Snapshot of Mathematical Background Demographics of a Broad Cohort of First Year Chemistry Science Students

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Abstract

A case study of the background mathematical skills of a varied group of first year chemistry students (n = 455) is presented. Potential student demographic factors, including school leaver, mature age, non-English speaking background, and pre-requisite or prior assumed mathematical and chemistry knowledge, were examined. The student cohort had a diverse background in mathematical knowledge with only 53% meeting the pre-requisite mathematics admission criteria used in Queensland. A voluntary survey was completed by some students (n = 57) from the total cohort, which identified the individual mathematical background of students, their perception of the importance of mathematical skills in their study and their confidence with mathematics. The survey responses indicated that students generally did not have high confidence with their mathematical skills; especially for those with poorer mathematics backgrounds. Interestingly, all students were in strong agreement regarding the importance of mathematics to their study of chemistry. Correlation of the student mathematics background with a chemistry diagnostic test revealed that prior achievement in mathematics impacted on performance within chemistry. We propose that integration of foundational and enabling mathematical skills with curriculum would build student confidence and is more likely to have success in enabling science students to engage and succeed.

Introduction

In the higher education sector, both in Australian and international contexts, the last twenty years has seen significant change from an elite system to a mass system, generating considerably wider participation in higher education. The Review of Australian Higher Education Report (Bradley, Noonan, Nugent, & Scales, 2009) highlighted the need for wider participation of different sections of the community. Consequently many students who may not have aspired to undertake university studies have been potentially able to do so. Student engagement and retention issues have been highlighted as a consequence of the increase in diversity of the student population and increased wider participation over the past decade (Coates, 2008; Lawrence, 2005).

In addition to the issues of diversity and engagement, Quantitative Skills (QS) among some science and mathematics university students within Australia and around the world are alarmingly low. Previous research in the UK shows that there has been a gradual decline since the 1980s in the numbers of students participating in higher level mathematics (Noyes and Sealey, 2012) and that students entering university are deficient in areas of mathematics deemed necessary in specific university subjects (Hoyles, Newman & Noss, 2001; Tariq, 2002; Matthews, Belward, Coady, Rylands, & Simbag, 2012, Matthews, Hodgson, &

Varsavsky, 2013). For instance in biochemistry and chemistry, the ability to utilize simultaneous equations, understand and manipulate logarithms and algebraically rearrange equations is fundamental to these sciences in numerous undergraduate programs. Yet, students coming into first year science programs struggle with these mathematical concepts. Failure on the student's behalf to grasp these concepts and apply them in the context of their discipline of choice often leads to feelings of anxiety, stress and lack of self-confidence, potentially resulting in the student dropping out of university (Rylands & Coady, 2009; Matthews et al. 2012). Considerable evidence shows that weak quantitative skills prohibit successful achievement in science.

There are many reasons for the mathematical deficiency of students entering university and it is not just a result of the decline in the proportion of school students taking higher-level mathematics courses. In fact, in Queensland, where this research has been conducted, the number of students studying the higher level Maths B and C subjects has risen very slightly over the last three years (Queensland Studies Authority, 2014). Traditionally Maths A has been recommended by School authorities for students weak in mathematics whereas Maths C (which is taken in conjunction with Maths B) is seen as an advanced course appropriate for courses such as engineering and physics. In Queensland the Maths A curriculum (basic) covers financial mathematics, applied geometry and elementary statistics and probability. Maths B (intermediate) covers functions, periodic functions, exponential and logarithmic functions and their applications, derivatives and integrals, as well as applied statistical analysis. Maths C (advanced) covers vectors, matrices, groups, real and complex numbers, structures and patterns, periodic functions, calculus and dynamics. However the number of students taking the easier Maths A exceeds that of the other two mathematics subjects combined and there is a consistent migration from Maths B into Maths A in year 12, with students presumably wishing to maximize their university entrance score. The decline in Australian students taking more advanced mathematics subjects has previously been highlighted (McPhan, Morony, Pegg, Cooksey & Lynch, 2008). The small upward trend in Maths C enrolments since 2009 can be attributed to the bonus points being offered by the University of Queensland to applicants who have studied Maths C (Queensland Studies Authority, 2014).

The reality is that numerical and mathematical deficiencies must be dealt with at the university level for students wishing to pursue careers involving a reasonable reliance on quantitative skills. In chemistry and biochemistry first year courses the mathematical skills that are lacking include: logarithms (fundamental in the calculation of pH and buffers) (Watters & Watters, 2006), basic algebraic manipulation (fundamental for example in applying the ideal gas law, the Henderson-Hasselbach equation and the Michaelis-Menten equation), the ability to apply integrated rate equations in chemical kinetics, and to understand basic concepts in thermodynamics such as application of the van 't Hoff equation. As an example of these problems faced by many higher education establishments, in a recent Week 2, Semester 2, diagnostic quiz in a first year Biochemistry course asked the following questions (no calculators allowed):

1. What is Log_{10} (10000)? (46.7% of students obtained the correct answer of 4.)
2. What is the pH of a solution of 0.001M NaOH? (36% of students gave the correct answer of 11.)
3. How many grams of NaOH are needed to make a 250 mL of a 0.5M solution? (Molecular mass of NaOH is 40g/mol). Answer = 5 g (Only 32.25% were able to answer this correctly).

These results clearly identify shortcomings in students' knowledge regarding the basic concepts of logarithms and algebraic manipulations. Whilst this problem was highlighted many years ago in a study performed in the UK (Tariq, 2002), it seems that little has changed. The proposed future removal of the Mathematics B prerequisite for entry into science programs at some Queensland universities will only exacerbate the above problems. Whilst many institutions offer bridging courses to students enrolling in semester 1 courses, students undertaking such courses do not achieve at the level of their more mathematically prepared peers (Poladian & Nicholas, 2013).

Schoenfeld pointed out around 20 years ago, that thinking mathematically enables people to identify patterns and regularities in phenomena, the essence of deep learning (Schoenfeld, 1992). He also emphasises the distinction between "working rote exercises" and "doing mathematics", i.e. procedural vs conceptual mathematics. Mathematical thinking goes beyond the procedures of doing problems to understanding. The long held criticism of mathematics teaching in schools is that it focuses on procedural tasks at the expense of developing a mathematical way of thinking. It has been reported that prior academic achievement, particularly in pre-college mathematics and science, serves as one of the strongest predictors of academic performance and retention in STEM (Science, Technology, Engineering and Mathematics) degrees (Russell and & Atwater, 2005; Crisp, Nora, & Taggart, 2009). A number of studies in the US have investigated the progress of Under Represented Minority (URM) groups in STEM degrees in post-secondary education. Initiatives that provide URMs with out-of class support have had some measure of success in increasing persistence in STEM degrees (Herrera & Hurtado, 2011).

Jackson and Johnson (2013) have examined the various mathematics support programs that have been instigated at different universities to tackle the "Mathematics Problem". These fall into two major approaches, centralised facilities which provide assistance to students through drop-in or structured sessions, or alternatively embedded support as part of course delivery with both strategies incorporating online and face-to-face support materials. Additionally, the use of technologies such as online mathematics support modules in biological contexts has had some success in the US (Thompson, Nelson, Marbach-Ad, Keller, & Fagan, 2010; Thompson, Cooke, Fagan, Gulick, Levy, Nelson, Redish, Smith, & Presson, 2013) and should be considered in any plan to increase mathematical standards. Another approach has been to introduce new courses, such as the Scientific Thought and Methods course described by Koenig, Schen, Edwards and Bao (2012).

In the present study we examined the background of students enrolled in a first semester, first year Chemistry course and investigated the relationship between their prior studies, and their confidence in mathematics and chemistry, with their results in early assessment items of the course.

Methodology

Course Context

The student sample was drawn from within a single first year first semester chemistry course (unit of study/subject) that requires mathematical skills to be used in a science context. The course was listed in the degree structure as a core or elective course, typically in first semester first year, of over 25 degree program structures predominantly from science, (including the biosciences, biomedical and medical science, environmental science, forensic science, and engineering offered at a Queensland University. The course (Chemistry 1) is a chemistry theory and laboratory-based course and is presented through traditional lectures, tutorials and wet laboratories to explain and discuss fundamental chemical concepts. The lectures provide the theoretical content, the tutorials focus on solving problem sets, and the laboratory practical sessions provide hands-on learning experience that complements related lecture material. The combination of learning activities provides active engagement and participation in the learning processes required to gain a thorough understanding of the course material and content, and the use of mathematical skills is embedded throughout the curriculum. The course received very positive reviews in previous years from the compulsory university student course experience (SEC) survey at the end of the semester of offer (2012, 2013) with 66-77% of students (226, 274 enrolled) giving the course an overall satisfaction rating. Typically within their first year of study, students in this course are enrolled in different degree programs (see below) with different entry requirements and pre-requisite mathematical knowledge. The increased enrolment (n = 455 in 2014) and widening demographics of the student cohort provides the ideal case study for a snapshot of the relevance of a student's mathematical background and mathematics skills at the commencement of their studies as a science student.

Participants

Within the first semester first year chemistry course, 455 students were enrolled. For all students, the data were de-identified prior to analysis. The data were clustered by student degree, background type, degree program enrolment, and admission requirements including mathematics pre-requisite knowledge. Further background data was obtained from the University degree entry data, namely; commencing or continuing student, high school leaver or mature age student, and student preference for enrolled degree. Students enrolled in the course comprised two sub-cohorts: those students who were entering university; and students who had completed some prior study at university. Students were typically taking the normal course load (40CP, where CP is the credit point value and 4 courses are over 1 semester of study) for the semester of study in their degree program, which included the 10CP first year chemistry course. At census date (end of week 4 of a 13 week semester), 36 students (representing 7.3% of the cohort) had withdrawn or dropped their enrolment, and thus their data were not included in the detailed analysis of the study.

Survey Design and Survey Data Collection

Students enrolled in the course were asked to respond to a survey at the commencement of their semester of study (see Table 1) and were invited to participate in a mathematical support program that is under development at our University. The survey was distributed during laboratory practical sessions (for degree programs with Maths A, Maths B or no Mathematics pre-requisites) in weeks 4-5 of semester, at which point students had completed a chemistry diagnostic test (constructed from the course textbook test bank) and had confirmed their enrolment. Only students that signed the informed consent form and volunteered to participate in the study completed the survey. In 2014, there were 57 respondents, representing 14% of the total student cohort, and 10-50% of the cohort in the respective type of degree program enrolment clustered by admission requirements including mathematics pre-requisite knowledge. The survey was designed to determine the level of student prior achievement in mathematics, student individual confidence in their mathematical skills, and student perception of the importance of mathematical skills to their studies. The questions were selected to get a snapshot of students' academic backgrounds in mathematics, and students were asked to rank their confidence and perceptions of mathematics at the commencement of their studies. In this context, the survey was deliberately short to engage students to respond.

The survey started with a question that allowed students to identify which program they were enrolled in. Questions 2-3 were questions to identify the academic background of students in science (chemistry and biology). Questions 3-8 were questions to identify the academic background of students in mathematics (Maths A, Maths B, Maths C or none). Questions 9-10 were questions to identify whether the student had undertaken transition study that had

Table 1: Student Survey entitled ‘Maths Skills Project Questionnaire’

Please Circle your responses.

1	What degree program are you enrolled in? (if your degree is not listed on the right, specify in this space)	B. Science	B. Biomed. Science	B. Biomol. Science	B. Med. Science	B. Eng.
2	What level of Chemistry did you successfully complete at School or later (eg TAFE)?	Year 10	Year 11	Year 12	Other Chemistry	None
3	What level of Biology did you successfully complete at School or later?	Year 10	Year 11	Year 12	Other Biology	None
4	What level of Maths did you successfully study at School in year 11?	None	Other Maths	Maths A	Maths B	Maths C
5	What level of Maths did you successfully study at School in year 12?	None	Other Maths	Maths A	Maths B	Maths C
6	If you completed year 12 Maths **A**, what grade did you achieve? (VLA to VHA)[1]	VLA	LA	SA	HA	VHA
7	If you completed year 12 Maths **B**, what grade did you achieve?	VLA	LA	SA	HA	VHA
8	If you completed year 12 Maths **C**, what grade did you achieve?	VLA	LA	SA	HA	VHA
9	Did you do the Chemistry Bridging Course?	YES	NO			
10	Did you do the Maths bridging course?	YES	NO			
11	How important do you think Mathematics is for the study of Chemistry? 1, not at all important – 5, very important	1	2	3	4	5
12	How important do you think Mathematics is for the study of Biology? 1, not at all important – 5, very important	1	2	3	4	5
13	Rate your confidence in your current chemistry knowledge? 1, not at all confident - 5, very confident	1	2	3	4	5
14	Rate your confidence in your mathematical skills? 1 not at all confident, 5 very confident	1	2	3	4	5

[1] Refers to the level of achievement given by the Queensland Studies Authority at the end of year 12 where VLA = very low achievement, LA = low achievement, SA = sound achievement, HA = high achievement and VHA = very high achievement. SA is required for University admission.

been offered to students commencing their degree. Questions 11-12 investigated student perception of the importance of mathematical skills to their studies, where biology was included for a comparison to aid in validation of the responses to the chemistry question. Questions 13-14 were used to identify student individual confidence in their mathematical skills. The responses were either: a selection from five choices (Q1-8); yes/no answers (Q9-10) or ranked from very important (5) to not at all important (1) for questions assessing their confidence or perceptions (Q11-14). The survey results were tabulated into *Microsoft Excel*™ for processing and correlation with other data, and are presented in the Results section.

De-identified Student Data Collection and Analysis

For each de-identified student, their background data were identified as (i) enrolled degree program, (ii) admission requirements for the degree including mathematics pre-requisite knowledge, and (iii) student preference for enrolled degree program. The de-identified data were categorised based on commencing status (students who were progressing directly into the first semester, first year course) or continuing status (students who has completed some prior study at university), whether the student was a high school leaver (16-18 years old) or mature age student (19 -46 years old), and whether the student had a Non-English Speaking Background (NESB; i.e. speak a language other than English at home). For the continuing students, Grade Point Average (GPA, on a scale of 1-7) prior to enrolment in the first year course was ranked as (i) GPA ≥4 (equivalent to passing all courses) prior to enrolment in the course and (ii) GPA < 4. All student data were recorded in a de-identified manner and then grouped according to the number of students by degree and by category (e.g. admission requirements, survey participant) for the purposes of this study.

The students in the course were categorised by the 'type' of degree program enrolled in on the basis of entry requirements and mathematics pre-requisite or prior assumed knowledge. Discipline areas that have very high entry requirements typically have a cut-off for entry into the degree program equivalent to an Overall Position (OP) of 1 or Australian Tertiary Admissions Rank (ATAR) of 99, whereas degree programs with lower entry requirements have cut-offs equivalent to an OP of 16 or ATAR of 67. University program admission requirements in Queensland have various pre-requisite, and/or prior assumed knowledge levels in mathematics such as, no mathematics, Maths A, Maths B and Maths C, that are described above. Thus the categories were defined as:

- Program type A (Medical Science, very high entry requirements, Maths B Pre-requisite);
- Program type B (Specialised science such as bioscience, biomedical science, forensic science, moderate entry requirements, Maths B Pre-requisite);
- Program type C (Engineering, Education, moderate entry requirements, Maths B Pre-requisite, Maths C recommended);
- Program type D (Science, lower entry requirements, Maths A or B Pre-requisite)
- Program type E (Environmental Science, lower entry requirements, Maths A or B prior assumed);
- Other (mixed areas, no mathematics pre-requisites or prior assumed)

All the above student data was tabulated into *Microsoft Excel*™ for processing and analysis.

The de-identified student data were analysed as follows. The enrolled cohort of 455 students was grouped according to degree program type (type A, n = 29; B, n = 150; C, n = 65; D, n = 140; E, n = 65). Each group was subdivided into the following categories: commencing or continuing student, high school leaver or mature age student; student preference for enrolled degree; academic capital (high, moderate or low based on OP cut-off of the degree program or GPA prior to enrolment). The students completing the chemistry diagnostic quiz (n = 376), as well as students who volunteered to be part of the survey (n = 57) and completed the survey, were expressed as a percentage of the total cohort (n = 455) or as a percentage of the category by program type (see above). For the survey responses, further analysis was carried out by cross-correlation of responses to questions on the mathematical backgrounds of students with their confidence or perception on the importance of mathematics and then with the broader data available.

Results

Evaluation of student background through general demographics

Figure 1 shows the breakdown of the general background demographics of the students enrolled in the first semester first year chemistry course aggregated by Program type (type A-E) and expressed as a percentage of the student cohort in that program type. The results indicate that a high percentage (> 68%) of students are commencing students and high school leavers in all degree programs, except for type C engineering/education programs which attract more mature age students/continuing students and interestingly have the higher mathematics (Maths C) recommended knowledge for admission. All students in 'type A Medical Science' had a 1st or 2nd preference for doing the program, whereas all other programs had variable 1st, 2nd and lower preferences for doing the program. Not surprisingly, 'Type A Medical Science' attracted the high achieving students, which had a strong sense of purpose for program choice. High percentages of students with poor OPs or ATAR scores were enrolled in degree programs with lower overall entry requirements, and the inclusion of lower admission requirements (Maths A or Maths B). Notably, the 'type D Science' and 'type E Environmental science' programs had students with the poorest academic capital entering into university study, with 57-79% of students having an OP > 12. By contrast, high performing students with moderate or very high OPs or ATAR scores were enrolled in degree programs with moderate to very high entry requirements and stronger pre-requisite requirements for mathematical pre-requisite knowledge; Maths B. Students that were in the NESB category were enrolled in higher percentages in the type A Medical Science (38%) program, and were comparable in the remaining programs (10-22%). Continuing students (~13%) with poor academic progress (GPA <4) were represented in all programs except 'type A Medical Science'.

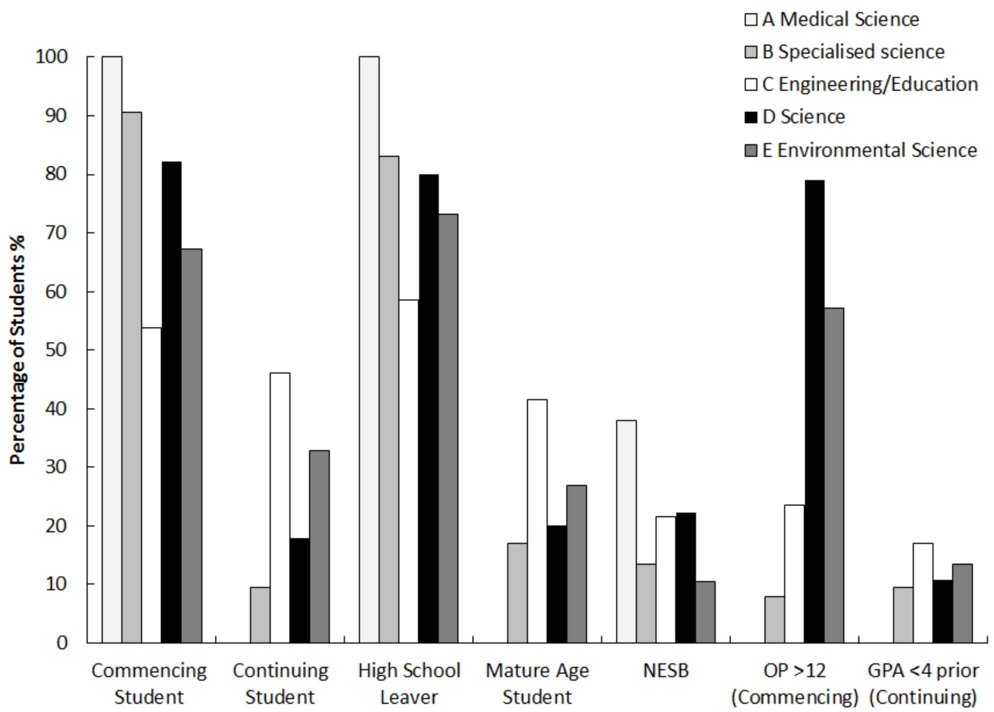

Figure 1: Background demographics of students (n = 455) enrolled in the chemistry course (expressed as percentage of the students with that background: Commencing student, Continuing student, High School Leaver (16-19 years), Mature Age Student (20-46 years), Non-English Speaking Background (NESB), Admission requirement of OP > 12 for commencing status and Grade Point Average (GPA) < 4 for continuing status) and by enrolment in degree program (A, Medical Science; B, Specialised Science; C, Engineering & Education; D, Science; E Environmental Science).

Mathematics Background Demographics Based on Admission Criteria

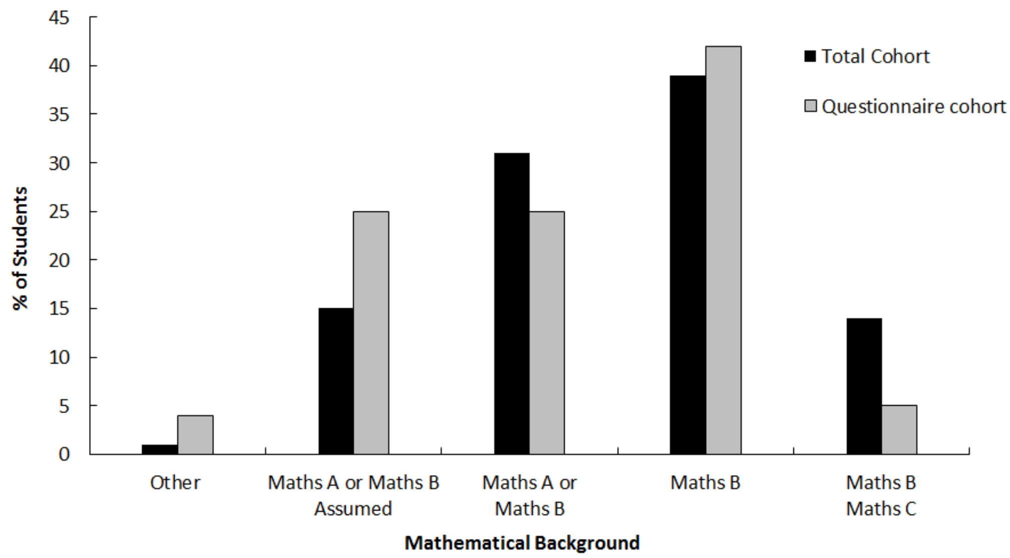

Figure 2: Mathematical background demographics (based on admission criteria) of students enrolled in the course expressed as a percentage of the total cohort of students (n = 455) and as a percentage of

students responding to the survey (n = 57): Maths B pre-requisite with Maths C recommended; Maths B pre-requisite; Maths A or B pre-requisite; Maths A or B prior-assumed; No Maths (Other).

The demographics of the students enrolled in the course aggregated by mathematical background (Maths B pre-requisite with Maths C recommended; Maths B pre-requisite; Maths A or B pre-requisite; Maths A or B prior-assumed; other mathematics) and expressed as a percentage of the student cohort (n = 455) and as a percentage of students responding to the survey (n = 57) is shown in Figure 2. The first year chemistry course, requires mathematical skills for formula manipulation, understanding of scientific notation, chemical calculations etc. The results indicate the percentage of students enrolled in the course who have achieved a sound mathematical background (based on admission criteria; Maths B) represent only 53% of the student body, with a significant percentage of students (up to 31%) potentially having less rigorous mathematical backgrounds (based on admission criteria; Maths A, or Maths A or B assumed), and a moderate percentage of students (up to 16%) having no guaranteed mathematical background at all upon admission for their degree program yet they have elected to study a chemistry course that requires a mathematical background. Figure 2 also shows the demographics of the students (by mathematical background) who had volunteered to complete the survey. The results indicate a mixed response rate dependent on the mathematical background of the students. Two interesting observations emerge from the data. There was a low response rate (5%) for those students with stronger backgrounds (based on admission criteria; Maths B required, Maths C recommended), a larger response rate (29%) for those students with weak backgrounds (based on admission criteria; Maths A or B prior assumed or no mathematics).

Survey Results

The majority of students responding to the survey were commencing students (84%), with continuing students comprising the remaining 16% of respondents of which 11% had good achievement (GPA>4.0). The NESB students were equally represented in the total cohort (18%) and the sub-group of students completing the survey (19%), thus the NESB was not a contributing factor to the analysis of the survey results.

The demographics of the students (by mathematical background based on program admission criteria) who had volunteered to complete the survey are discussed above (Figure 2), whereas questions 6-8 allowed identification of the specific mathematical background and achievement level of students completing the survey. From these latter responses, 44% of students had studied Maths A, 49% of students had studied Maths B or Maths B/C, and 7% being non-school leaver students. Figure 3 displays the distribution of responses indicating students who had studied higher levels of mathematics (Maths B and C) also had higher achievement levels (HAs and VHAs where HA = high achievement and VHA = very high achievement) and thus stronger mathematical backgrounds, as compared to the students who had studied lower levels of mathematics (Maths A). Notably, of the students who had studied Maths A, 32% had commenced with Maths B in year 11 and had changed to the lower level Maths A by year 12.

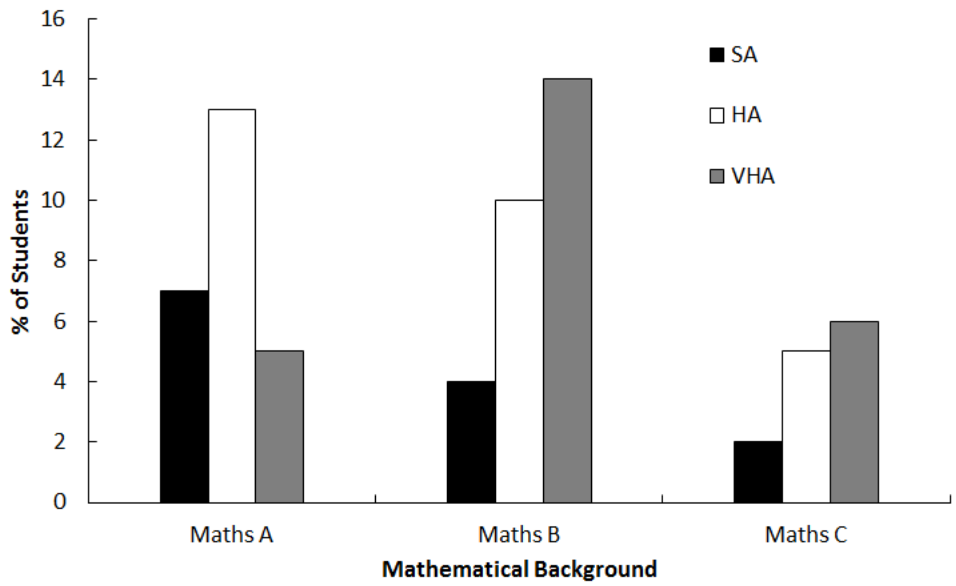

Figure 3: Mathematical background demographics (based on survey responses) of students enrolled in course and completing the survey expressed as a percentage of students responding to survey (n = 57): Maths A, Maths B or Maths C; SA = sound achievement, HA = high achievement and VHA = very high achievement.

Questions 2-3 identified the academic background of students in science (chemistry and biology). More students from the survey cohort had studied biology and completed it in year 12 (84%) as compared to students who had studied chemistry and completed it in year 12 (72%). Interestingly, of the students who did not complete chemistry in year 12 (n = 16), 88% still identified that mathematical skills were important or very important to their chemistry studies in question 11.

An average rating of 4.2 on the 5-point scale (5 = very important) was obtained for question 11 (student perception of the importance of mathematical skills to their chemistry) whereas a lower rating of 2.9 on the 5-point scale was obtained for question 12 (student perception of the importance of mathematical skills to their biology). The distribution of responses indicating the proportion of students who felt that mathematical skills were important to their chemistry or biology studies, is shown in Figure 4.

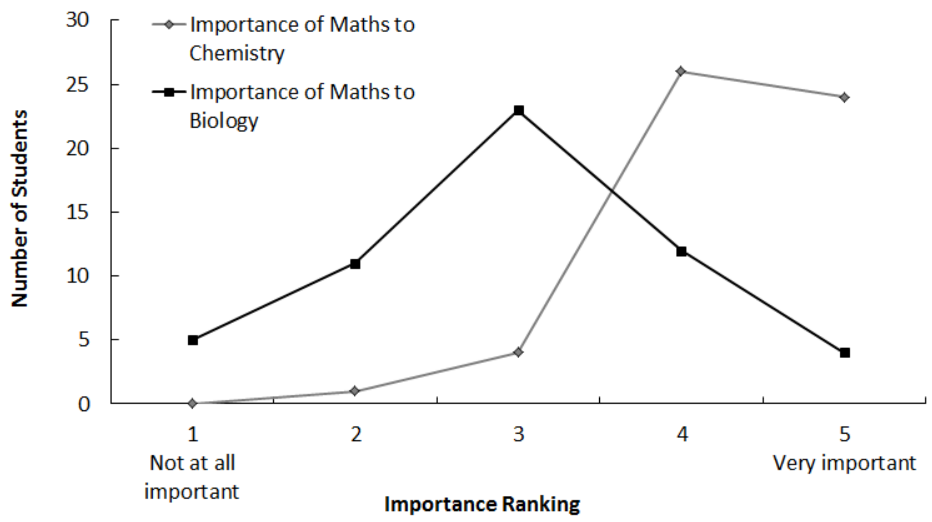

Figure 4: Students perception of the importance of Maths to chemistry or biology (based on survey responses) of students enrolled in the course and completing the survey expressed as number of students responding to questions 11 and 12.

An average rating of 2.6 on the 5-point scale (5 = very important) was obtained for question 13 (student confidence with chemistry) and a similar rating of 2.9 on the 5-point scale was obtained for question 14 (student confidence with mathematics). Figure 5 displays the distribution of responses indicating students were slightly more confident with their mathematical skills than their chemistry skills.

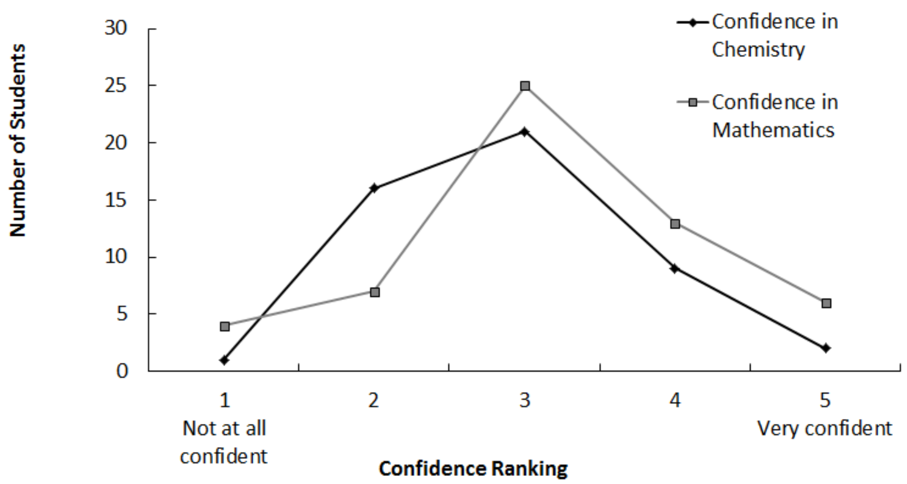

Figure 5: Students' perception of confidence in chemistry or mathematics (based on survey responses) of students enrolled in the course and completing the survey expressed as number of students responding to questions 13 and 14.

Only 9% of students had undertaken transition study in the form of a bridging course in Mathematics (question 10), with all of these students rating their confidence in mathematics as low (1, 2 or 3 on the 5 point confidence scale, where 1 is not at all confident). Similarly only 16% had completed a bridging course in chemistry (question 9), with all but one of these students rating their confidence in mathematics as low (1, 2 or 3 on the 5 point confidence scale where 1 is not at all confident).

Mapping of Mathematics Background Knowledge with a Diagnostic Assessment Item

The chemistry, science and mathematical backgrounds of the survey cohort were then compared with the early assessment item in chemistry in first semester. The chemistry diagnostic test quizzes students on both background chemistry knowledge and mathematical manipulation of chemistry problems. Students who had listed "other" as their mathematical background (n = 4) in the survey responses were removed from this analysis. About 60% of the survey cohort obtained a pass grade (5-10 out of 10) on the chemistry diagnostic test. The majority of students who passed the chemistry diagnostic test had a Maths B or Maths B/C background in combination with chemistry prior knowledge (Figure 6). Students with prior chemistry knowledge and Maths A background had a higher representation in the fail category of the chemistry diagnostic results. Figure 7 shows this trend was also observed for the total cohort when mapped against the maths prior knowledge based on admission criteria of program.

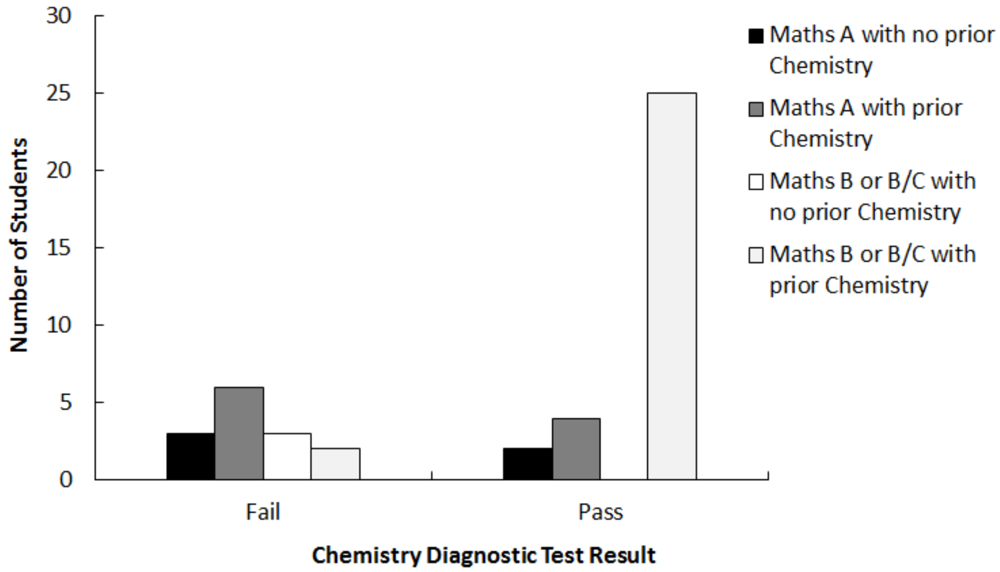

Figure 6: Students' overall performance in chemistry diagnostic quiz based on their prior mathematical and chemistry study.

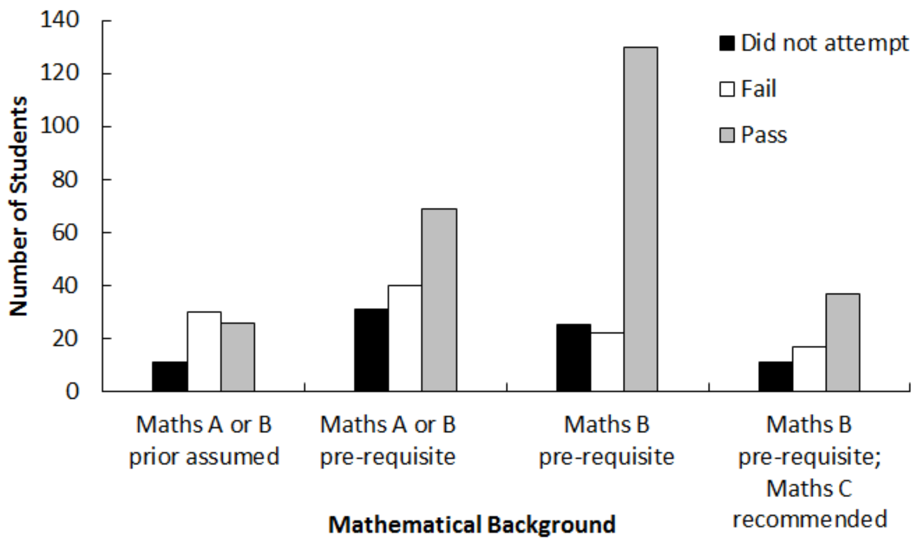

Figure 7: Students' performance in chemistry diagnostic quiz by maths prior knowledge based on admission criteria of program

Issues Arising from the Study.

The student cohort in Chemistry (first semester, first year) provided the ideal case study for a snapshot of mathematics skills of primarily first year students from a student cohort that has diverse demographics arising from the Bradley agenda (Bradley, Noonan, Nugent & Scales, 2009) of wider participation and due to Chemistry 1 being listed as a core or elective course choice in 25 degree programs from a Queensland University with varied overall and mathematics admission requirements. From this study it was noted that success in formative assessment in chemistry was enabled by a stronger mathematical background (Maths B, Maths B/C) in combination with chemistry prior knowledge. This study supports the conclusion that students entering university and electing to take science subjects requiring background knowledge in mathematics and science have an increased academic risk if their academic background does not include sound achievement of pre-requisite knowledge.

The context of student perception was of interest in this case study. Students, irrespective of their background knowledge, strongly identified the importance of mathematical skills to their chemistry studies. By contrast the perceived importance by students of mathematical skills to their biology studies was notably lower. The confidence level of students was an issue for concern. Although a large proportion of students felt that mathematical skills were important to their chemistry studies, the overall confidence of students to both their mathematical studies and chemistry was only of an average level. This was highlighted by those students undertaking bridging courses typically having little to no confidence with their chemistry and/or mathematical skills, and a larger response rate to the survey and intended participation in the Mathematics support program by students with weaker backgrounds (Maths A or B prior assumed or no mathematics).

Although the sample size for the survey cohort was small (n = 57), an interesting issue was that for the students with a Maths A background, 32% of students had changed from Maths B in year 11 to Maths A in year 12. This is consistent with recent statistics reported by the Queensland Studies Authority (Queensland Studies Authority 2013). There is potentially a compound effect here. In the survey cohort it was noted that the achievement levels of students completing Maths B were higher than Maths A; with a greater number of Maths B students obtaining a HA or VHA.

Analysis of the demographics of the survey cohort indicated that there was a higher response rate by students with poorer mathematical backgrounds. Survey responses rates can be low due to student non-engagement. However this survey was administered with a clear background introduction and thus the overall low response to the survey from the total cohort may indicate a non-awareness of the importance of successful mathematics study or lack of confidence or over confidence in the remaining students with poorer backgrounds.

A Strategy for a Mathematical Support Program.

A potential way forward is to develop a mathematical support process and tools that provide an experiential approach to learning, with a view to helping students to build on their prior knowledge and understand how to construct new knowledge from authentic experience (Rodgers, 1994). Inclusive in improving student retention is to help students become more self-confident in their own abilities. Although bridging programs between high school and university provide some transitional support, this approach is optional and many students do not participate in bridging programs, perhaps because they do not appreciate that quantitative skills are needed in chemistry or biology. Formative assessment can provide students with early feedback on their progress at university. A mathematics support program is under development at our University and is based on similar programs in other institutions, such as La Trobe University (Jackson & Johnson, 2013). Students who perform poorly in these formative tasks will be offered the opportunity to undertake the support program to develop their mathematical knowledge. Provision of context-based worksheets should enable weaker students to see the contextual basis of mathematical methods related to their specific discipline. Further provision of online tools should enable the students to practice the appropriate mathematical skills, in a low-pressure manner, until they have mastered the required skill and gained confidence.

Conclusions

From this study it was noted that the most important factor influencing academic progression of chemistry students was the strength of mathematical background, and student confidence with their mathematical skills. Confidence is lower for those with poorer backgrounds in mathematics and chemistry. This highlights the need for better integration of curriculum with foundational and enabling numerical and mathematics skills and proficiency. A focus on mathematical skills in context for curriculum and teaching is important in the context of engaging students in science as a career, and timely as Australian Universities consolidate their threshold standards and program learning outcomes for science degree offerings under a new regulatory framework.

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References

Bradley, D., Noonan, P., Nugent, H., & Scales, B. (2009). *Review of Australian Higher Education:Final Report.* Canberra: Department of Education, Employment and Workplace Relations. Retrieved on February 18, 2013, from http://www.innovation.gov.au/HigherEducation/ResourcesAndPublications/ReviewOfAustralianHigher Education/Pages/ReviewOfAustralianHigherEducationReport.aspx

Coates, H. (2008). *Attracting, Engaging and Retaining: New Conversations about Learning.* Australasian Student Engagement Report. Camberwell: Australian Council for Educational Research. Retrieved on February 18, 2013, from http://research.acer.edu.au/ausse/16/

Crisp, G., Nora, A. & Taggart, A. (2009). Student Characteristics, Pre-College, and Environmental Factors as Predictors of Majoring in and Earning a STEM degree: An analysis of Students attending a Hispanic Serving Institution. *American Educational Research Journal*, *46*, 924-942, Retrieved on May 21, 2014 from http://www.jstor.org/stable/40284742

Herrera, F. & Hurtado, S. (2011). AERA lecture "Maintaining Initial Interests: Developing Science Technology, Engineering and Mathematics (STEM) Career Aspirations among Underrepresented Racial Minority Students. Retrieved on May 21, 2014 from http://www.learningace.com/doc/1805670/fa9bce40c60fd6e611b2650274547292/aera-2011-herrera-and-hurtado-maintaining-initial-interests

Hoyles, C., Newman, K., & Noss R. (2001) Changing patterns of transition from school to university mathematics. *International Journal of Mathematical Education in Science and Technology*, *32*, 829-845.

Hunt, D. N. & Lawson, D. A. (1996). Trends in mathematical competency of A-level students on entry to university. *Teaching Mathematics and its Applications*, *15*, 167-173.

Jackson, D. C. & Johnson, E. D. (2013). A hybrid model of mathematics support for science students emphasizing basic skills and discipline relevance, *International Journal of Mathematical Education in Science and Technology*, *44*(6), 846-864. http://dx.doi.org/10.1080/0020739X.2013.808769

Koenig, K., Schen, M., Edwards, M. & Bao, L. (2012). Addressing STEM Retention through a Scientific Thought and Methods Course, *Journal of College Science Teaching* , *41*, 23-29.

Lawrence, J. (2005) Addressing diversity in higher education: two models for facilitating student engagement and mastery. In: Proceedings of the 28th *HERDSA Annual Conference: Higher Education in a Changing World*, Sydney, NSW: Higher Education Research and Development Society of Australasia, Inc. Retrieved on February 18, 2013, from http://www.herdsa.org.au/wp-content/uploads/conference/2005/papers/lawrence.pdf

Matthews, K. E., Belward, S., Coady, C., Rylands, R. & Simbag, V. (2012). The state of quantitative skills in undergraduate science education; Findings from an Australian Study. Report associated with an ALTC funded project. Retrieved on May 21, 2014 from http://eprints.jcu.edu.au/26400/1/QS_report_July2012.pdf

Matthews, K. E., Hodgson, Y. & Varsavsky, C. (2013). Factors influencing students' perceptions of their quantitative skills. *International Journal of Mathematical Education in Science and Technology*, *44*(6), 782-795.

McPhan, G. Morony, W., Pegg, J., Cooksey, R., & Lynch, T. (2008) Maths? Why not? Canberra: Department of Education, Employment and Workplace Relations.

Noyes, A. & Sealey, P. (2012). Investigating participation in advanced level mathematics: A study of student drop-out. *Research Papers in Education*, 27(1), 123-138.

Poladian, L. & Nicholas, J. (2013). Mathematics Bridging Courses and Success in First Year Calculus. *Lighthouse Delta 2013: The 9th Delta Conference on teaching and learning of undergraduate mathematics and statistics, 24-29 November 2013, Kiama, Australia* Retrieved on May 26, 2014 from http://delta2013.net/documents/program/1A-4-

Poladian.pdf
Queensland Studies Authority (2014). Trends & Issues in curriculum and assessment: Identifying enrolment trends in senior mathematics and science subjects in Queensland schools. Retrieved on May 21, 2014 from https://www.qsa.qld.edu.au/29940.html
Queensland Studies Authority (2013). Queensland Studies Authority: Subject enrolments and levels of achievement. Retrieved on May 19, 2014 from https://www.qsa.qld.edu.au/downloads/publications/qsa_stats_sen_subjects_2013.pdf
Queensland Studies Authority (2008). Mathematics senior syllabus. Brisbane: The State of Queensland (Queensland Studies Authority) Retrieved on May 23, 2014 from http://www.qsa.qld.edu.au/downloads/senior/snr_maths_a_08_syll.pdf http://www.qsa.qld.edu.au/downloads/senior/snr_maths_b_08_syll.pdf http://www.qsa.qld.edu.au/downloads/senior/snr_maths _c_08_syll.pdf
Rodgers, C.R. & Frieberg, H. J. (1994). Freedom to learn (3rd Ed). Columbus, OH: Merrill/MacMillan, Available Online: http://www.educationau.edu.au/archives/cp/04f.htm
Russell, M. L. & Atwater, M. M. (2005). Travelling the Road to success: A discourse on persistence throughout the science pipeline with African American students at a predominantly White Institution. *Journal of Research in Science Teaching*, *42*(6), 691-715.
Rylands, L. J. & 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.
Schoenfeld, A. H. (1992). Learning to think mathematically: problem solving, metacognition, and sense making in mathematics. In D. Grouws (Ed.) Handbook for Research on Mathematics Teaching and Learning, Chapter 15 Macmillan, NY.
Tariq, V. (2002). Decline in numeracy skills among bioscience under graduates. *Journal of Biological Education*, *36*(2), 76-83.
Thompson, K.V., Nelson, K.C., Marbach-Ad, G., Keller, M., & Fagan, W.F. (2010). Online interactive teaching modules enhance quantitative proficiency of introductory biology students. *CBE Life Science Education*, *9*(3), 277-83.
Thompson, K.V., Cooke, T. J., Fagan, W. F., Gulick, D., Levy, D., Nelson, K. C., Redish, E.F., Smith, R. F. & Presson, J. (2013). Infusing quantitative approaches throughout the biological sciences curriculum. *International Journal of Mathematical Education in Science and Technology*, *44*(6), 817-833.
Watters, D.J. & Watters, J.J. (2006). Student Understanding of pH:"I don't know what the log actually is, I only know where the button is on my calculator". *Biochemistry and Molecular Biology Education*, *34*, 278-284.