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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Designing Curriculum Resources to Support Teacher Learning

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This paper presents an analysis of how resources were designed to support implementation of the new Queensland senior secondary mathematics syllabuses. The analysis draws on the concept of educative curriculum materials that build teachers' subject matter knowledge and pedagogical content knowledge. Such resources are intended to help teachers "learn how to learn" to teach mathematical content that is new or unfamiliar to them.

Introduction of the Australian Curriculum: Mathematics at F–10 and senior secondary mathematics levels has led to diverse initiatives by state and territory education jurisdictions to provide resources and support for teachers. This paper examines one aspect of the Queensland Department of Education's *M in STEM* initiative, which involves collaboration with university-based mathematics education researchers to develop a professional learning suite for secondary school mathematics teachers. The resources are intended to strengthen teachers' curriculum knowledge and pedagogical practices across six topics: productive dispositions, problem solving and inquiry, modelling, reasoning, new content in the senior mathematics syllabuses, and strategies for long term retention of knowledge and preparing students for assessment.

The aim of this paper is to analyse the process used to develop resources for one of the focus topics in the professional learning suite: learning to teach new content in the senior secondary mathematics syllabuses. The analysis draws on the concept of *educative curriculum materials*, that is, curriculum resources that are designed to promote teachers' learning of mathematical content and pedagogy as well as student learning (Ball & Cohen, 1996; Davis & Krajcik, 2005). The paper addresses the following research question:

- How can curriculum resources be designed to support mathematics teacher professional learning in the context of curriculum reform?

Curriculum Context

In 2019, the Queensland Curriculum and Assessment Authority (QCAA) introduced new syllabuses for senior secondary mathematics based on the subjects developed by the Australian Curriculum, Assessment and Reporting Authority (ACARA, n.d.): General Mathematics, Mathematical Methods, and Specialist Mathematics (version 8.4). The new syllabuses included mathematical content that was either new or at a higher level of difficulty than in the previous Queensland syllabuses for the equivalent subjects of Mathematics A, Mathematics B, and Mathematics C respectively. The new suite of subjects represented the most significant change to senior secondary mathematics curriculum in Queensland since the previous syllabuses were launched in 1992.

The support offered to teachers for implementing a new syllabus is often in the form of instructional materials that help teachers interpret the official curriculum and create their own personal plans for teaching specific groups of students (Remillard & Heck, 2014). One challenge in designing such resources is to find a realistic balance between pedagogical prescription and professional autonomy (Davis & Krajcik, 2005). Determining the appropriate amount of guidance needed by senior secondary teachers was a particular challenge for General Mathematics, the subject most likely to be taught by out-of-field teachers who have undertaken limited advanced studies of mathematical content and little or no formal preparation in teaching mathematics. Text-based and online curriculum materials are also more educative for teachers if combined with in-person social support (Robutti et al., 2016). However, delivering a state-

wide professional learning program containing face-to-face elements is challenging in Queensland, the Australian state with the most decentralised population spread over a very large area (see Australian Bureau of Statistics, 2022; Geosciences Australia, 2023). Each of these constraints influenced the design of the *M in STEM* professional learning suite.

Theoretical Background

The design of resources for one of the *M in STEM* focus topics is analysed by reference to five high-level guidelines for educative curriculum materials set out by Davis and Krajcik (2005). They proposed that educative curriculum materials should:

- Develop teachers' capacity to anticipate and interpret student thinking during instructional activities, as well as how to respond to student thinking (e.g., by using appropriate examples or instructional representations);
- Support teachers' learning of the subject matter and related disciplinary practices;
- Help teachers recognise how a learning objective, instructional activity, or lesson Sequence is related to the curriculum as a whole;
- Make visible the resource developer's pedagogical reasoning, thus enabling teachers to integrate this knowledge into their own repertoire;
- Promote teachers' pedagogical design capacity so they are able to make principled adaptations to the original curriculum materials.

In these ways, educative curriculum materials build teachers' subject matter knowledge and pedagogical content knowledge.

Designing Curriculum Resources for General Mathematics

In the curriculum context outlined above, consultation with the Queensland Department of Education led to a decision to focus on teaching new content in the General Mathematics syllabus (QCAA, 2019). It was not feasible to design curriculum resources for every topic in the syllabus that was likely to be new or unfamiliar to teachers. Instead, three syllabus topics considered to be most demanding for inexperienced or out-of-field teachers were selected: linear equations and their graphs; geometric sequences; and planar graphs, paths, and cycles.

Teachers are also time poor and not always willing to engage with extensive materials. Thus, the resources needed to concisely address key ideas for teaching while simultaneously illustrating how teachers could "learn how to learn" to teach other new topics in the syllabus. This was done by creating, for each topic, a series of three recorded PowerPoint presentations outlining evidence-based pedagogical strategies (1 hour total) and a placemat that defined the topic together with planning and teaching principles. These static resources were supplemented by an interactive 40-minute online professional discussion with teachers from around the state.

The intention was to develop a consistent structure for the recorded presentations that would expose the pedagogical decision-making underpinning the design. The rationale for these decisions was also made explicit in the placemat representing the design process. The design process moves through three stages: (a) interrogating the senior syllabus to identify and understand the subject matter; (b) mapping connections backwards, forwards, and across the Australian curriculum; and (c) designing pedagogy by selecting appropriate representations and real-life examples, and addressing common misconceptions that hinder student learning. The design process for the geometric sequences PowerPoint presentation is illustrated in Table 1 and mapped against Davis and Krajcik's (2005) guidelines for educative curriculum materials.

The principles underpinning the design process illustrated in Table 1 were articulated in the topic placemat, which is presented in abbreviated form in Figure 1. The placemat highlights the teacher's role in bringing the curriculum to life for students, by moving back and forth between the curriculum world, real world, and classroom world.

Table 1

Design Process for Geometric Sequences PowerPoint Presentation

(a) Interrogate the syllabus

Educative curriculum materials guideline 2: Support teachers' learning of subject matter

What subject matter is included?

- Generating sequences using recursion or rule for the n^{th} term
- Displaying the terms of a sequence in tabular or graphical form
- Using geometric sequences to model and analyse (numerically or graphically only) practical problems involving geometric growth and decay

How are key terms defined?

- Syllabus glossary definition of a geometric sequence, "a sequence of numbers where each term after the first is found by multiplying the previous term by a fixed non-zero number (excluding ±1) called the common ratio" (QCAA, 2019, p. 59)
- Common ratio > 1 → exponential growth; Common ratio < 1 → exponential decay
- Illustrate two methods of generating the geometric sequence 2, 6, 18, 54, …:
- Recursion relation $t_1 = 2, t_{n+1} = 3t_n$ for $n \geq 1$
- Rule for the n^{th} term $t_n = 2 \times 3^{n-1}$ for $n \geq 1$

Why is the topic important?

- Geometric sequences are used to understand real life situations and solve real life problems involving exponential growth and decay

(b) Map the curriculum

Educative curriculum materials guideline 3: Relate the topic to the curriculum as a whole

What prior learning have students experienced from the F–10 mathematics curriculum?

- Understand the connection between algebraic and graphical representations
- Solve basic problems involving simple and compound interest

What other topics in the General Mathematics syllabus connect to this topic?

- Loans, investments, and annuities: Use a spreadsheet to investigate the effect of interest rate on the future value of an investment

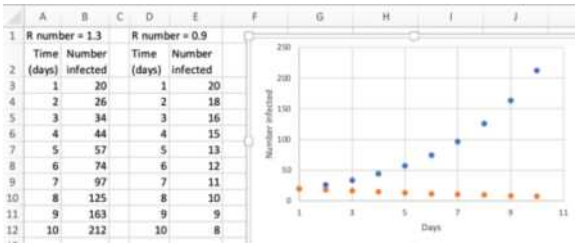
What other curriculum areas connect with this topic?

- Physics and ancient history: radioactive decay, carbon dating
- Biology: population growth, bacterial growth, spread of infectious diseases such as COVID-19

(c) Design pedagogy

Educative curriculum materials guideline 1: Anticipate, interpret, and respond to student thinking

- Select appropriate representations and link to real life examples.

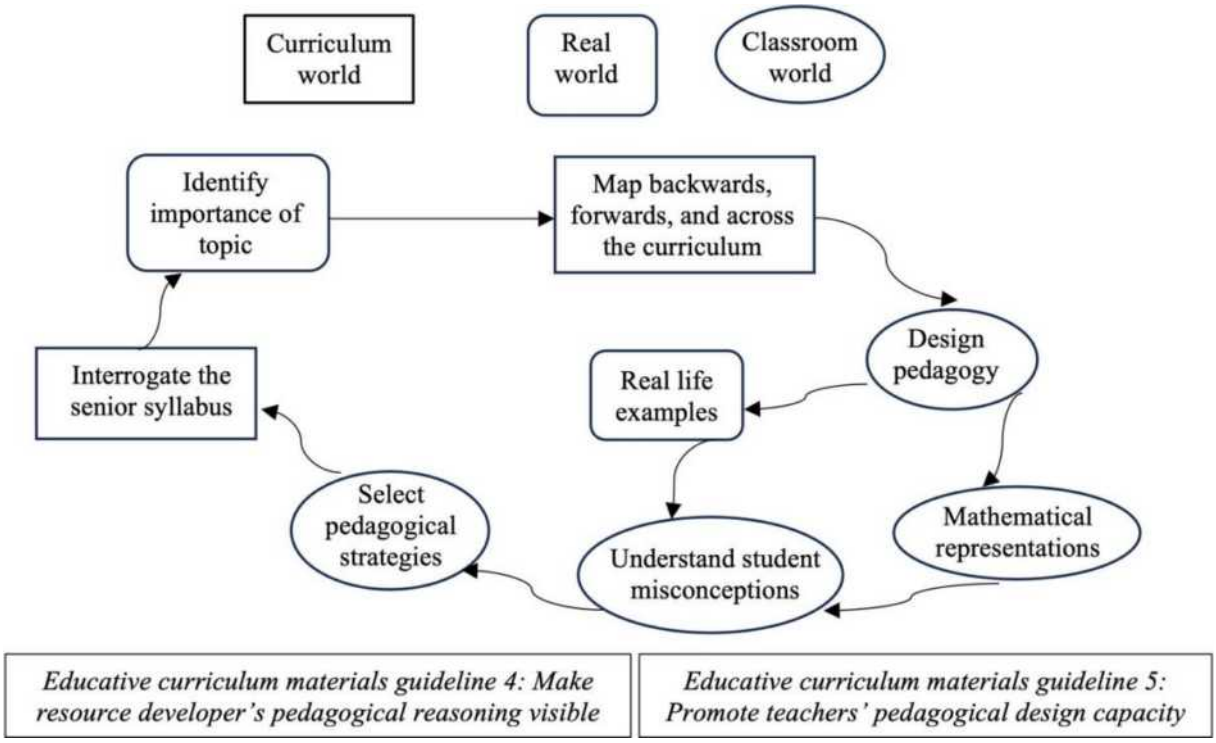


	A	B	C	D	E
1	R number = 1.3			R number = 0.9	
2	Time (days)	Number infected		Time (days)	Number infected
3	1	20		1	20
4	2	26		2	18
5	3	34		3	16
6	4	44		4	15
7	5	57		5	13
8	6	74		6	12
9	7	97		7	11
10	8	125		8	10
11	9	163		9	9
12	10	212		10	8

- Understand and respond to students' thinking
- Recognise misconceptions about working with numerical expressions in exponential form.
- Encourage students to explore both recursion relationships and the rule for n^{th} term to define sequences
- Provide experiences for students to explore and compare additive and multiplicative patterns that model arithmetic and geometric sequences respectively
- Use technology so students can investigate patterns of growth and decay in sequences, generating both tables of values and graphs

Figure 1

Placemat for Teaching New Content in Senior Mathematics



Concluding Remarks

This paper illustrates one approach to designing educative curriculum materials that support teacher learning as well as student learning. In principle, the resources developed for Queensland senior secondary mathematics teachers align with the guidelines proposed by Davis and Krajcik (2005). However, little is known about teachers' uptake of these resources and what difference this makes to their professional knowledge and classroom practice. These promise to be fruitful areas for future research on teachers' learning in times of curriculum reform.

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