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Background

The forum was organized by the First Year in Maths (FYiMaths) project and hosted by the Institute of Innovation in Science and Mathematics Education (IISME) in response to a growing awareness of the many challenges faced by mathematics academics dealing with diverse student cohorts.

FYiMaths (an Office of Learning and Teaching funded project) team members recently conducted interviews with mathematics academics and found a significant concern about the mathematics background of students entering degrees in science and engineering, which in many cases is inadequate for the chosen degree. Many universities are attempting to address this with diagnostic testing, bridging programs, reviewing curriculum and by providing maths support centers. In many cases, the deficiency of mathematics preparation for these degree programs is due to an 'assumed knowledge' entry requirement for mathematics subjects rather than a strictly required mathematics prerequisite.

At the same time there is widespread concern that the numbers of students studying an intermediate or advanced level of mathematics[1] in senior high school is falling, that there are insufficient qualified maths teachers (Barrington 2012) and that the national results for primary school numeracy are lower than many other countries (Thomson, De Bortoli et al. 2013). As universities are attempting to deal with less mathematically skilled students in science and engineering, it appears that this is symptomatic of a larger problem.

Attendees: 145 registrations

Universities represented: 26 Australian and one New Zealand.

Background of Participants: mathematics, physics, engineering, environmental science, physical science, biology, chemistry, information technology, education, curriculum experts, academic support.

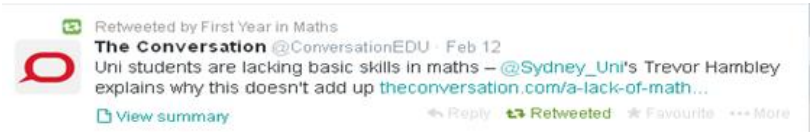
The aim of this national forum was to enable the science, mathematics, engineering and education specialists, peak mathematical bodies and education policy makers to discuss their concerns, find out about university responses and the impact of the current system of assumed knowledge requirements.

[1] In most states there a range of mathematics subjects in the final years of high school which we classify as general, intermediate and advanced. The assumed knowledge in mathematics for entry to science and engineering programs varies, but is generally at the intermediate level.

Keynote Speakers

Opening presentations by Professor Trevor Hambley, the Chief Scientist, Professor Ian Chubb and Professor Terry Speed, provided 3 different perspectives on the importance of mathematics undergraduate education to the future of STEM programs.

- **Professor Trevor Hambley, Dean of Science, University of Sydney,** opened proceedings by reflecting on the pivotal role of mathematics in the study of science and the need to communicate this more clearly to teachers, parents and students. He introduced Adam Spencer as the newly appointed University of Sydney's Mathematics and Science Ambassador, whose role will involve promoting the opportunities and value of doing maths and science.



- **Professor Ian Chubb, Chief Scientist of Australia**, provided the opening keynote address, encouraging the forum participants to view themselves as a community of interest with the potential to influence education policy. He spoke of the contrasting growth in enrolments in STEM degrees, but the decreasing numbers of students studying high level mathematics. He encouraged participants to do what they can to support the training and professional development of teachers, strive to capture students' interest in mathematics through quality teaching and to attempt to bridge the school/university divide. He suggested strategies for this included universities offering professional development programs for teachers, more cross disciplinary collaboration between the science, engineering and mathematics disciplines in universities and making the message clear to all that (the right) maths is the foundation stone for studying STEM degrees.

- **Keynote Speaker, Professor Terry Speed, Principal Research Scientist, Walter and Eliza Hall Institute,** who was recently awarded the 2*013 Prime Minister's Prize for Science,* spoke of his own experiences of teaching and stressed the importance of context for teaching mathematics and statistics, providing background to explain why students need to learn the maths linked with what they will use it for in the future. His key point was that teaching needed to provide the 'application before theory' in order for students to make sense of it. Professor Speed's inspiring presentation reflected the passion of the audience for mathematics.

While the issues are complex and span secondary and higher education sectors, the key messages from these speakers focused on what university academics can do to effect change. Ian Chubb encouraged universities to address the lack of professional development opportunities for teachers in mathematics, by developing specialist training programs and building strategic alumni for their

teaching graduates. In order to make maths the foundation stone of STEM programs academics need to work together in developing maths curriculum that is connected to its application in STEM and builds on students' prior knowledge and experiences.

Presentations on teaching practices addressing low maths skills

The forum presentations covered a wide range of practices and programs that have been developed in response to the low level of maths skills of students entering tertiary science and engineering courses. The presentations demonstrated how universities are reviewing the way they teach mathematics and structure their courses in order to redress these deficiencies.

A series of short presentations provided snapshots of initiatives across a range of institutions:

- **Jackie Nicholas, Mathematics Learning Centre, The University of Sydney**, reported on the range of entry points available at the university and positive impact of the bridging program on students who did not have the required *assumed knowledge*.

- **A/Prof. Katherine Seaton, La Trobe University**, reported on La Trobe's review of mathematics curriculum following a change in mathematics prerequisites and course structure to address students' diverse backgrounds.

- **Dr Danica Solina, UTS:Insearch** reported on the approach taken in a pathways course teaching physics to students with weak mathematics preparation. The program involved a series of exercises and homework tasks designed to influence student self-awareness, improve study skills and reinforce course content.

- **Dr Irene Penesis, Australian Maritime College, University of Tasmania,** reported on a project in progress to develop mathematics courses to provide a pathway from TAFE programs to engineering at university.

- **Jo-ann Larkins, Federation University (formerly Monash University, Gippsland)** spoke about the development process for a new foundation mathematics unit for science students, which involved consultation across the science disciplines to identify the key areas of mathematics they needed to address and develop course materials with contextualized problems and materials.

- **A/Prof. Carmel Coady and Dr Ragbir Bhathal, University of Western Sydney,** reported on a revised approach to teaching mathematics to engineering students, involving a readiness test, revised curriculum to integrate maths with engineering content and a range of support services.

- **Dr Layna Groen, UTS**. At UTS students entering science and engineering courses do a mathematics readiness survey to determine the appropriate pathway for their first year,

which includes an additional foundation maths course for students not achieving the required grade. Mastery learning is incorporated, involving a set of learning and assessment tasks that are criterion referenced and sets a prescribed level of achievement. When students do not meet this standard in assessment, remedial tasks provide students with further opportunities to achieve success.

Participants also heard a number of longer presentations, as detailed below.

- **Dr Glennys O'Brien, University of Wollongong and Dr Gwen Lawrie, University of Queensland** spoke about the relationship between assumed knowledge in mathematics and first year chemistry. They discussed two projects involving the development of diagnostic tests, with feedback and supported learning programs to address the diverse mathematical skills of students in first year chemistry. They identified that the testing improved students' self-awareness and confidence in the application of mathematics in chemistry. Additional learning resources supported improved student outcomes; however students still experienced difficulties in areas such as quadratics, logs and exponentials. The projects' findings indicate that teaching foundation mathematics contemporaneously with first year chemistry is not successful, as students need to have these mathematical skills before they apply them in Chemistry, particularly those concerning abstraction and problem solving.

- **A/Prof. Kim Beswick, President of the Australian Association of Maths Teachers, University of Tasmania,** spoke about the importance of building students' understanding of maths, through changing the way it is taught and assessed at all levels of education. The current education system focuses on performance in assessment, rather than depth of understanding, which impacts on students' ability to apply mathematics beyond Year 12. It is clear that broad cross-sectoral collaboration is needed to address the problems in mathematics at university.

- **Professor Jo Ward, Dean of Science, Curtin University**, provided a Dean's perspective on the issues that had been discussed in the forum thus far. She reiterated the importance of the STEM disciplines working together to develop strategies to address the issues. In terms of individual institutions she urged participants to approach their Dean's with developing solutions that meet institutional key performance indicators, and to pursue these vigorously by collecting data, presenting problems and identifying solutions.

- **Michael Jennings, University of Queensland and Dr Janelle Wilkes, University of New England.** Michael Jennings presented the GetSet diagnostic test used at the University of Queensland. The test has been useful in alerting students to what they need to know to study engineering, gauges students' levels of understanding and identifies any at risk students. Janelle Wilkes reported on UNE's customisation of this test (EngCAT) to gain a better understanding of their first year engineering and science students and improve progression rates for the program. This was a useful case study of how an institution can adapt a test for their own needs, including the practicalities of IT and

consultation across the different schools of science. Both found a correlation between the test and student's GPA.

- **Kelly Matthews, University of Queensland,** presented on a project to assess the mathematical and statistical knowledge of life sciences students in order to identify how this knowledge is used in science and inform curriculum development. The project used the Quantitative Skills Assessment of Science Students (QSASS) to test applied maths and statistical knowledge of final year students and provide some indictors of the level of maths and statistics knowledge needed by students. It also highlights the importance of cross disciplinary collaboration between life scientists and mathematicians/statisticians.

The presentation sessions highlighted the significant changes institutions are making in first-year curriculum, teaching and assessment to address the needs of diverse student cohorts. The key measures identified in these sessions were:

- Developing a range of teaching approaches that scaffold learning through tasks and assessments that focus on developing key mathematical skills, building student's confidence and self-awareness, using a variety of paper and online tasks and assignments.
- Diagnostic testing is being used by many institutions before the beginning or early in the first semester of first year. Testing may be compulsory or voluntary, and may direct student enrolment in specific courses, or leave the decision open to the student. Diagnostic data has been analysed by a number of institutions to determine subject and degree program redesign that involves collaboration with all disciplines that use mathematics as a service discipline. This has been successful at a number of institutions in engaging academics across the STEM disciplines in identifying the key mathematical skills their students need, providing context and examples of maths applications to use as teaching case studies and importantly in establishing consultative relationships that will enable future consultation and course review.
- Bridging programs are a common way to enable students without mathematics from school to develop the required mathematical skills for STEM programs. There are two main models of bridging program: a pre-semester short course that is fee based and open to the public, and a semester course that is credited as part of a degree program. The presenters reported mixed results from their bridging programs, with concerns expressed about the depth of knowledge developed and the challenges of teaching mathematics alongside other STEM subjects requiring this knowledge.

Discussion Sessions

The discussion sessions focused on the ways institutions were dealing with the students without the required assumed knowledge in mathematics. The groups were organized according to disciplines to identify areas of commonality related to the discipline.

Discussions highlighted that across all disciplines the lack of prerequisites for mathematics has resulted in a perception by students that mathematics is not necessary for engineering or science. In addition to this there is a general confusion amongst students (parents and teachers also) around the term 'assumed knowledge' and what it means, due to the wide variety of policies and terminology used by institutions. Participants discussed the different terminology used to identify high school mathematics subjects, different levels of mathematics for similar degree programs at different institutions and variation in enforcement of assumed knowledge requirements, both across institutions and faculties within the same institution.

The groups identified the range of programs, support services available to assist students. These are:

- Foundation courses in mathematics, including bridging programs prior to beginning of semester, or semester long units
- Drop in help centre, either run by the mathematics department or by the university
- Roaming help in the library to provide study support
- Incorporating mathematical content into lectures for science and engineering courses
- Maths tutoring by older students
- Diagnostic testing to identify students with insufficient mathematical skills, followed up with a range of supports
- Teaching approaches that incorporate revision and practical tasks to embed mathematical skills
- Increasing the amount of time spent on mathematical content in science courses to allow students to build their confidence and competence
- Assessment tasks that measure understanding.

A number of institutions used mandatory diagnostic tests, which directed students to specific forms of remedial support, or determined their enrollment in specific first year mathematics subjects streamed according to mathematical background. A number of institutions have developed their own tests, or adapted those from other institutions. Some institutions offer non-compulsory tests as an option to students for revision of high school mathematics, or as a tool for identifying areas of weakness. Participants acknowledged that testing needed to be handled carefully in order not to deter students.

In chemistry and life sciences a key issue is the ability of students to apply mathematical knowledge and identify appropriate mathematical tools to solve and deal with abstract problems, solve equations and perform calculations. Successful initiatives included building mathematics explicitly into the content in lectures, providing a range of academic support services and consulting with colleagues on the problems used and student responses. Some institutions have developed short mathematics courses that are specifically for chemistry and life sciences students, usually around 3 weeks either before or early in semester 1, ensuring maths content is covered prior to the discipline content which requires its application. Delegates from chemistry and life sciences emphasized the importance of allowing students time to develop the mathematical skills they needed to use in science and the opportunity for practice and application of skills.

Mathematics and teacher training were discussed in the context of addressing systemic problems in mathematics education. Students' approaches to mathematics are formed in early primary school. Participants felt there needs to be more input from mathematicians in the training of primary school teachers to improve their confidence in mathematics.

The following recommendations were developed for immediate action:

> **Recommendation 1**. Assumed knowledge requirements need to be clear and unambiguous, allowing students to identify the essential skills needed. Some suggested that a national standard or uniform definition of 'assumed knowledge' would be helpful. Assumed knowledge should clearly identify the actual mathematical ability and level of achievement required to succeed in the degree program.

In the longer term participants recommended the following:

> **Recommendation 2**: Work with secondary mathematics teachers to support them during training and later with professional development. This may involve individual universities offering professional development programs in mathematics, building links with teachers' professional bodies and establishing working relationships with university education faculties.
>
> **Recommendation 3**: Develop shared resources including diagnostic testing, bridging units and documentation of institutional entry requirements.

Conclusions and next steps

The forum was successful in drawing attention to the complex and challenging problems currently facing universities in teaching mathematics and science to students who are increasingly underprepared for these courses. The forum brought together representatives of science, mathematics, engineering and education from the majority of universities in Australia who demonstrate an active and passionate interest in maintaining the quality of their teaching and ensuring the success of their students. This opportunity to share insights and information represents a first step in the development of a greater understanding of the extent of the challenges that exist and presents opportunities for future collaboration.

Professor Chubb characterized the forum as an important 'community of interest' who need to use their influence to bring about change. The forum participants agreed that the following steps are needed to begin this process:

- Forum organisers will,
    - Issue a communique to the Ministers for Education and their opposition counterparts, the Deans of Science and Engineering, Universities Australia and the Chief Scientist to ask them consider the impact of the current assumed knowledge entry requirements on maths and science education.

- The First Year in Maths Project will,

  - Develop case studies of how institutions are dealing with assumed knowledge, the challenges they face, the practical responses and the outcomes for students, are important for informing the debate.
  - Develop a primer of assumed knowledge entry requirements to demonstrate the nature of inconsistencies and source of confusion for students.
  - Develop a repository of diagnostic tests as a resource for academics. Document the range of pathways students take into science and engineering degrees.

- Individual forum participants can,
  - Work with colleagues in their institution to identify how they can better assist students without the required assumed knowledge in mathematics. Document and circulate data to colleagues and initiate discussion between schools and faculties.
  - Contact colleagues at other institutions who have trialed teaching or assessment practices in mathematics and build communities of practice around particular interests.
  - Conduct local research into teaching and learning practices in mathematics and use the results to highlight problems and possible solutions.
  - Encourage communication between science, mathematics, statistics and engineering academics to on these issues to develop a coherent response and address the needs of their students.
  - Encourage their institution to engage in cross-sectoral collaboration by building relationships between mathematics, science and education departments.

References

Barrington, F. (2012). Year 12 Mathematics Student Numbers, Australian Mathematical Sciences Institute, Melbourne.

Thomson, S., et al. (2013). "PISA 2012: how Australia measures up: the PISA 2012 assessment of students' mathematical, scientific and reading literacy."

National Forum Presentations are available at: fyimaths.org.au/workshops/national-forum

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