

# SUPPORTING THE DEVELOPMENT OF QUANTITATIVE SKILLS IN FIRST YEAR CHEMISTRY

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## ABSTRACT

To address the deficiencies in student quantitative skills, an extensive project was implemented during 2012 in a large enrolment first year chemistry subject. An initial exercise involved an extensive survey of all students to determine the diversity of the student cohort. Students also completed a diagnostic test which was developed to facilitate self-diagnosis of concepts that were particularly challenging. A collection of tutorial materials were prepared to assist students in developing their quantitative skills. These materials included a support booklet entitled "Maths for Chemistry – Essential Skills for First Year Chemistry" which was disseminated to all students. The aim of the booklet was to assist students who did not satisfy the level of assumed knowledge, but also to act a refresher for all students. Online self-test quizzes were generated for each topic, allowing students to focus on particular concepts that were hindering their understanding of chemistry. This project was one of numerous initiatives implemented by the School of Chemistry and Forensic Science with the overall result a significant improvement in the pass rate of the subject, and based on focus groups conducted at the end of Autumn 2012, a more enriched learning experience for students.

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## INTRODUCTION

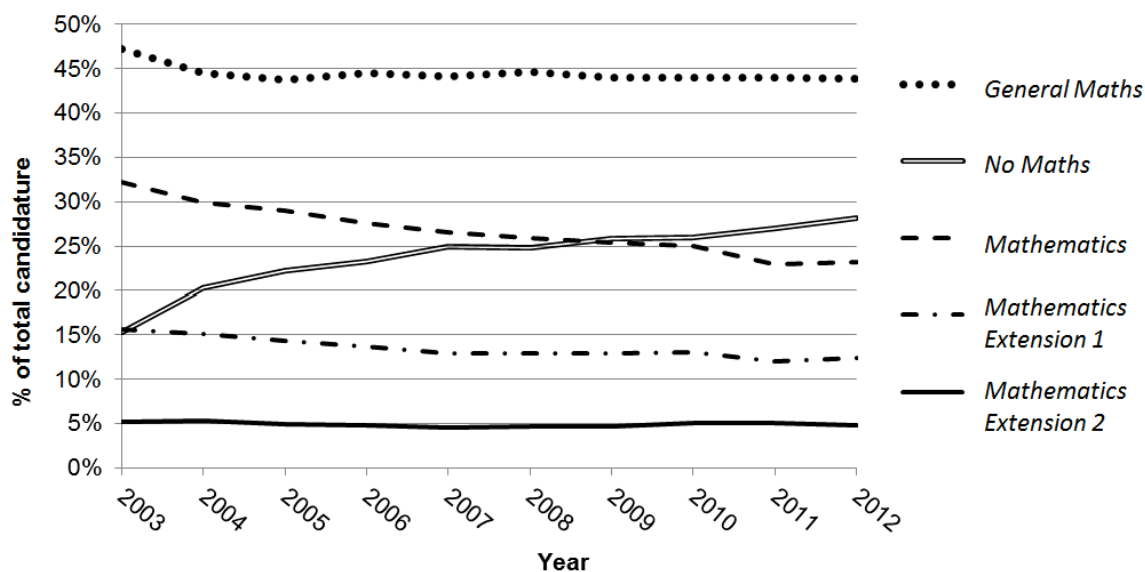
*The universities cannot ignore the downward change in mathematics preparedness affecting entering students.*

Professor Gavin Brown

The quantitative skills of students entering first year tertiary science studies have been in decline for a number of years. This is an observation supported by a significant downward trend in the proportion of students studying advanced mathematics at secondary school. Such a trend has been attributed to factors such as the inadequate training of secondary school teachers and the negative attitude of students towards mathematics (Brown, 2009).

The importance of a strong background in mathematics is pivotal to the successful study of wider science disciplines such as chemistry, physics and biology. An extensive study by Sadler and Tai (2007) identified that a rigorous high school mathematics background was a significant predictor of performance in biology, chemistry, and physics courses at the tertiary level. While the correlation between mathematics preparedness and disciplines such as physics and chemistry supported common thinking, the link between mathematics and the biological sciences was less intuitive (Sadler & Tai, 2007).

Despite the literature supporting the study of mathematics and its importance for success in tertiary science education, the number of students enrolling in mathematics at the senior secondary level is in decline. A review of data from the NSW Board of Studies between the period 2003 and 2012 indicated that almost 30% of all students are currently electing not to study any mathematics at the Higher School Certificate (HSC) level, as shown in Figure 1. This trend is not isolated to NSW, with comparable national mathematics participation rates also in decline (Ainley, Kos, & Nicholas, 2008). While it not clear the total extent to which science students are represented in the cohort not studying mathematics, a survey of Year 12 science students (n=1157) indicated that only 79% also study mathematics (Ainley, Kos, & Nicholas, 2008). This data would support the general consensus that many first year science students are arriving at university lacking necessary numeracy skills (Belward, Mullamphy, Read, & Sneddon, 2007).



**Figure 1: Enrolments in NSW HSC Mathematics subjects as percentage of the entire candidature (2003-2012)**

The lack of mathematics preparedness for first year chemistry was considered a significant challenge at our institution. *Chemistry 1* is a large enrolment, first year subject delivered to the bulk of Faculty of Science undergraduate students. In the previous few years, failure rates in *Chemistry 1* were observed to be increasing. A review of completed assessment material from previous semesters strongly supported the hypothesis that this increasing failure rate was in part attributable to a lack of confidence and ability in completing the necessary calculations. During 2011, the failure rate in *Chemistry 1* reached a maximum of 41%. Failure rates such as this can have a significant impact on the journey of students as they navigate the difficult transition into higher education (Gabb, Milne and Cao, 2006), hence the requirement for immediate action.

A First Year Experience grant was developed to further explore the observed problem and develop strategies to address the issue of mathematics preparedness in first year chemistry. According to Kift, six principles are critical for curriculum development at the first year level: Transition, Diversity, Design, Engagement, Assessment and Evaluation & Monitoring (Kift, 2009). Of particular importance to this current project were the principles of transition and design. In regard to transition, the first year curriculum “*should be designed to mediate and support transition as a process that occurs over time*” (Kift, 2009). This involves the intentional integration of appropriate support to ensure a seamless transition from their previous educational experience, which is often insufficient for success in first year higher education. The second key transition principle, design, requires the development of student centred and scaffolded resources. It is necessary to provide the foundation and integration of support materials, noting that engagement of students is as important as the development of the materials. Both of the aforementioned transition principles were actively considered when undertaking this project.

The first component of this project was the survey of all students commencing *Chemistry 1* in Autumn 2012 (n=794). This was undertaken to capture the diversity of both the mathematics and chemistry background studies of our student cohort. Research suggests that student cohorts are becoming increasingly diverse from both a cultural and academic perspective (Kajander & Lovric, 2005). The survey results indicated that HSC General Mathematics was the highest level of study for 33% of our student cohort, despite HSC Mathematics (one level advanced) being prescribed as assumed knowledge. Of equal concern were the 38% of students who had not studied any chemistry at a senior secondary level. Additional information was also requested about the completion of any remedial bridging courses. Such courses are offered by numerous institutions to aid students who self-identify as lacking necessary background knowledge. Despite the significant proportions of students without HSC Chemistry or HSC Mathematics (or the more advanced subjects), only a small number completed bridging courses. For chemistry, 22% of students lacking HSC Chemistry completed a chemistry bridging course. Preparedness for mathematics was even more concerning,

with only 12% of the group without the necessary background knowledge completing a mathematics bridging course.

Having established the extent of diversity amongst our first year cohort, a series of scaffolded resources were disseminated to all students to address the anticipated deficiencies in quantitative skills. A diagnostic test was developed to allow students to self-diagnose whether any concepts were particularly challenging (logarithms, algebra etc.). For students who did identify challenging concepts, a collection of materials to assist in developing their quantitative skills was made available. A booklet entitled "Maths for Chemistry – Essential Skills for First Year Chemistry" was produced and disseminated to all *Chemistry 1* students. The aim of the booklet is to assist students who do not satisfy the level of assumed knowledge, but also to act a refresher for all students. Online self-test quizzes were generated for each topic, allowing students to focus on particular concepts that were hindering their understanding of chemistry.

The final results achieved by students in *Chemistry 1* were correlated with the data collected during the survey on background studies in mathematics and chemistry. A strong correlation between the level of background study and success in the subject was observed. While the mean failure rate of the subject was 16%, the subject failure rates of students with and without background studies in chemistry and mathematics were 6% and 35% respectively. The overall mark achieved by these cohorts was also significantly different ( $p < 0.05$ ). The completion of a bridging course was also observed to have a significant effect on success in the subject. For the cohort who had not studied chemistry at the senior secondary level, completion of a bridging course resulted in a significant improvement in the final mark achieved ( $p = 0.05$ ) and the failure rate decreased.

The specific impact of mathematics preparedness was also analysed in Chemistry 1. Consistent with the observations of Sadler and Tai (2007), successful subject completion and final marks were directly correlated with the level of mathematics studied at the HSC level. The only deviation from this trend was the achievements of the cohort who did not study senior secondary mathematics, with a superior pass rate observed. Table 1 summarises the results observed.

**Table 1: Effect of mathematics preparedness on results achieved in Chemistry 1**

Highest Level of Maths	n	Fail Rate of Cohort (%)	Average Mark (%)
No HSC Maths	36	22	55
HSC General Maths	190	30	55
HSC Mathematics	279	12	64
HSC Extension 1 or 2	165	5	67
<b>Mean All Students</b>		<b>16</b>	<b>62</b>

Key principles considered during the design of these materials were sustainability and accessibility. All resources were made available to students via the learning management system (Blackboard™) utilised at our institution. This mechanism of dissemination satisfied the principle of accessibility. It also provided useful evaluation data through the statistics tracking mode which indicated sustained usage of the materials, with spikes observed around major assessment tasks. The ongoing sustainability of the resources beyond the granting period was also a priority and these resources have again been disseminated to students in Autumn 2013. The effectiveness of the project will again be evaluated through the use of student focus groups and assessment task achievements.

Given the positive outcomes observed through the provision of support around quantitative skills, a Faculty wide initiative is being implemented. This will involve a systematic review of all first year science subjects to identify all quantitative skills necessary for first year studies. The project will also further develop and refine the diagnostic testing strategies for identifying at risk students in the first

year science student cohort. This approach will build upon an existing project at this institution for assessing the mathematic skills of newly enrolled Engineering students.

This project was one of numerous initiatives implemented by the School of Chemistry and Forensic Science with the overall result a significant improvement in the pass rate and based on focus groups conducted at the end of Autumn 2012, a more enriched learning experience for many students. In Autumn 2011, the failure rate for *Chemistry 1* reached 41%. Following the implementation of these initiatives, the overall failure rate improved to 16%. An improvement in student outcomes was also observed in *Chemistry 2*, with failure rates also decreasing, even though no significant reforms in curriculum design or assessment arrangements were made during 2012 in this subject. It is strongly believed that the initiatives implemented during *Chemistry 1* contributed to the development of confident learners who were prepared for the journey of higher education.

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