracy, fail to access it (Pell & Croft, 2008). More recent research (McNaught & Hoyne, 2011) has examined the issues associated with students commencing university lacking skills in rudimentary mathematics and identified factors that have precipitated this state of affairs. The first is that students are now completing less rigorous mathematics courses in their senior secondary education, with many studying no mathematics at all. Additionally, they find that the current generation of school leavers have become calculator dependent, lacking mental mathematical skills and the ability to reason and analyse without the use of technology.

It may be well understood that students need a certain level of mathematics to study engineering or physics; however, the numeracy demands in other disciplines such as in nursing, business,

[2] May be known as subject or unit at other institutions.

education, or indeed science disciplines such as biology or earth sciences are not so evident or explicit. In this regard, the literature provides a wealth of evidence that students are underprepared to manage the numeracy demands in a range of courses such as nursing (Eastwood, Boyle, Williams, & Fairhall, 2011), health sciences (McNaught & Hoyne, 2013), and business (McClure & Sircar, 2008). However, poor mathematical skills are only part of the problem. The phenomena of mathematics anxiety or mathematics phobia has been well documented (Wilkes, 2010; Rylands & Coady, 2009; Li, 2003) as a key reason for school students, and adults alike, having an aversion to studying mathematics and using even simple mathematics in their daily lives. The long-term outcome of mathematics anxiety/phobia is low numeracy levels or innumeracy. As previously stated, the implications of this for students being able to manage tertiary numeracy requirements is that low levels of numeracy are more problematic than poor literacy when it comes to successfully undertaking higher education studies. According to Pell and Croft (2008) students' lack of mathematical preparedness results in disillusionment, loss of self-esteem and, ultimately, withdrawal from tertiary education. On the other hand, Thomson and Hillman (2010) have determined that students who recognise the value of mathematics are more likely to be successful in their tertiary study endeavours.

Whilst the field of research in numeracy and mathematics education is extensive, work that has been conducted in the tertiary sector is limited, with most studies concentrating on preparedness for university mathematics (for example Wilkes, 2010; Jennings, 2009; Jourdan, Cretchley, & Passmore, 2007). However, Galligan and Taylor (2005) have conducted one very useful study that investigated academic numeracy in non-mathematical university courses. They found a significant mismatch between the skills of commencing students and the numeracy demands embedded in courses. To address this mathematical under-preparedness many Australian universities offer learning support services in mathematical and numeracy skills. Numeracy support strategies that tertiary institutions are adopting include enabling programs, voluntary workshops, self-diagnostic tools, online support materials, and one-to-one support (Galligan and Hobohm, 2015). Whilst these strategies provide students with constructive numeracy learning support, all are provided outside of the formal curriculum thus involving additional, sometimes quite significant, time commitments for students requiring such support. The distinguishing feature of initiative presented here, is that the numeracy learning support occurs within the curriculum in the form of a credit-bearing topic designed to prepare students to manage the numeracy or mathematical requirements of their course, regardless of the discipline.

Recently Galligan (2013a) and Oliver (2013) have argued that few Australian universities actively aim to improve students' academic numeracy despite the fact that Graduate Qualities and the Graduate Employability Indicators suggest that they should. Students should leave their university studies more competent, confident and critically aware of the mathematics in their courses, in their professions, and in their personal lives. Hence, 'like academic literacy, academic numeracy is a university-wide issues and if it is to be seriously addressed, then a systematic approach is essential' (Galligan, 2013a, p.744). In reflecting this recommendation the initiative presented in this paper involves adopting a university-wide approach to developing students' academic numeracy skills in order to best develop their capacities to manage the numeracy demands in their programs.

TAKING A UNIVERSITY-WIDE APPROACH

Akin to most other Australian universities, it has become clear at Flinders University that due to the widening participation agenda there is a critical need to address the literacy and numeracy skills of many students in an effort to provide these students with the best possibility of success. A number of strategic actions have been adopted in the past few years to deal with this issue: the current Teaching and Learning Plan comprises a commitment to enhance the academic literacy and numeracy skills of undergraduate students via for-credit studies; a priority action of the 2012 Operational Plan was the implementation of the First-Year Transition and Retention Project encompassing 'a number of initiatives…[including] the development of a strategy to build first year literacy/numeracy'; and also in 2012 Vice-Chancellor's Committee endorsed the adoption, development and implementation of credit-bearing numeracy and literacy topics.

The adoption of a university-wide approach to addressing students' academic literacy skills was successfully completed in 2013 as Faculties are now required to demonstrate either that context-specific literacy content is integrated into professionally-oriented courses, or alternatively they are responsible for accommodating the for-credit topic *Academic and Professional Communication* in the

course rules for generalist undergraduate degrees (Brady, 2013; Pourshafie & Brady, 2013). The university's attention then turned to addressing students' academic numeracy needs. The leadership for this project was assigned to the university's academic support unit, the Student Learning Centre (SLC).

During 2013 the SLC conducted a numeracy audit of all courses with non-specialised mathematics components to provide base line data on the breadth and depth of the numeracy demands in programs across the university. The co-ordinators of 29 different courses submitted a response. The audit revealed the considerable extent to which students need to draw upon their academic numeracy skills. For example: 100% of courses require skills in reading graphs; 96% include reading and interpreting statistics information; and 91% require the use of arithmetic operations, percentage and interpreting graphs. Additionally, the qualitative data collected in the numeracy audit provided very concerning picture of the students' inability to manage these numeracy requirements from the point of view of all the 29 course co-ordinators that responded. Recent studies by Wandel et al (2015), and Galligan et al (2013), have similarly reported low levels of teaching staff satisfaction with regard to students' mathematical preparedness for university study. In addressing the question: *"What deficiencies do commencing students have in meeting the numeracy demands of your program?"* some of the responses provided by course co-ordinators were:

- *[Students] don't meet expectations, [they] come in with Year 9 maths as a max or refuse to know any maths at all; Some students don't even know how to add up a bill in the supermarket but expect to be able to study science*
- *Poor grounding in very basic maths; intimidated by numbers*
- *They cannot work with decimal point or fractions and these skills are required for medication calculations. Also can't understand basic statistical information in journals nor work out what their grade might be in a topic if it is divided between several pieces of work*
- *Cannot divide by 10 or 100, cannot convert between orders of magnitude (eg milligrams to micrograms); do not check their mathematical calculations, and do not think about how to best order of magnitude they should expect for an answer to their*
- *Many students are simply afraid of anything mathematical; without this cultural shift there is little prospect for anything*

Clearly there was a mismatch between the students' skills and the numeracy demands embedded in their programs, an issue that has been highlighted in the literature. In the meantime, there appeared to be no positive signs that problems associated with the students' lack of mathematical competence were being resolved.

Thus, a working party comprising representatives from each Faculty and key academics from the SLC was formed to recommend a university-wide framework that would be adopted to ensure students become sufficiently competent in numeracy to participate effectively in their studies. The key features of this framework are, firstly, that Faculties will be responsible for identifying students' numeracy needs through methods that may include reviews of academic progress, or discipline-specific competency testing. Secondly, Faculties will provide students with opportunities to become competent in their numeracy skills through the explicit integration of course or program specific numeracy content (an approach mostly likely to be suited to professionally oriented programs or courses); or through the incorporation of a credit-bearing academic numeracy topic within course rules, either for all students or for targeted students. To provide such an opportunity, the credit-bearing topic *Academic and Professional Numeracy* has been designed and delivered by the SLC in collaboration with the School of Computer Science, Engineering and Mathematics. The curriculum development phase of this project took place in 2014 and the topic was delivered for the first time in 2015.

ACADEMIC AND PROFESSIONAL NUMERACY

The focus and purpose of Academic and Professional Numeracy is to address the numeracy requirements across all disciplines. Given that the numeracy demands of different courses require different mathematical, statistical or quantitative skills according to the discipline, and given also that students possess differing pre-existing skills and knowledge, as well as different perceptions of their personal numeracy, the *Academic and Professional Numeracy* topic is customised using a modular approach to the curriculum. The topic comprises four modules, selected from a larger suite of modules (Table 1).

Table 1: Modules and their content

Module	Name	Contents
A	Number Fundamentals	Whole number operations, the properties of whole numbers including integers.
B	Further Number Concepts	Operations involving fractions, decimals and percentages, rounding, significant figures.
C	Extended Number Concepts	Ratio and proportion, use of exponents and logarithms, scientific notation
D	Algebra	Algebraic terms and expressions, solving linear equations, formulae
E	Graphing	Reading and interpreting graphs and charts, plotting graphs, equations of straight lines, scatter plots, lines of best fit.
F	Spatial Thinking	Plane geometry, units of measurement, measurement of 2D and 3D figures, trigonometric ratios, Pythagoras rule
G	Statistics	Representations of statistical information, sampling, measures of central tendency and variation, analysis of data
H	Counting and Probability	Counting techniques, permutations and combinations, representation of probability events, experimental and theoretical probability,

The 12 teaching weeks that comprise a semester are divided into four sets of three-week blocks. In each of the three-week blocks two different modules are delivered concurrently. *Academic and Professional Numeracy* can be selected as an elective in any course that provides for some free-choice in the course rule. It can either be self-selected by students who recognise its potential value, or students with limited mathematical background will be referred to the topic by academic staff. The four modules that students select may be recommended because they address the numeracy demands of a particular course or discipline context, or individual students could select modules to suit their own numeracy learning needs. From the beginning of 2016 topic has been designated core in 6 courses, and in 2017 *Academic and Professional Numeracy* will be mandated for all students in Bachelor of Science programs who do not have an appropriate level of senior secondary mathematics in their background. An 'assessment for learning' design has been incorporated into the topic with students needing to attempt (but not necessarily pass) formative weekly in-class quizzes. The summative assessment is in the form of an end of module quiz that must be passed. As mathematics anxiety is a common phenomenon amongst the students, breaking the summative assessment into four smaller tasks is a less daunting proposition than a traditional end of semester exam.

The uptake of *Academic and Professional Numeracy* in its initial year of delivery, 2015, was modest. As with many curriculum innovations, interested academic colleagues adopted a cautious watch and wait approach when it came to recommending the topic to their students. The topic offered in Semester 1, Semester 2 and a mid-year intensive version attracted 81 enrolments in that year. The institution mandated student evaluation of the topic in 2015 was, however, very encouraging. A score of 4.1 (on a 5 point Likert scale) was recorded to the statements "I had a clear idea what was expected of me" and "I have had a worthwhile learning experience", and a score of 4.2 recorded for " I developed my ability to think critically and analytically". The qualitative responses in student evaluation were even more encouraging, for example:

- *The structure of the lectures was really helpful – starting at the assumption that a student in the class was completely unfamiliar with the topic and progressing rapidly toward a fluent (at a basic level) understanding … a pleasant surprise based on my previous math experiences*
- *I enjoyed the way the topic was structured eg focus on one area for three weeks then have a test. I found this was an easier way to learn, as you could focus on one thing at a time*
- *[The aspect of the topic that helped me learn] was the scaffolded teaching approach - building each week on what we learned in the previous week.*
- *The information was scaffolded really well and provided a strong foundation for future topics.*

Student feedback also tendered a range of perspectives that provided some constructive critique. Firstly, despite the fact that the modular structure of the topic was ultimately well received it did initially generate confusion as the structure differed considerably from the traditional means of topic delivery. The major source of this confusion resulted from the university's timetabling mechanisms

being unable to accommodate sufficiently well the topic's modular nature. Timetables, and timetablers, prefer topics to run for a whole semester with one lecture and one tutorial per week. Additionally, some students wanted more time to cover particular concepts, whilst others wanted less! Finally, whilst a deliberate decision was taken in developing the curriculum that the topic would not involve the use of calculators, this aspect of the topic was not well received from the group of students who were entirely calculator dependent.

The author acknowledges that this initial set of student evaluation data is lacking depth, both in the quantum of data and its analysis. Further studies are being planned to more fully evaluate the topic. Firstly, students' motivations and expectations in selecting the topic will be investigated, together with whether their expectations had been met. Additionally, a study is planned to quantitatively evaluate the efficacy of the topic by examining the overall results of students from like courses who have completed the topic compared to those that have not.

Enrolments in the *Academic and Professional Numeracy* for 2016 amount to 131 students, close to a doubling of 2015 enrolments. An analysis of the course enrolments of 2015 and 2016 cohort of students (Table 2) is evidence that the whole-of-institution approach to enhancing students' academic numeracy skills appears to have been quite successful because students in a wide range of courses covering a breadth of disciplines have undertaken the topic.

Table 2: Student enrolments in Academic and Professional Numeracy by course

Course	% of Students by Course	Number of Students by Course n = 212
B. Education (Early Childhood/Primary)	30%	64
B. Information Technology	18%	39
B. Science	17%	36
B. Education (Middle/Secondary)	14%	29
Other Bachelor courses (Social Sciences)	8%	16
B. General Studies	6%	13
B. Health Sciences	3%	6
Other Bachelor courses (STEM)	3%	6
Other Bachelor courses (Arts/Humanities)	1%	3

CONCLUSION

This paper has detailed the journey undertaken at one university in moving toward an institution-wide approach to developing students' academic numeracy skills. The imperatives presented in the literature indicate that the issues associated with students managing the numeracy demands of their courses have implications for students themselves, and the institution. From the student point of view, meeting the numeracy requirements of their course will ultimately lead to a greater chance that they will be successful in their studies. From the institution point of view this will result in improved retention rates. Additionally, the literature also advocates that a whole-of-university approach as the best means to develop students' capacities to manage the numeracy demands in their courses. As part of this project, a numeracy audit of non-specialist mathematical courses revealed the breadth and depth of the numeracy demands in those programs, and the extent to which students needed to draw upon their academic numeracy skills. To address these issues a new credit-bearing topic *Academic and Professional Numeracy* has been developed and is now being delivered to students who are engaged a broad range of disciplinary fields. This topic can either be self-selected by students who recognise its potential value, or students with limited mathematical background will be referred to the

topic by academic staff. Increasingly, *Academic and Professional Numeracy* is being mandated as core in courses. Evaluation data collected during early implementation suggests that the topic is supporting students' learning needs with regard to developing their academic numeracy. The initial success of the topic has been reflected in the uptake that is occurring to include it as core in a range of courses. On-going evaluation and tracking of student progress in their field of study will continue to determine the effectiveness of this initiative.

REFERENCES

Brady, K. (2013*). Towards a university-wide approach to developing first-year students' academic literacy and professional communication skills.* Paper presented at the 16thInternational First Year in Higher Education Conference. Wellington: New Zealand.

Eastwood, K., Boyle, M., Williams, B. & Fairhall, R. (2011). Numeracy skills of nursing students. *Nurse Education Today*. 31, 815-818.

Galligan, L. (2013a). A systematic approach to embedding academic numeracy at university. *Higher Education Research & Development, 32*(5), 734-747.

Galligan, L. (2013b). Becoming competent, confident and critically aware: Tracing academic numeracy development in nursing. *Adults Learning Mathematics: An International Journal, 8*(1), 20-30.

Galligan, L. & Hobohm, C. (2015). Investigating students' academic numeracy in 1st level university courses. *Mathematics Education Research Journal*, *27*(2), 129-145.

Jennings, M. (2009). Issues in bridging between senior secondary and first year university mathematics*. In Proceedings of the 32nd Annual Conference of the Mathematics Education Research Group of Australasia. MERGA32 (pp. 273-280).*

Jourdan, N., Cretchley, P., & Passmore, T. (2007). Secondary-tertiary transition: what mathematics skills can and should we expect this decade?. In *Proceedings of the 30th Annual Conference of the Mathematics Education Research Group of Australasia (MERGA 30)* (Vol. 2, pp. 463-472). Mathematics Education Research Group of Australasia (MERGA).

Li, Q. (2003). Would we teach without technology? A professor's experience of teaching mathematics education incorporating the internet. *Educational Research*, 45(1), 61-77.

McClure, R., & Sircar, S. (2008). Quantitative literacy for undergraduate business students in the 21st century. *The Journal of Education for Business*, *83*(6), 369-374.

McNaught, K. & Hoyne, G. (2013). Testing program reveals deficient mathematics for health science students commencing university. In *Design, develop, evaluate: The core of the learning environment. Proceedings of the 22nd Annual Teaching Learning Forum*. Perth: Murdoch University.

McNaugth, K. & Hoyne, G. (2011). Mathematics for first year success. In *Proceedings of the14th Pacific Rim First Year in Higher Education Conference.* Fremantle, WA.

Oliver, B. (2013). Graduate attributes as a focus for institution-wide curriculum renewal: innovations and challenges. *Higher Education Research & Development, 32(3), 450-463.*

Parsons, S. & Bynner, J. (2005). *Does numeracy matter more*? London: Institute of Education.

Pell, G., & Croft, T. (2008). Mathematics support—support for all? *Teaching mathematics and its applications*, *27*(4), 167-173.

Pourshafie, T. K., & Brady, K. (2013). Academic advisors as agents of change in collaborations with faculty based staff. *Journal of Academic Language and Learning*, *7*(2), A165-A174.

Rylands, L. & Coady, C. (2009). Performance of students with weak mathematics in first year mathematics and science*. International Journal of Mathematical Education in Science and Technology*, 40(6), 741-753.]

Skalicky, J., Adams, A. & Brown, N. (2010). *Tertiary numeracy enquiry*. Centre for the Advancement of Learning and Teaching, University of Tasmania.

Taylor, J. & Galligan, L (2009). *Research into academic numeracy*. Poster presented to Australian Learning & Teaching Council First Year Experience Curriculum Design Symposium, Brisbane, Qld., 5-6 February.

Taylor, J., & Galligan, L. (2002). Overcoming beliefs, attitudes and past experience: The use of video for adult tertiary students studying mathematics in isolation. *Australian Senior Mathematics Journal*, 16(1), 20-33.

Thomson, S., & Hillman, K. (2010). *Against the odds: Influences on the post-school success of 'low performers'*. Adelaide: National Centre for Vocational Education Research.

Wilkes, J. (2010). Addressing the diversity of student mathematics preparedness for engineering surveying: A proposal for a technology supported learning scaffold. In R. Muldoon (Ed.), *Rethinking learning in your discipline. Proceedings of the University Learning and Teaching Futures Colloquium 2010.* Armidale, NSW: Teaching and Learning Centre, University of New England.