

Enhancing students' mathematical aspirations and mathematical literacy as the foundation for improving STEM learning



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Research on raising students' mathematical aspirations

Secondary school students are increasingly opting out of mathematics subjects that provide the knowledge base for tertiary degrees, thus closing down opportunities for employment and further study. Between 1994 and 2012, participation rates for intermediate level mathematics subjects dropped from 38 per cent to 27 per cent of the Year 12 cohort, and from 16 per cent to 9 per cent for advanced mathematics (Kennedy, Lyons & Quinn, 2014).

Research conducted in Australia and the UK has aimed to understand the challenges of building aspirations for studying higher-level mathematics at school (for example, McPhan et al., 2008; Noyes, Wake & Drake, 2011). However, this research has tended to use *retrospective* designs that ask students or teachers to look back in time to recall factors influencing subject choices. An alternative approach involves using a *prospective* design to explore students' aspirations for

Abstract

Mathematics is the foundational enabling discipline that underpins STEM and its other constituent disciplines of science, technology and engineering. Central to Australia's mathematical vitality is universal access to high-quality mathematics education. Without this, young people are at risk of early school leaving, low participation in post-school education and training, poor employment outcomes, and social isolation (COAG, 2008; Parsons & Bynner, 2005). But Australia faces significant problems in ensuring that all young people are successfully engaged in learning mathematics at school, and in providing them with teachers who can inspire their learning.

This paper explores approaches to addressing two problems that continue to challenge researchers, practitioners, and policy makers: (1) raising students' mathematical aspirations and (2) enhancing mathematical literacy across the school curriculum. It draws on the findings from two current research projects. The first project is developing case studies of schools that have increased student participation in higher-level mathematics in the senior secondary school years. The second project builds on a long-term research program for embedding numeracy across the curriculum by creating a suite of online videos illustrating what numeracy looks like in real classrooms in different school subjects.

studying mathematics while these aspirations are formed in 'real time'. This is the approach my colleagues and I are using to investigate effective schooling practices that promote sustained student interest and engagement in secondary school mathematics (Ng, Goos & Bahr, 2014). This paper offers a snapshot of initial findings from one case study school that has recorded substantial increases in enrolment in intermediate and advanced mathematics subjects over the past six years. We observed mathematics classrooms and interviewed the mathematics Head of Department, other mathematics teachers, groups of Year 10 and Year 11 students, and one of the school's career guidance counsellors to gain insights into factors influencing students' emerging aspirations for studying mathematics.

Effective practices: Promoting aspirations for studying mathematics

Our case study school is a co-educational government high school located in an outer metropolitan area in south-east Queensland. In 2013, the year before our study began, the school had an enrolment of 814 students, with 145 in Years 11/12, and a school ICSEA value of 975. In the previous year, around one-third of Year 12 graduates went to university, while the remaining destinations were evenly divided between TAFE/vocational study and employment. Between 2008 and 2013, enrolments in Mathematics B, the senior secondary intermediate mathematics subject, increased from 28 to 56 without any increase in the total Year 11/12 cohort, while at the same time enrolments in Mathematics C, the advanced subject, increased from 7 to 12. This school had recorded one of the highest percentage increases in enrolments in intermediate mathematics of any government school in south-east Queensland, and it also had one of the highest percentages of its senior secondary cohort taking this subject.

Our preliminary analysis of interviews with teachers, students, and a guidance counsellor suggests that there are both whole-school factors and mathematics classroom factors influencing students' decisions to persist with higher-level mathematics beyond Year 10.

Whole-school factors that seem to matter are: (1) pastoral care and subject selection guidance with a strong focus on building awareness of personal strengths, connecting mathematics to post-school goals, and encouraging aspirational subject choices; and (2) early identification of mathematical capability and flexible placement of students in class groups that extend their capabilities. The school used Year 7 NAPLAN results¹

initially to place students in different Year 8 mathematics classes, including an 'extension' class, and modified these class groupings in subsequent years based on school assessment and Year 9 NAPLAN results. The mathematics Head of Department expected that students in the extension classes would proceed to enrol in intermediate and perhaps advanced mathematics in Year 11. However, there was some evidence that student behaviour, rather than mathematics capability, was a determining factor in class allocation. One student who was enrolled in Year 11 intermediate mathematics recounted how he had been placed in 'the lowest maths class' in Years 8–10, even though he obtained the highest possible NAPLAN result in Year 7. According to this student, 'I was so far ahead of everyone else, that it was just – I had nothing else to do, so I would play games and muck around with my mates.' Despite earning grades of A for mathematics achievement, his D grades for effort ensured that he remained in the regular mathematics classes instead of the extension class, until the Head of Department intervened: 'It took four years to realise that I was actually pretty good at maths, until they finally moved me up. I don't know what happened there', the student says.

Classroom factors also matter, with students in junior mathematics extension classes commenting on their preference for open-ended investigation tasks that challenged their thinking, and a 'loose/active' lesson structure that allows them to 'roam around the room and get help from other people or work together on things'. Their teacher encourages both independence and communal accountability by asking students to 'use all the lifelines' – their own thinking, their partner, their group – before asking her for help.

The mathematics Head of Department reported that in all classes, the emphasis is on success, enjoyment, challenge and awareness of the value of mathematics in enhancing post-school choices. Vocational education has a high profile in this school, but the great majority of students on this pathway take one of the pre-tertiary mathematics subjects instead of pre-vocational mathematics, because they have enjoyed the experience of mathematical challenge and success. Thus the approach taken by this school seems to build mathematical aspirations in all students, not only those who intend to go to university.

Research on enhancing mathematical literacy

Australian students' performance in the Programme for International Student Assessment (PISA) of mathematical literacy has declined since 2003, and there are persistent equity gaps in the performance of students from disadvantaged groups (Thomson, De Bortoli & Buckley, 2013). In Australia it is more common to refer to mathematical literacy as *numeracy*,

¹ Year 7 was the final year of primary school in Queensland at the time of this study.

and numeracy is identified as a general capability that must be developed across all subjects in the Australian Curriculum. Being numerate involves more than mastering basic mathematics, because numeracy connects the mathematics learned at school with out-of-school situations that additionally require problem solving, critical judgement, and making sense of the non-mathematical context.

Numeracy can be addressed across the curriculum by attending to numeracy demands and opportunities as they emerge when teaching subjects other than mathematics. This does not mean that teachers in other subjects should be required to be expert teachers of mathematics. It does mean that teachers need to be familiar with the inherent numeracy demands of their subject, be able to recognise a numeracy opportunity when it arises, and have the disposition and pedagogical skill to take advantage of such opportunities. These have been the goals of a long-term research program that has enhanced numeracy teaching across a range of school subjects, including mathematics, history, science, English, health and physical education, and studies of society and environment (Cooper et al., 2012; Gibbs et al., 2012; Goos, Geiger & Dole, 2014; Peters et al., 2012; Willis et al., 2012). This program was based on a multi-faceted model of numeracy that represents a synthesis of research related to effective numeracy practice. The model incorporates the dimensions of *mathematical knowledge*, *contexts*, *dispositions* and *tools*, embedded in a *critical orientation* to using mathematics (see Table 1).

Effective practices: Promoting numeracy across the curriculum

The numeracy model has been used to identify the numeracy demands of non-mathematics subjects in the Australian Curriculum, investigate teachers' understanding of numeracy, and analyse teachers' capacity to recognise and take advantage of numeracy opportunities in the subjects they teach. This work has culminated in development of a set of online resources for teachers comprising six videos: four illustrating how teachers are embedding numeracy in the subjects they teach, one showing teachers discussing how they established a numeracy committee within their school, and one in the form of a PowerPoint presentation with voiceover that explains the numeracy model. Each video is accompanied by discussion questions that are designed to engage the viewer with the numeracy model (for example) as the underlying design for a lesson.

The video resources were developed for the Queensland College of Teachers and are available on the QCT ClassMovies website (<http://www.classmoviestv.com/qctuq>).

Mathematical knowledge	Mathematical concepts and skills; problem-solving strategies; estimation capacities
Contexts	Capacity to use mathematical knowledge in a range of contexts, both within schools and beyond school settings
Dispositions	Confidence and willingness to use mathematical approaches to engage with life-related tasks; preparedness to make flexible and adaptive use of mathematical knowledge
Tools	Use of material (models, measuring instruments), representational (symbol systems, graphs, maps, diagrams, drawings, tables) and digital (computers, software, calculators, internet) tools to mediate and shape thinking
Critical orientation	Use of mathematical information to: make decisions and judgements; add support to arguments; challenge an argument or position

Table 1 Elements of the numeracy model

Improving Australia's mathematical vitality: What will it take?

This brief research summary has focused on only two of the many issues that need to be addressed in order to improve Australia's mathematical vitality. The first, raising students' aspirations for studying higher-level mathematics at secondary school, recognises the significance of the mathematical sciences for the nation's future economic growth (Commonwealth of Australia, 2015). The second, enhancing the mathematical literacy of all students, acknowledges the social burden of poor numeracy in limiting young people's life chances (Parsons & Bynner, 2005). While mathematics teachers have an important role to play in encouraging aspirational mathematics subject choices, teachers of all subjects are responsible for developing their students' subject-specific numeracies. The evidence from the snapshots of practice presented here suggests that at least part of 'what it takes' to improve young people's mathematical futures is a whole-school approach to understanding and operationalising the ways in which mathematics enhances learning in other disciplines as well as post-school study and career options.

References

- Commonwealth of Australia. (2015). *Vision for a science nation. Responding to Science, Technology, Engineering and Mathematics: Australia's Future*. Consultation Paper. <http://www.science.gov.au/scienceGov/news/Documents/VisionForAScienceNationRespondingToSTEMAustraliasFuture.pdf>
- Cooper, C., Dole, S., Geiger, V. & Goos, M. (2012). Numeracy in Society and Environment. *Australian Mathematics Teacher*, 68(1), 16–20.
- Council of Australian Governments (COAG). (2008). *National numeracy review report*. http://www.coag.gov.au/sites/default/files/national_numeracy_review.pdf
- Gibbs, M., Goos, M., Geiger, V. & Dole, S. (2012). Numeracy in secondary school mathematics. *Australian Mathematics Teacher*, 68(1), 29–35.
- Goos, M., Geiger, V. & Dole, S. (2014). Transforming professional practice in numeracy teaching. In Y. Li, E. Silver & S. Li (Eds.). *Transforming mathematics instruction: Multiple approaches and practices* (pp. 81–102). New York: Springer.
- Kennedy, J., Lyons, T. & Quinn, F. (2014). The continuing decline of science and mathematics enrolments in Australian high schools. *Teaching Science*, 60(2), 34–46.
- McPhan, G., Morony, W., Pegg, J., Cooksey, R. & Lynch, T. (2008). *Maths? Why not? Final report*. Canberra: Department of Education, Employment and Workplace Relations. <http://simerr.une.edu.au/pages/projects/10mathswhynotreport.pdf>
- Ng, C., Goos, M. & Bahr, N. (2014). *Is maths for me? Understanding and promoting disadvantaged students' academic aspirations for mathematics*. ARC Discovery Project DP140101431
- Noyes, A., Wake, G. & Drake, P. (2011). Widening and increasing post-16 mathematics participation: Pathways, pedagogies and politics. *International Journal of Science and Mathematics Education*, 9, 483–501.
- Parsons, S. & Bynner, J. (2005). *Does numeracy matter more?* London: National Research and Development Centre for Adult Literacy and Numeracy.
- Peters, C., Geiger, V., Goos, M. & Dole, S. (2012). Numeracy in Health and Physical Education. *Australian Mathematics Teacher*, 68(1), 21–27.
- Thomson, S., De Bortoli, L. & Buckley, S. (2013). *PISA 2012: How Australia measures up*. Melbourne: Australian Council for Educational Research.
- Willis, K., Geiger, V., Goos, M. & Dole, S. (2012). Numeracy for what's in the news and building an expressway. *Australian Mathematics Teacher*, 68(1), 9–15.