Symposium: Effective Mathematics Teaching: Building Partnerships to Co-Develop Evidence-Based Capability

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Providing professional development at scale requires engaging diverse stakeholders to ensure support is based on research evidence and meets a range of teachers' needs. This symposium outlines research, partnerships and initiatives undertaken by a mathematics team in a state department of education to build a cohesive network of resources and professional learning to improve mathematics teaching and learning across the state.

Supporting teachers with relevant resources and professional learning is a priority to promote improvement in mathematics teaching and learning. At a systemic level, providing support at scale while recognising the highly diverse needs of teachers and schools is a well-documented challenge. A significantly revised mathematics curriculum has heightened the need for timeliness and range of expertise and perspectives. Collectively, the papers in this symposium tell a story of how a state department of education strategically partnered with mathematics education researchers, teachers and schools to design and implement a range of co-ordinated initiatives to support teachers and improve students' learning in mathematics.

In the first paper, Wood and her colleagues outline the history and background of ways that the Queensland Department of Education (the Department) have sought to support teachers to develop their mathematics pedagogy through a range of strategic partnerships across two decades. In *Building system-wide mathematics pedagogy through collaborative partnerships*, the authors discuss the impetus behind building teachers' pedagogical expertise in guided mathematical inquiry by working with mathematics education researchers as critical friends and developing resources at scale. In the second paper, *Designing curriculum resources to support teacher learning*, Goos details her theoretical analysis of the design of resources supporting teachers to "learn how to learn" to teach content that was new to them in the Queensland senior secondary mathematics syllabuses. Her paper exemplifies the Department's initiative to create a suite of professional learning materials for teachers designed by mathematics education researchers in a range of topics in mathematics curriculum, pedagogy, and classroom strategies. In the next paper, *Building capability: What to do when you don't know what to do*, school practitioners Moran and Lambie discuss how their school worked with a mathematics education researcher as a critical friend to address a problem of practice: improving students' performance on a new state assessment using complex, open-ended problems. They provide school-based evidence of how the using a research-based framework supported students to build confidence in addressing these tasks. Finally, in *Building capability for teachers of mathematics*, Horne and Hillman outline the partnership between the Department and an experienced teacher to develop resources that build teachers' capabilities in teaching mathematics. The 'How to Teach Mathematics Toolkit' seeks in particular to support beginning teachers and those teaching mathematics out-of-field in an online resource.

(2024). In J. Višňovská, E. Ross, & S. Getenet (Eds.), *Surfing the waves of mathematics education. Proceedings of the 46th annual conference of the Mathematics Education Research Group of Australasia* (pp. 67–83). Gold Coast: MERGA.

Building Capability: What to do When You Don't Know What to do

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The Queensland Certificate of Education (QCE) system is Queensland's senior school qualification. To support the introduction of the system in 2019, existing senior syllabuses were redeveloped and a new senior assessment model was established, this included the implementation of a mandatory high-stakes assessment task, the Problem-solving and Modelling Task (PSMT) in all four mathematics syllabi. The PSMT required new skills from both students and teachers to manage complex, open-ended investigations. In this paper, we reflect on our school's approach to build teacher capability in designing PSMTs and supporting student engagement with PSMTs.

In 2019, the new Queensland Certificate of Education (QCE) system was introduced. To support the introduction of the system, existing senior syllabi were redeveloped and a new senior assessment model was established to strengthen the quality and comparability of school-based assessment. These changes included the introduction of a mandatory high-stakes assessment—the Problem-solving and Modelling Task (PSMT)—to four senior mathematics syllabi: Essential Mathematics, General Mathematics, Mathematical Methods and Specialist Mathematics. PSMTs are designed by schools and then must be approved by the state assessment authority. Designing these tasks and supporting students to successfully engage with them required new skills. The PSMT was designed to evaluate a student's ability to respond to an investigative mathematical scenario or stimulus in relation to the mathematical concepts they have learned against four assessment criteria: Formulate, Solve, Evaluate and verify, and Communicate (QCAA, 2021). In most cases, the key feature of this task has been to provide for a response that addresses a real-life application of mathematics. Indeed, rich mathematical understanding goes beyond being able to correctly complete mathematical exercises, but also to make connections and transfer learning to unfamiliar problems (Skemp, 1978; Sullivan, 2011). As Peter Sullivan (2011) advised, "One of the major constraints that teachers experience when utilising such tasks is that many students avoid risk taking and do not persist with the challenges that are required in order to complete the task." (p. 38).

In this paper, we reflect on how our department in a state secondary school, in which the two authors were teacher leaders at the time, sought to facilitate this process for teachers and students. We drew on research and partnered with a university researcher, using a framework and seeking strategies to support students to build problem solving competence on complex, unfamiliar problems to allow us to reflect on, improve, and evaluate our progress.

Initial Practice of PSMTs

With the introduction of the new senior syllabi, our mathematics department wanted to ensure students were given every opportunity to perform well in the PSMT. A decision was made to introduce a practice PSMT as part of the problem-solving proficiency of the Australian curriculum at Year 10 to strengthen transition from junior to senior secondary mathematics courses. While we gave plenty of scaffolding on how to set out the response and developed understanding of the valued features outlined in the marking criteria, many students struggled to complete the task and wanted to be shown how to find the answer (Sullivan, 2011). This expectation was in line with the students' experiences of class work, but could not be provided in a PSMT setting where students are required to develop their own unique response to the set problem.

We noticed that our initial PSMT results in 2019 indicated that our high achieving students, who were preparing to study Mathematical Methods (Cohort A), generally performed well, with

88% passing (grade of C or better); whereas students who were preparing to study General Mathematics (Cohort B) did not have the same level of success, with only 63% passing. To better understand where our students were struggling, we followed up with some students to seek their feedback. Many told us that they simply did not know what to do and the teachers could not tell them, so they gave up. Essentially, they did not know how to start, and if they did attempt the problem and got stuck, they struggled to look for alternative approaches. We wondered how to help students with the challenge, 'What do you do when you don't know what to do?', so that they would have the confidence and skills to solve the unfamiliar problems posed by PSMTs.

A New Approach

We realised that it was necessary to employ a different pedagogical approach to improve student success and disposition. We were teaching mathematics using direct instruction with a gradual release of responsibility and a move from simple to complex questions. We also had an established problem-solving approach. However, these approaches were not helping students address unfamiliar, open-ended tasks like PSMTs. That is, our pedagogies were based on students being modelled how to do the mathematics first, before moving to a related application or a question they were less familiar with; however, even in these instances, the problems we gave students were fairly well-defined and typically had a single correct answer. The difference the PSMT posed was that students needed to come up with a way of responding to the task that was not directly modelled first by the teacher; and to find a solution to a task that did not come with an answer page to reassure them of their accuracy.

We decided to explore different pedagogical approaches that may help address students' unwillingness to make a start on the PSMT and complete it without teacher guidance. We conducted a search for solutions and identified research on the pedagogy of mathematical inquiry. Mathematical inquiry is an approach to solving complex, open-ended problems that relied on mathematical evidence (Makar, 2012). (Excerpts are from a video case study created about our journey by the Queensland Department of Education for the M-in-STEM Professional Learning Suite.)

> Guided inquiry [is] responding to the question, 'What do you do when you don't know what to do?' Complex open-ended problems like problem-solving and modelling tasks ask students to negotiate, adapt and revise their solution. This can be a real challenge for students. (K. Makar, quoted in Queensland Department of Education, 2022, 02:56)

We contacted the researcher, who agreed to discuss their research with us and act as a critical friend. We were particularly interested in their 5D model (Discover, Devise, Develop, Defend, Diverge; Allmond et al., 2010), which seemed to align well with the criteria already used with PSMTs. The Discover phase in the 5D model extends the QCAA modelling criteria by providing students with extra scaffolding to get started with the problem. It also engaged students with the problem context in a low-stakes setting before starting to plan a possible solution. This seemed particularly helpful when students did not know how to start the PSMT.

Together with the researcher, we (second author) designed an inquiry approach to support students in approaching the PSMT confidently and appropriately, using the 5D model as a guiding framework. We observed how students responded and plans to evaluate student data on improvement:

> In the past, our students have struggled to engage because of the size of the [PSMT] task. What we are seeing now, is that by using the 5Ds, students are less stressed and more engaged with the problem-solving and modelling tasks, and in turn, more willing to engage with [the] assessment. Next, would be a checkpoint at the halfway mark to see how much of the task students have completed. We can compare this directly with previous assessment pieces. Thirdly, we'll be comparing student achievement data. (K. Lambie, quoted in Queensland Department of Education, 2022, 05:54)

From 2020, we also began giving our Year 9 students inquiry tasks similar to PSMTs to give them additional practice, each time using the 5D framework as a scaffold. In particular, five lessons were developed to assist Year 9 students in unpacking a PSMT-like task using the 5D inquiry model. This approach sought to:

- Give students an opportunity to experience risk in a low stakes environment;
- Reduce the size of the task;
- Reduce student stress;
- Include a ‘checkpoint’ opportunity, where students shared their interim progress and discussed difficulties they were encountering with peers to generate possible ideas.

The benefit of providing students with an age-appropriate and curriculum-aligned inquiry task in Year 9 was that the students became much more confident by Year 10 because they had gone through a similar process the year before. As students were initially unfamiliar with this assessment style, the Year 9 task was designed to give students confidence moving forward and from the beginning, the Year 9 cohort demonstrated a high passing rate (93%). They also transitioned well into the more challenging Year 10 practice PSMT. We looked at the practice PSMTs again to see whether our Year 10 students felt more confident. Indeed, within these two years, students’ practice PSMTs significantly improved (Table 1), particularly the Year 10 lower-performing students (Cohort B) who increased their passing rate from 63% in 2019 to 96% in 2021.

Table 1

Practice PSMT Aggregated Results From our Year 10 Cohort

	PSMT percentage of students passing (grade C or better)	
Subject	**2019**	**2021**
Cohort A	88%	99%
Cohort B	63%	96%

Building Thinking Classrooms

Following our work above, we have continued to seek ways to improve students’ learning and their confidence to tackle complex, unfamiliar tasks. We recently attended a two-day professional development workshop provided by the Department on how to build thinking classrooms in mathematics (Liljedahl, 2020). The *Building Thinking Classrooms* workshop, delivered by Professor Peter Liljedahl represented the next step in our journey to increase problem-solving opportunities and success for students in our classrooms. Liljedahl’s approach to mathematics teaching emphasised a combination of group work, open-ended questions and opportunities to explore and test understanding in a low-risk environment. The combination of random grouping, the use of vertical whiteboards and the collaborative solving of problems that had not been previously modelled provided a fun-filled and engaging opportunity to solve mathematics problems in a safe and supportive environment. One of the difficulties we continue to have is getting students to make a start on solving problems when they are not sure if their selected methods will lead them to the answer. Liljedahl’s work provided us with further strategies to address this challenge with our students.

Following the workshop, we shared two different activities with the other teachers at our mathematics meetings and we have written a number of *Building Thinking Classrooms* activities into our mathematics plan. As we move towards the implementation of Australian Curriculum: Mathematics (Version 9), we have identified opportunities to embed these practices across all year levels, and our teachers are on board with this new approach, already incorporating the activities in their classrooms across all year levels. Teachers are motivated to learn more about the approach and how they can continue to support student engagement and success in mathematical problem-solving.

Conclusion

As a school, we are always interested in improving student learning. In particular, we were wanting to support students to respond to the challenge of "What do you do when you don't know what to do?" The inclusion of mathematical processes in the newly revised Australian Curriculum: Mathematics (v9.0) (Australian Curriculum, Assessment and Reporting Authority [ACARA], 2022) provides increased opportunities for students to address this challenge. "The mathematical processes ... are mathematical problem-solving and investigation processes that students learn to use in mathematics, and that draw upon students' mathematical process skills and proficiency in mathematics in an interconnected way" (ACARA, 2022, Mathematics, Key Considerations, Mathematical Processes section). We have been encouraged by the Year 10 practice Problem-solving and Modelling Tasks (PSMTs) in their capacity to increase student confidence, persistence, and skills in addressing complex, unfamiliar problems. Three approaches have assisted us to support students in this way: Drawing on research and working with a researcher as critical friend to guide the direction of our improvements to be evidence-based; engaging with the 5D framework (Allmond et al., 2010) and Thinking Classrooms material (Liljedahl, 2020) to improve our problem-solving pedagogy; and using data to reflect on, improve and evaluate our progress.

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