

Teacher knowledge as fundamental to effective teaching practice

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Mathematics teaching, and the ways in which ‘ineffective’ teaching impacts on students’ learning, has long been the topic of discussion around many a national policy table. Given that mathematics plays a central role in shaping how individuals deal with various spheres of private, social, and civil life, mathematics student outcomes have traditionally been a key rallying point for administrators and policy makers. Concerns that mathematics teaching contributes to poor students’ achievements, relative to international benchmarks, have recently put huge political pressure on education systems in a number of Western nations. Stakeholders tend to blame sitting governments at both state and national levels for not doing enough to demonstrate good or internationally comparable student performance.

The current debate resembles the debates that preceded it in at least one important respect: that young people cannot do mathematics sufficiently well because, in part, teachers are not doing their job sufficiently well. The terms of the debate have prompted governments to respond with inquiries, with new initiatives, and with new policy, and the comprehensive strategy designed to boost mathematics standards in the UK is a case in point. In my own country, New Zealand, the current response consists of a suite of proposals including more public–private partnerships, increased class size, and teachers’ salaries commensurate with competence. If the proposals are implemented, inevitably, there will be some who stand to win and some who do not.

Effective teaching is not necessarily a consequence of new policy. Lying at the heart of effective teaching are the knowledge and skill that an individual teacher brings to the cognitive demands of teaching. What teachers do in classrooms is very much dependent on what they know and believe about mathematics and on what they understand about the teaching and learning of mathematics (Anthony and Walshaw 2007). Successful teachers are those with both the *intention* and the *effect* to assist students to make sense of mathematics (Jaworski 2004). A teacher with merely the intention of developing student understanding will not necessarily produce the desired effect. What is clear, however, is

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that repertoires of sound content knowledge and pedagogical knowledge will provide the means to realise the good intention.

A core infrastructural element of effective mathematics teaching, then, is teacher knowledge. Sound content knowledge is a prerequisite for accessing students' conceptual understandings and for deciding where those understandings might be heading. It plays a critical role in extending and challenging students' conceptual ideas. Sound subject knowledge enables teachers to mediate between the mathematical tasks, the artefacts, the talk, and the actions surrounding teaching/learning encounters. Teachers with limited subject knowledge have been shown to focus on a narrow conceptual field rather than on forging wider connections between the facts, concepts, structures, and practices of mathematics.

Similarly, mathematics pedagogical knowledge, that is, teachers' knowledge of how to teach the content, is critical for effective teaching. Pedagogical content knowledge influences the connections teachers make between aspects of mathematical knowledge. It also influences the interactions between the teacher and students as well as the teacher's professional reflections in action within the classroom. In short, sound content and pedagogical content knowledge provides the resources for an on-the-spot synthesis of actions, thinking, theories, and principles within classroom episodes (Ball and Bass 2000).

The point that effective teaching demands sound teacher knowledge is emphasised in all four articles within this issue of the *Journal of Mathematics Teacher Education*. The authors of the four articles ground their research in the understanding that teachers who are able to develop and enhance student mathematical understanding are those that have a sound knowledge base. Knowledge of content and knowledge of pedagogy related to content, as well as knowledge of students' thinking, all lead to more effective teaching. The authors provide clear research evidence that demonstrates the importance of teacher knowledge in the planning and the teaching of classroom mathematics.

The article by Carol Murphy investigates the relationship between teacher content knowledge and knowledge of how to teach the content within the classroom. In 'The role of subject knowledge in primary prospective teachers' approaches to teaching the topic of area', Murphy explores the ways in which subject knowledge is transformed into teaching plans. The participants in the study were four elementary prospective teachers who had completed a 1-year postgraduate certificate course and were due to commence their final teaching practice. Using the participants as four separate cases, Murphy investigates the ways in which the strengths and limitations of the four teachers' knowledge influence the teachers' selection of teaching activities. Specifically, she wanted to find out what kinds of activities prospective teachers plan for their students when they (the prospective teachers) either lacked or had secure understanding of the mathematical concept of area.

Given that area measurement is a more abstract concept than is linear measurement, the notion of area provided a window into the relationship between the conceptual basis of prospective teachers' subject matter knowledge and the way they planned to teach that subject matter. Thus, area provided a resource for determining whether a reliance on formulae use for understanding the topic led to teaching that emphasised procedural knowledge, and, similarly, whether an understanding of the dynamic and inexact nature of area measurement was given expression in the plans that the prospective teachers developed. Principal data sources in the study used to investigate the relationships were lesson plans and follow-up interviews. The teachers planned an introductory lesson on area for a year 4 class (8–9 years old) and were subsequently interviewed about their plan and were then provided with four tasks as a way of assessing their content knowledge.

The research found that although two of the prospective teachers had some understanding of the inexactness of area measures, none of the four teachers fully conceived of area as dynamic. Explanations from three of the teachers were influenced by their own knowledge of area. The fourth and least confident and less procedurally accurate of the four teachers planned an inquiry approach in which students' own strategies were intended to help them develop understandings of the concept. These findings from a small-scale study have led Murphy to question, tentatively, earlier findings that claim that teachers who are confident in their own knowledge of the content are likely to teach in a way that conforms to the principles of inquiry teaching.

The article by Sibel Yeşildere Imre and Hatice Akkoçm takes us into the classroom and the observations made there by prospective teachers. In 'Investigating the development of prospective mathematics teachers' pedagogical content knowledge of generalising number patterns through the school practicum', Imre and Akkoçm look at how classroom observations made by three prospective teachers, and follow-up discussions, might enhance prospective teachers' pedagogical content knowledge. While the prospective teachers had not experienced generalisation in their own elementary or secondary education, all three had taken a calculus course within their undergraduate coursework. The goal of the research was to investigate the knowledge of school students' understandings and difficulties as well as knowledge of strategies and representations related to algebraic pattern at the 12-14 years of age level, or grades 6-8.

Before the observations, the three prospective teachers had planned and taught a videoed micro-lesson on generalising number patterns and had evaluated their teaching from the video clip. Interviews also took place. The prospective teachers observed their mentors in the classroom and were also able to view videos of the mentors' lesson on return to the university. They shared their perspectives of the mentors' lessons and later taught a micro-lesson on generalising number patterns again and, as before, viewed the video clip of their lesson and made a self-evaluation. Again, interviews offered clarity and provided additional information for the researchers.

Yeşildere and Akkoçm found that prior to the practicum, the three participants tended to look for relationships among the first few terms of a pattern sequence, focusing on the relationship between consecutive terms. Following the practicum and during the second micro-teaching experience, the participants emphasised the importance of the relationship between the order of terms and consecutive terms—an emphasis that opened up the possibility of articulating the general structure of the pattern. Yeşildere and Akkoçm conclude that the observations of the mentor's teaching and their own observations of students' difficulties in the classroom served as a catalyst for the enhancement of the prospective teachers' pedagogical content knowledge.

The article by Rod Nason, Chris Chalmers, and Andy Yeh takes us into a university computer-supported environment where a group of prospective teachers is engaged in a Lesson Plan Study. Nason, Chalmers, and Yeh, in 'Facilitating growth in prospective teachers' knowledge: Teaching geometry in primary schools', report on an intervention focused on constructing a knowledge-building community for prospective primary [elementary] teachers. In this environment, the creation of 'epistemic artefacts', specifically, computer-supported collaborative learning tools, played a central role. Twenty-one prospective teachers enrolled in their third-year teacher education course formed seven teams, each with three members, and designed a lesson plan to teach a geometrical concept. They did this in face-to-face meetings, with access to hard copy resources and online assistance. The prospective teachers posted their lesson plans online for the purpose of sharing with and seeking feedback from other teams. Responses revolved around what was

liked, what could be improved, what was similar, and what was different about the lesson plan from one group to the next.

Two cognitive scaffolds, in the form of the online tool Knowledge Forum[®], and a framework developed for shaping discourse, were used in the study. After the 4 weeks of feedback and lesson plan revision, each team then submitted a final lesson plan as a PowerPoint presentation to the forum. Reflections on how their feedback was used and how they used the feedback provided to them were also part of the data sources used in the study. Nason, Chalmers, and Yeh found that substantial advances in the use of teaching interventions were made as a result of the intervention. The content, in the way it was organised, represented, and presented, also underwent change. In addition, significant advances were made to questioning techniques.

The online asynchronous sharing tool and the structure offered for feedback provided a springboard for deeper and more meaningful discussions on pedagogical issues relating to geometric concepts. This applied to discussions both within and between teams. Nason, Chalmers, and Yeh are of the view that the artefacts shared online provided a vehicle for collaborative knowledge building that would not easily be replicated in face-to-face discussions. In providing cognitive scaffolding, the environment contributed to significant advances in students' development of lesson plans and, hence, to their pedagogical content knowledge.

In the Around the World category, Alice Artzt, Alan Sultan, Francis R. Curcio, and Theresa Gurl explore pedagogical content knowledge through the lens of a course developed to create synergies between higher-level undergraduate mathematics courses with the secondary school curriculum. In 'A capstone mathematics course for prospective secondary mathematics teachers', Artzt, Sultan, Curcio, and Gurl report on the design of their Math 385 course for prospective secondary mathematics teachers. The intent of the course is to develop in prospective teachers a sound understanding of what it means to teach at the secondary school level. Student-centred instructional strategies and lessons planned to demonstrate 'MATH-N-SIGHT' are the objectives.

The mainly student-directed course begins with a professor teaching the prospective teachers the first of the content strands within the secondary school curriculum. Through a series of carefully structured scaffolding meetings, groups of prospective teachers are tasked with the responsibility of planning and teaching one of the remaining four content units, comprising five cohesive lessons. The course is writing intensive and requires the presentation of a final portfolio. The specific benefits for students noted by the researchers were, namely, an appreciation of cooperative learning, the development of reflective practice, the importance of mathematical knowledge for teaching, the preparation and implementation of lessons plans, and multiple ways of thinking about and solving mathematical problems.

Artzt, Sultan, Curcio, and Gurl investigated the extent to which completion of the course might serve as a predictor of successful completion of another course at the university offered after the completion of the Math 385 course, specifically focused on the methods of teaching secondary mathematics. They found a positive correlation between the two course completions. The Math 385 course, the researchers maintain, equips prospective teachers for teaching secondary mathematics, whilst providing them with strategies to continually lift their teaching effectiveness.

Implications for practice

Although the research reported in this issue took place in a range of different settings across the world, specifically in England, Turkey, Australia, and the United States, there

are striking resemblances from one to another. All emphasise the importance of teacher knowledge as a resource for teaching, and as critical to the development of prospective teachers' effectiveness. Through the four articles, we learn the importance of teacher knowledge in informing decisions about the particular content that students will learn. That is to say, we learn that teachers' decisions about instructional activities fall back on the knowledge that they hold of the content to be taught. We learn more about the relationship between content knowledge and pedagogical content knowledge. Moreover, we learn that teacher knowledge and pedagogical content practices can be enhanced with the support and encouragement of a community of learners.

Teachers' conceptual understanding and knowledge is critically important at any level. It follows that when prospective teachers demonstrate limited or confused understanding of the subject knowledge relevant to the lesson, unless rectified, their future students will struggle to make sense of the relevant mathematical concepts. Teachers who are unclear in their own minds about particular mathematical ideas may struggle to teach those ideas and may resort to examples that prevent, rather than help, student development. Teachers' limited knowledge may lead them to misunderstand their students' solutions and may lead them to give feedback that is inappropriate or unhelpful. In short, teachers' fragile subject knowledge often puts boundaries around the ways in which they might develop students' understandings.

On the other hand, teachers with sound knowledge make good sense of mathematical ideas. They develop the flexibility for spotting opportunities that they can use for moving students' understandings forward. When teachers use their knowledge to enhance student learning, they are engaging in effective practice. Not only are they advancing students' understandings, they are also, ultimately, adding value to the wider community of individuals.

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