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.

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Building System-Wide Mathematics Pedagogy Through Collaborative Partnerships

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Research shows that when students engage with mathematical inquiry their problem-solving skills are strengthened. Demands in the revised Australian curriculum raised problem-solving of new senior secondary mathematics assessment, specifically in Queensland Problem-solving and Modelling Tasks (PSMTs). The challenge for Queensland was to scale inquiry pedagogies through secondary state schools in a way that was age appropriate and curriculum-aligned. A system, researcher and teacher collaboration produced a suite of resources and capability materials to build inquiry pedagogies of secondary teachers and ultimately students' problem-solving skills.

When students engage with guided mathematical inquiry, their problem-solving skills are strengthened (Lazonder & Harmsen, 2016). In addition, students experience greater engagement, enjoyment, and achievement (Collie & Martin, 2017). However, research outlines the difficulties that teachers experience in learning to adopt and appropriately guide their students' learning to engage in mathematical inquiry (Makar, in press; Munter, 2014). Facilitating system-wide pedagogical change in mathematics classrooms requires a multi-faceted, scalable approach (Roesken-Winter et al., 2021; Spillane et al., 2018).

This paper outlines the direction, history and development that the Queensland Department of Education made over 15+ years in supporting teachers to engage in adopting guided mathematical inquiry and problem-solving state-wide across all levels of schooling. The implications of this journey can provide guidance for system-level change over time in other jurisdictions. The outcomes highlight the importance of vision, partnerships, resource development and time in seeing systemic improvement in mathematics pedagogy from primary through secondary.

Queensland's Journey

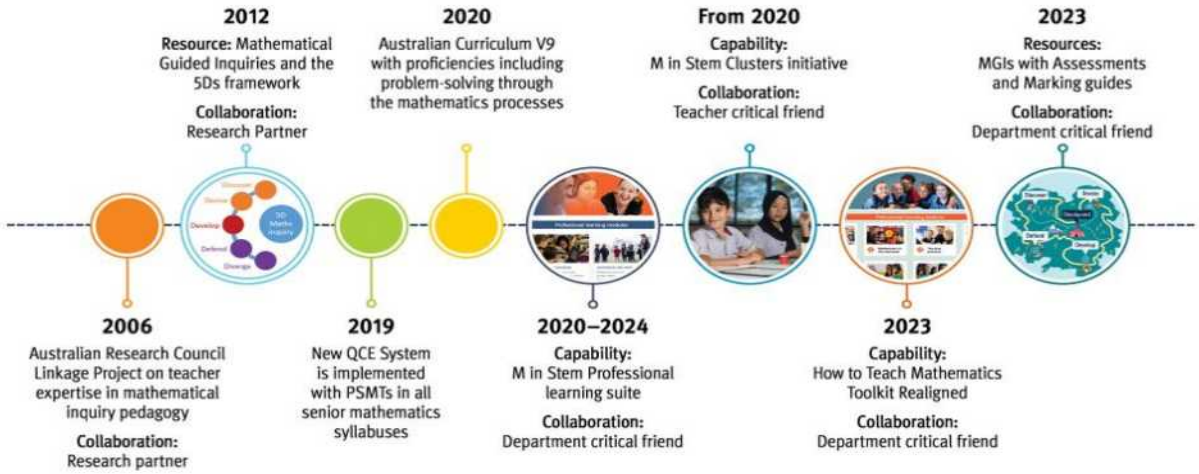
In 2023 the Queensland Department of Education (the Department) reaffirmed its commitment to prioritising achievement in mathematics in the education strategy, Equity and Excellence—a progressive, high performing education system realising the potential of every student—and continued a systematic approach to lifting outcomes for students in mathematics through building teacher capability. The Department has established a Prep to Year 12 approach to developing students' problem-solving skills with a focus on building teacher capability in inquiry pedagogies particularly in the secondary phase of schooling. Central to this has been collaborative partnerships with mathematics education researchers (Rosenquist et al., 2015). The Department's journey of valuing evidence-based practice through partnering with researchers has spanned almost two decades. In 2006, a formal partnership was initiated between the Department and a university in the form of an Australian Research Council (ARC) Linkage Project. The aim of the project was to study teachers' evolving experiences as they developed expertise in teaching mathematics through inquiry. The partnerships expanded to other universities over the years.

A Strategic Approach to Building Teacher Capability in Mathematics Pedagogy

The M-in-STEM initiative of the Queensland Department of Education was established in 2019 to strengthen age-appropriate and curriculum-aligned pedagogical practices of teachers of mathematics in Prep to Year 12. Through the STEM team, the Department engaged with fourteen mathematics education researchers from seven universities across Queensland and beyond to co-develop resources and capability programs to support teachers in adopting inquiry and problem solving pedagogies. The partnerships contributed to a range of co-ordinated and differentiated resources to build teacher capability (Figure 1), with many of these partnerships continuing.

Figure 1

Nature and Outcomes of Research Collaboration



Professional learning resources were developed for teachers across a range of experiences. The *How to Teach Mathematics Toolkit* was designed to support beginning, returning and out of field teachers of mathematics and is self-paced and online. Mathematical inquiry is addressed in two modules: Teaching practices—the pedagogy of inquiry, and Problem-solving—using the mathematical guided inquiries (MGIs). A partnership with a mathematics education researcher saw the adaptation of a framework for effective teaching of mathematics (National Council for Teachers of Mathematics [NCTM], 2014) supported with video content unpacking the framework and its implementation in classroom practice.

The M in STEM professional learning suite was developed to support experienced teachers of mathematics, particularly in secondary. Researchers co-developed professional learning resources with evidence-based pedagogical approaches across a range of topics supported with video content of classroom implementation. For example, in the inquiry module, the video case study *Effective inquiry strategies: Implementing a mathematical inquiry framework* documents how a secondary school adopted the 5Ds approach (Allmond et al., 2010) by implementing MGIs by collaborating with a mathematics education researcher. The partnership supported a consistent approach to inquiry across Years 7 to 10 in the school to ensure their students developed the age appropriate and curriculum aligned skills they needed to meet the demands of the PSMT into Years 11 and 12.

M in STEM Clusters Initiative

Building capabilities at scale required systemic partnerships between the Department, schools, and mathematics education researchers to support teachers with identified problems of practice (e.g., Koichu & Pinto, 2018). More direct collaboration between researchers and

teachers was facilitated through the M in STEM clusters initiative. Researchers walked the journey of school improvement in mathematics with middle and aspiring leaders working in a cluster with a similar problem of practice. Researchers played the role of critical friend and provider of professional learning.

Case Study—M in STEM Collaborative Mathematics Inquiry

In 2021 a cluster of six state secondary schools undertook a collaborative inquiry to investigate how to improve implementation and outcomes in the PSMT requirements of the senior secondary mathematics syllabuses. PSMTs were prioritised as they contributed 20% of the final mathematics grade in Year 12. Pre-intervention data analysis across the six schools showed that students achieved lowest in the *Solve* and *Evaluate and Verify* criteria of the PSMT (compared with, for example, *Communicate*). The working hypothesis was that low performance in Solve was due to difficulties in the *Formulate* criterion, and, that low performance in Solve led to difficulties in the Evaluate and Verify criterion. Furthermore, both teachers and students were challenged by the language of the PSMT criteria.

In discussing the problem of practice with a content expert researcher as critical friend, the cluster agreed to use brainstorming in senior secondary (Years 11 and 12) to support student confidence in the Formulate and Evaluate and Verify stages of PSMTs. Taking an inquiry approach, the cluster backward mapped from the intended student outcomes and class behaviours, requisite teacher practice and professional learning, and the expected evidence of these anticipated changes, to understand how the cluster leaders needed to create the conditions for the change to occur. The M in STEM initiative provided the professional learning in instructional leadership and opportunities for intentional collaboration.

Schools in the cluster introduced brainstorming in junior secondary to strengthen problem solving skills and a whole school approach to language and pedagogy for problem solving tasks. Co-developed lesson plans and teaching resources were developed for implementation across the schools that developed brainstorming skills. Brainstorming encourages people to think in a free and open way with no restrictions. As a result, they often generate more possibilities than they would using a structured approach (Dugosh et al., 2000). The shared lessons were implemented with classroom routines and norms established to build students' confidence in the process and a safe environment for sharing ideas. *Fermi* problems were also used to stimulate ideas to evaluate and make assumptions. Fermi problems are miniature modelling problems that emphasise estimation (Albarracín & Ärlebäck, 2019).

Monitoring and reviewing activities including classroom walk-throughs, feedback from teachers and students, and pre- and post-intervention data analysis, showed an increase in confidence in both brainstorming and PSMT processes for students and teachers, improved disposition towards PSMTs for teachers and students and improved assessment literacy. The school found evidence of its effectiveness not only in the initial criterion (Formulate), but gave students confidence to proceed across all four criteria (Formulate, Solve, Evaluate and Verify, Communicate). A video capturing the case study was provided to all schools as an example of a high quality strategy and benefit of engaging a critical friend. The benefits of working in a cluster were identified as access to critical friend, opportunities to collaborate with other schools, and professional learning around an inquiry approach to school improvement.

Next Steps

The quality assured and curriculum-aligned materials developed through system-researcher partnerships are provided to all Queensland state schools to lift mathematics outcomes for students. In addition system-researcher-teacher relationships have further strengthened the network of mathematics educators across the state. While we have significant case studies demonstrating impact (see for example, Moran & Lambie, 2024), next steps are to gather further

evidence of reach and impact of these materials. This includes evidence of downloads and access to online resources and professional learning, localised case studies of impact in schools and clusters, opt-in surveys of teacher feedback after engaging with and implementing the materials, and monitoring trends in system-wide mathematics reporting data.

This paper outlined strategies that enact the Department's commitment to strengthening teaching and learning in mathematics at scale to ensure every student realises their potential. It exemplifies the Department's focus on fostering collaborative partnerships to build evidence-based, inquiry pedagogies in mathematics across the system to build problem-solving skills.

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