Challenges and opportunities in teaching mathematics

Merrilyn Goos
University of Queensland
<m.goos@uq.edu.au >

At the special conference celebrating the 50th anniversary of the Australian Association of Mathematics Teachers (AAMT), I was asked to speak about challenges and opportunities in teaching mathematics as a stimulus for discussion of AAMT's "future directions". With an open invitation to be a little provocative I chose the five challenges depicted in Figure 1. I have framed these challenges as questions to draw you into a conversation with your colleagues … and, vicariously, with me. I end my brief discussion of each challenge with another kind of question that I hope will point us towards opportunities and directions for the next 50 years.

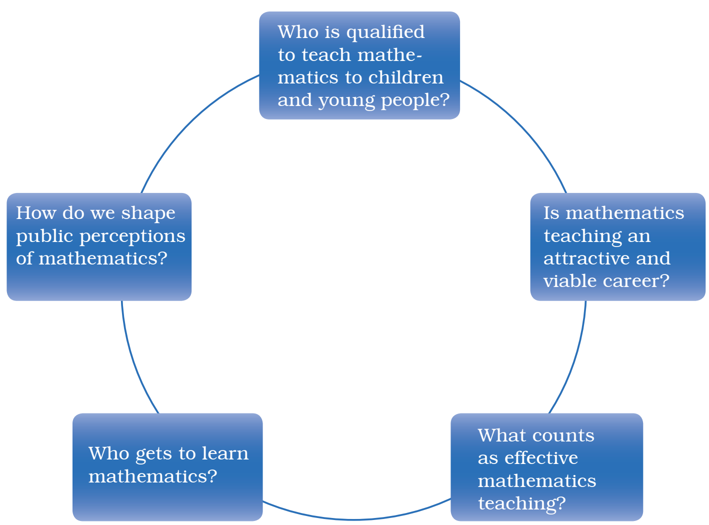

Figure 1. Five challenges for teaching mathematics in Australia.

Who is qualified to teach mathematics to children and young people?

What does it mean to be "qualified" to teach mathematics? This is an important question because any profession is distinguished in part by a body of specialised knowledge, practices, and ethical orientations that new entrants to that profession are expected to acquire. More than ten years ago AAMT developed a set of professional standards that identified the knowledge, attributes, and practices required for excellent teaching of mathematics. For example, excellent teachers have "a thorough knowledge of the students they teach", "a sound, coherent knowledge of the mathematics appropriate to the student level they teach", and "rich knowledge of how students learn mathematics" (AAMT, 2006). This AAMT initiative showed tremendous foresight in making a case for professional teaching standards specific to the discipline of mathematics.

Now we have the more generic Australian Professional Standards for Teachers (AITSL, 2014), with the three domains of professional knowledge, professional engagement, and professional practice structured similarly to those proposed by the AAMT Standards. For example, in the Professional Knowledge domain, teachers are required to know students and how they learn, and know the content and how to teach it. University programs for initial teacher education are accredited, in part, on the basis of ensuring that our graduates satisfy these requirements.

However, initial teacher education in Australia is undergoing substantial reforms (see http://www.aitsl.edu.au/initial-teacher-education/ite-reform). One of the new requirements is that all graduates of primary initial teacher education programs will not only be prepared to teach across the primary curriculum, but also have advanced knowledge and skills in one subject area. Priority for subject specialisation will be given to mathematics, science, and languages.

We might wonder whether it makes sense to say that a new graduate, however well prepared to teach primary school mathematics, could be regarded as having "advanced skills and knowledge" in mathematics and mathematics teaching.

> What should be the role of a mathematics subject specialist in the primary school? How should new graduates take up such a role?

Another aspect of deciding who is qualified to teach mathematics is to consider the long standing under-supply of secondary school mathematics teachers with formal qualifications for this role. By this I mean teachers who have taken university courses in both mathematics and mathematics teaching methods to the extent required by program accreditation standards. (The current requirements can be found in AITSL, 2015). Depending on the source of data, it seems likely that at least 20% of lower secondary school mathematics classes are taught by teachers without formal qualifications as mathematics teachers (McKenzie et al., 2014).

This is not a new problem. And I can't see the situation changing in a country like Australia that is geographically large but with a small, dispersed population. So even if we achieve some success in recruiting more people into secondary mathematics teaching I think it's unlikely that every secondary school in the country will be fully staffed with "qualified" mathematics teachers.

This leads me to wonder about the professional identity and status of "out-of-field" teachers of mathematics, and the extent to which we welcome them as valued colleagues within our professional community. Are they "one of us"?

> How are out-of-field mathematics teachers positioned in our profession? What kind of professional support is being offered, or should be offered, to enable out of field teachers to develop professional knowledge for mathematics teaching?

Is mathematics teaching an attractive and viable career?

Now let's zoom in on those who have decided to become secondary mathematics teachers. How good are we at supporting and retaining them within our profession?

I have found no data specific to mathematics teaching, but instead I draw on a study conducted by the Queensland College of Teachers (2013) on attrition of recent graduate teachers. The study identified and surveyed teachers who had been removed from the register within four years of graduation in the years from 2006 to 2008 (13.5% of this cohort), and conducted interviews with a sample of the survey respondents.

The report of the Queensland College of Teachers (QCT) study indicates that attrition exacerbates shortages in some specialist areas and some geographical locations, and that "secondary teachers of science, special education and mathematics are most likely to leave teaching" (QCT, 2013, p. 3). From the rich information provided by this report, two findings stood out for me:

- Only 20% of Queensland teachers graduating in the period from 2011–2013 were appointed to permanent positions.
- There were limited support activities for beginning teachers: the activity that respondents found most valuable was observing other teachers' lessons (85.2% agreement); yet this was also the least common (only 50% of respondents had done so).

Perhaps we can do little about the systemic problems with workforce planning that lead to uncertainty of tenure for beginning teachers. But let me tell you about the options listed in the survey for supporting new graduates … induction programs, professional development workshops, being observed and receiving feedback … none of these was perceived to be as valuable as having the opportunity to observe a more experienced teacher in the mathematics classroom. Will you offer this opportunity to a beginning teacher in your school?

> How should beginning teachers of mathematics be supported to stay and flourish, in our profession?

What counts as effective mathematics teaching?

As professional educators we are under increasing pressure to justify our practices in terms of improving students' learning outcomes. This is why a research team of which I am a member was recently commissioned by the Office of the Australian Chief Scientist to begin developing an evidence base for best practice in mathematics education. Our task was to identify schools showing high gains in NAPLAN Numeracy from Years 3–5 and Years 7–9 during 2011–2013 and 2012–2014 and to examine their practices in mathematics education. For jurisdictions where no gain scores were available for Years 7–9—that is, those for which Year 7 was in primary school while Year 9 was in secondary school—we instead selected schools with superior NAPLAN performance in Year 9.

There are many methodological challenges in a project like this: for example, we cannot be sure that the students in any school who sat for the Year 5 NAPLAN tests are the same students who, two years earlier, sat for the Year 3 NAPLAN tests at the same school. And we also know that NAPLAN performance, just like any other type of academic performance, can be influenced by a range of factors within and beyond the school. We designed our data collection to investigate this complex web of influence, using surveys of school leaders, teachers, and students in schools throughout Australia, together with case studies in 52 schools that met the NAPLAN "success" criteria outlined above.

We found that while there was no single approach to teaching mathematics amongst the "successful" schools, these schools did share some common characteristics. In particular, schools that had achieved high NAPLAN gains or high NAPLAN performance demonstrated a clear and purposeful focus on mathematics/numeracy and strong curriculum leadership with a collegial approach to professional learning. In these schools, teachers were enthusiastic about teaching mathematics and were committed to developing students' mathematical understanding. From this project, we discovered that mathematics leadership was crucial to students' learning.

> How can schools be supported to develop mathematical leadership capacity?

Who gets to learn mathematics

There are many ways of interpreting this question. Let's look first at who succeeds in learning mathematics, based on 2012 PISA data.

In PISA 2012, Australian students' mathematical literacy performance was significantly above the OECD average (Thomson, De Bortoli, & Buckley, 2013). However, there were statistically significant differences between the mean achievement scores of Australian students in different groups.

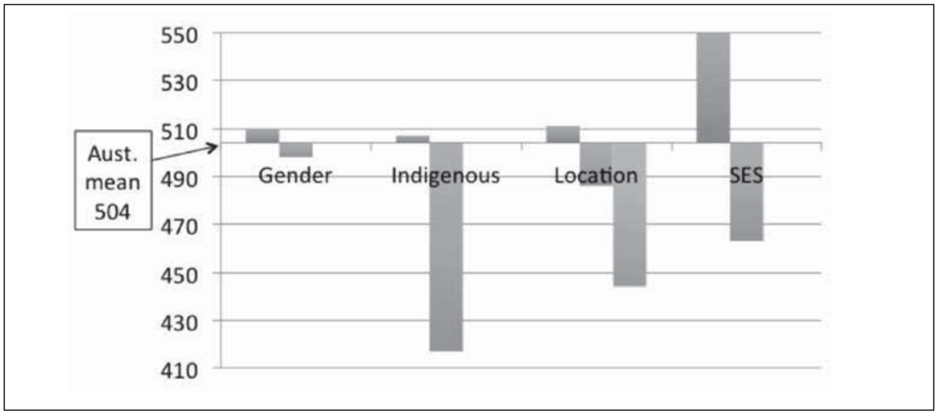

Figure 2. Mathematical literacy performance differences in PISA 2012 for Australian students.

In Figure 2, I have set the *x*-axis to cross the *y*-axis at a PISA score of 504, which was the 2012 mean score for Australian students. I have done this to highlight differences in achievement—all of which are statistically significant. The graph is meant to show the following differences:

- boys achieved a higher score than girls, with the difference equivalent to about one-third of a school year;
- non-Indigenous students achieved a higher score than Indigenous students, with the difference equivalent to about two and a half years of schooling;
- students who attended metropolitan schools achieved a higher score than students in provincial schools (a difference of almost three-quarters of a school year) or remote schools (a difference of almost two years of schooling); and,
- high socio-economic status (SES) students achieved a higher score than low SES students, with the difference between students in the highest and lowest SES quartiles equivalent to about two and a half years of schooling.

Another way to look at the question of who gets to learn mathematics is to ask which students are given the opportunity to study mathematics subjects that keep them on a pathway towards tertiary study. My colleagues and I are investigating this question through research in secondary schools that have been successful in building students' academic aspirations for studying advanced mathematics in the senior secondary years.

One school uses Year 7 NAPLAN results initially to place students in different Year 8 mathematics classes, including an extension class, and modifies these class groupings in subsequent years based on school assessments and Year 9 NAPLAN results.

The mathematics Head of Department expected that students in the Year 10 extension classes would proceed to enrol in intermediate and perhaps advanced mathematics subjects 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.

This student mused: "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."

Both the big picture PISA data and this single student's experience suggest that we have a long way to go to ensure that opportunities to succeed in learning mathematics are equitably distributed amongst Australian students.

> How can schools support and challenge all students to learn mathematics?

How do we shape public perceptions of mathematics?

There are many benefits to be gained from the increasing attention that policy makers are directing towards mathematics, numeracy, and STEM education. These terms are not interchangeable, but are we clear about their meanings and the relationships between them? The distinction between mathematics and numeracy is elegantly expressed by Steen (2001) as follows:

> Mathematics climbs the ladder of abstraction to see, from sufficient height, common patterns in seemingly different things. Abstraction is what gives mathematics its power; it is what enables methods derived from one context to be applied in others. But abstraction is not the focus of numeracy. Instead, numeracy clings to specifics, marshalling all relevant aspects of setting and context to reach conclusions. (p.17)

So, I can see from this explanation that it is context that distinguished numeracy from mathematics. However, I am yet to find a convincing explanation for what STEM is, and for the relationship between its constituent disciplines of science, technology, engineering and mathematics. And I'm not sure whether the plethora of STEM education conferences is helping to shape public perceptions of mathematics in ways that mathematics educators would find helpful.

> How do we develop a consistent understanding and language for communicating what we know, believe, and do as mathematics educators?

Concluding comments

There were many challenges for me to choose from in responding to this AAMT invitation, and many ways in which I could have worded the five that I eventually selected. My choice is personal and idiosyncratic … which challenges would have been on your list? What is your vision for the next 50 years of mathematics teaching in Australia?

References

Australian Association of Mathematics Teachers (2006). *Standards for excellence in teaching mathematics in Australian schools.* Retrieved 28 September 2016 from http://www.aamt.edu.au/Better-teaching/Standards/Standards-document

Australian Institute for Teaching and School Leadership (2014). *Australian professional standards for teachers.* Retrieved 28 September 2016 from http://www.aitsl.edu.au/australian-professional-standards-for-teachers/standards/list

Australian Institute for Teaching and School Leadership (2015). *Accreditation of initial teacher education programs in Australia. Standards and procedures.* Retrieved 28 September 2016 from http://www.aitsl.edu.au/docs/default-source/initial-teacher-education-resources/accreditation-of-ite-programs-in-australia.pdf

McKenzie, P., Weldon, P., Rowley, G., Murphy, M., & McMillan, J. (2014). *Staff in Australia's schools 2013: Main report on the survey.* Canberra: Department of Education.

Queensland College of Teachers (2013). *Attrition of recent Queensland graduate teachers.* Brisbane: QCT. Retrieved 28 September 2016 from http://qct.edu.au/pdf/Retention_Research_Report_RP01.pdf

Steen, L. A. (2001). The case for quantitative literacy. In *Mathematics and democracy: The case for quantitative literacy.* National Council on Education and the Disciplines.

Thompson, S., De Bortoli, L., & Buckley, S. (2013). *PISA 2012: How Australia measures up.* Melbourne: ACER.