Reconceptualising Professional Development of Mathematics Teachers in Southeast Asia: Mapping the Growth in the Trajectory of Teacher Knowledge

Mohan Chinnappan
University of South Australia
Email Address: Mohan.Chinnappan@unisa.edu.au

INTRODUCTION

In recent debates about teaching and learning, arguments about the need to better understand students' engagement with mathematics and lifting their performance is gaining increasing currency among mathematics teachers, educators and policy makers. The issue has received a high level of visibility in light of two major developments. First, the quality of our teaching is being judged on the basis of students' performance in international tests such as PISA and TIMSS. There are concerns about the use of such test results in order to draw conclusions about the quality of our teaching in mathematics and the resulting ranking of schools and countries. Nevertheless, a number of national educational policy statements, including Malaysia are increasingly supportive of this international program and are keen for their students to move up the performance ladder on the basis of mean test scores.

The growing interest in and the role of international tests in global benchmarking is also indicative of an implicit acknowledgement that such tests do provide a reliable window into the quality of students' learning outcomes and by extension, the quality of mathematics instruction. Despite the reservation from some segments of the teaching profession about using test results to judge teaching quality, this perceived relationship has been given greater weight by the need to produce a workforce that is quantitatively literate and scientifically talented in order to meet the demands of a knowledge-based economy. Such a view is based on the assumption that a rich pool of scientific talent is a prerequisite for driving and sustaining an advanced economic system which calls, in turn, for citizens to work both independently and in collaboration during the search for solution of complex problems of the day such as climate change.

The scenario that I have sketched above places a premium on learning quality and evidence of such learning in mathematics. But what are the critical variables that warrant our attention in this equation about learning quality and learning outcome? In this paper, my arguments are driven by the assumption that teaching and teachers play a significant role in initiating and maintaining learning and learner engagement, and ultimately the quality of mathematical learning outcomes that are required to fulfil the demands of the two aforementioned developments.

The relationship between teaching, teachers and the quality of mathematics learning is a complex one and multidimensional. One useful way to untangle this network of relationship is to examine the question of what is the nature of mathematical understanding and what is it about teaching that could make a significant impact on students' experiences with and understanding of mathematics. I suggest that analysis of the former is critical to developing arguments about the latter. Several reasons could be advanced to explain this nexus but I suggest we commence our analysis from the vantage point of organisation of mathematical knowledge that girds students' learning and teachers' knowledge that drive their classroom practice. Classroom practices could include a number of elements including the quality of conceptual representations provided for learners, examination of alternative solution strategies, questions posed and pondered on during instruction, the quality of problems that students are challenged with and the quality of general discourse that is generated in mathematics classrooms.

LEARNING MATHEMATICS AND QUALITY OF STUDENT UNDERSTANDING

A recurring theme in Australian and international literature on mathematics education is the quality of learning in mathematics that we would like our students to develop. However, the notion of quality of learning has been interpreted differently. Our characterization of this important construct is aligned with the perspective of knowledge development, access and use. That is, we make the assumption that the analysis of knowledge and its application during problem solving episodes will provide a reliable indicator of students' quality of learning in mathematics.

Knowledge for mathematical learning can broadly be classified into two components: concepts and processes. Studies of mathematical thinking and learning have tended to examine concepts that students learn and subsequently use in the solution of problems. Such a position is based on the premise that concepts and processes are different entities and that processes are called upon to act on concepts during problem solving. We, however, adopt an alternative assumption in capturing the richness of students' algebra and geometry conceptual knowledge. The development of concepts must be examined in the context of its use, that is the co-development of mathematical concepts and problem-solving processes. Lesh (2007) suggested that this approach would provide a situated understanding of mathematical concepts which are fundamental to modelling complex problems. The embedded nature of concepts and meaning-making suggest the need for frameworks that emphasise connectedness in characterising the quality of mathematical learning.

SCHEMATISED KNOWLEDGE

Schemas are knowledge structure or chunks of meaningful mathematical information. Cognitive psychologists and mathematics educators in describing knowledge acquisition and utilization have adopted the framework of schemas. For example, Mayer (1992) advocated the identification of schema during mathematical learning. It is suggested that learning involves the acquisition and automation of disparate information into schemas. As the schemas become automated, accessing and using these schemas impose less cognitive load (Chinnappan, 2010). Knowledge that is organized into schemas has been shown to be easier to access than those that are not because in processing the connected knowledge, less of the limited working memory capacity is used; thus, freeing up mental resources to analyse the more difficult parts of problems. Sweller (1989) suggested that the study of schema or schematised mathematical knowledge would provide useful insights into students' algebraic and geometric knowledge. Chinnappan (1998) used schemas to analyse Year 10 students' understanding of properties of 2 and 3-dimensional figures and theorems that capture relations among angles and sides of such figures. Invariably, connectedness forms an important facet of a schema-based examination and analyse of quality of mathematical knowledge. We are currently measuring connectedness by considering type of relations between two or more units of knowledge and the number of such relations.

MATHEMATICAL UNDERSTANDING

While schema analysis is expected to generate data that can be used to make judgments about quality of concepts, we aim to provide a second learning platform for students to exhibit the sophistication of their concepts. Developments in cognitive psychology have given currency to the view that understanding of a mathematical concept is reflected by the representation of that concept in problems (Anderson, 2009). Thus, one useful way to examine students' understanding of geometry and algebra concepts would be to analyse the nature of problem representations that they are able to construct with these concepts. Accordingly, students will be expected to develop multiple representations for a given set of problems and articulate differences and similarities among the representations. In doing so, students are expected to reveal shades of meaning that they may have developed with algebraic and geometric concepts but could not exhibit them in schema-based activities. The representational notion of concepts can be seen as an extension of connected learning. The quality of reasoning that students could produce in their justification of links among the representations constitutes mathematical understanding (Barmby et al., 2009). The generation and discovery of links among representations are referred to as representational fluency (Lesh, 2007).

In a review of research on mathematical problem solving, Lesh (2007) argued the need to reconceptualise problem solving as representational fluency in ways that would reflect students having to function in high-performance work environments such as engineering and design. He argued for research that provides students with opportunities to reveal their thoughts via model-eliciting activities are needed in order to better examine the quality of mathematics concepts students have acquired. Such problems are often open-ended and somewhat ill-structured. It would also seem that the reduction in cognitive load that is involved in the activation and use of schematized mathematical knowledge also could catalyse the ease with which students could move across representations.

Students develop deep understanding when they grasp the relatively complex relationships between the central concepts that anchor a particular problem representation. Thus, instead of being able to recite only fragmented pieces of information, they understand a concept in a relatively integrated way. Students with better understanding can be expected to discover relationships, solve problems, construct explanations and draw conclusions. Students have only shallow understanding when they do not or cannot use knowledge to make clear distinctions, present arguments, solve problems or develop more complex understanding of other related phenomena. We propose to capture these different levels of understanding by drawing on Barmby et al.'s (2009) model.

TEACHER KNOWLEDGE AND MATHEMATICS TEACHING

A significant number of research studies (e.g., Even & Tirosh, 1995; Huang & Kulm, 2012; Imre & Akkoc, 2012) have attempted to examine the quality of mathematics teaching by considering the knowledge base that teachers need, activate and exploit during the course of their practice. It would seem reasonable that teachers with rich and sophisticated mathematical and pedagogical knowledge would have positive effect on the learning gains of their students (Fennema & Franke, 1992). Interest in mathematics teacher knowledge that supports better learning has generated several productive lines of inquiry. There is now a great deal of excitement and focus on the clarification of the nature of this knowledge, ways to measure this knowledge and, the use of that information to support the on-going professional development of mathematics teachers (Tajudin & Chinnappan, 2015).

The pioneering work of Shulman (1976) opened the field into the analysis of teaching quality and provided the impetus for the investigation of teacher knowledge underlying teaching. He identified two major dimensions of that knowledge that is fundamental to his work: Subject-Matter Knowledge (SMK) and Pedagogical Content Knowledge (PCK). SMK is about the content knowledge of mathematics that teachers need to perform their work. Included in the teachers' repertoires of subject-matter knowledge are: (1) substantive mathematical knowledge such as facts, ideas, theorems, mathematical explanations, concepts, processes (and connections between these elements), (2) understanding of knowledge about the nature and discourse of mathematics, (3) knowledge about mathematics in culture and society, and (4) conventions that are used by the mathematics community in communicating information. The strand of knowledge that is referred to as PCK consists of a number of sub-strands including knowledge about the learner and knowledge about teaching mathematics.

This pioneering work led to a stream of studies in SMK and PCK. For example, Ma's (2010) inquiry provided empirical support for the claim that subject-matter knowledge is critical in the development of pedagogical content knowledge. In a similar vein, Chinnappan and Lawson (2005) demonstrated that within the domain of plane geometry, competent high school teachers tend to have built and accessed richer and better-connected strands of both these knowledge dimensions. The field was further extended by Deborah Ball and her colleagues at the University of Michigan with the conceptualisation of SMK and PCK into sub-dimensions. For example, SMK was unpacked in terms of Common Content Knowledge and Specialised Content Knowledge in generating a model of teacher knowledge -Mathematical Knowledge for Teaching (MKT) (Ball, Hill & Bass, 2005; Ball, Thames & Phelps, 2008).

MATHEMATICS TEACHER KNOWLEDGE AND PROFESSIONAL DEVELOPMENT: NEED FOR A PARADIGM SHIFT

Professional development (PD) of mathematics teachers or staff development as it is commonly known has been defined in multiple ways but the common theme in most definitions refer to activities or programs that are designed to enhance and support teacher learning such that it will have a positive effect on the learning of their students. Equally, these programs are aimed at encouraging teachers to become reflective learners within a community of professionals. However, in general, organisers of PD programs are less forthcoming about the kind of learning that teachers need in order to improve their classroom practice.

While most programs of PD focus on scaffolding teachers as learners, less is known about the substance of this learning and its role in fostering learning among students. My arguments are premised on the assumption that if PD programs are to provide effective learning experiences for mathematics teachers, it is essential that we are clear about the nature of this learning, outcomes of these learning experiences and strategies to measure these outcomes. This position calls for a paradigm shift in our characterisation of teacher learning, in general, and teacher learning in the context of PD programs that target mathematics pedagogy. In this new paradigm, teacher educators and professional development programmers need to bring teacher knowledge and its development to the centre of their programs and planning. My earlier analysis of the body of knowledge that mathematics teachers need to function effectively as practitioners provides us with a powerful theoretical lens that can be used to guide the design and assessment of teacher learning activities that are completed during PD programs.

A knowledge-based analysis goes beyond providing guideline for the PD requirements for teachers of mathematics. Currently, there are debates about lifting the professional status of teachers in general and, mathematics teachers in particular. While formal qualifications have traditionally been used to accredit teachers to the profession, this strategy has proven to be somewhat limited in identifying teachers who can provide high quality teaching and prepare to learn while in practice. The analysis of teacher knowledge that underpins exemplary practice, I would suggest, not only provides a more reliable index of teacher quality but is also useful in identifying individual learning areas for continuous professional development.

KNOWLEDGE-DRIVEN PD PROGRAMS FOR MATHEMATICS TEACHERS IN THE MALAYSIAN AND SOUTH EAST ASIAN CONTEXT

The Knowledge-based models for PD programs that I am proposing here are relevant to current debates about mathematics teaching in Malaysia and South East Asian countries. The National Education Blueprint for educational reform in Malaysia has identified a number of priority areas including making teaching a profession of choice and having high-performing school leaders.Through this priority statement, the Government of Malaysia acknowledges that teachers are key stakeholders and instrumental in enhancing the quality of education that is provided by the system. In doing so, the status of teaching is being elevated and school leaders will be entrusted with responsibility to attract and retain student teachers of high calibre into the teaching profession. The implication for mathematics teacher and teaching is that the Ministry of Education and teacher education institutions ought to be developing strategies to recruit prospective teachers who are dedicated to their profession by demonstrating a commitment to continuous development. In this sense, one way to measure their dedication and commitment is to map the trajectory of their knowledge growth along the model of Mathematical Knowledge for Teaching as proposed by Ball.

The SEAMEO Regional Centre for Science and Mathematics Education (SEAMEO RECSAM) has recently engaged in an exercise that resulted in proposing a framework for developing mathematics teaching standards for South East Asian countries. One of the key dimensions of this framework is professional knowledge which attempts to unpack strands of knowledge that mathematics teachers need to better engage students from diverse socio-economic and cultural backgrounds.We could commence such an exercise by reconceptualising the constructs of SMK and PCK for ASEAN countries such that the framework is culturally sensitive and pliable for policy generation. The above initiative by international centres of excellence is timely and provides further evidence of the unpacking knowledge that girds mathematics teachers and aids in developing guidelines for recognition of the profession.

More generally, the quality of mathematics teaching, professional development and the support structures to enhance teacher knowledge should be evaluated against the background of steps that are afoot to increase the profile of mathematics teachers in Southeast Asia. Given that STEM workers are going to form a significant proportion of future workforce in knowledge-driven economies such as that of Malaysia, it is imperative that policy frameworks are put in place in order that the mathematics teaching profession is better resourced and rewards teachers who strive to build deep and sophisticated content and pedagogical knowledge. In this regard, teacher education institutions can be expected to play a leading role in researching and assisting the wider community to better understand this body of knowledge. Major employers of mathematics teachers including the Ministry of Education Malaysia would be beneficiaries of results of Research and Development rogrammes that are initiated and sustained by teacher education institutions (IPGs) and public universities such as UiTM.

A further implication is the need for government and private-sector support for engaging the international community about cutting-edge research projects and findings in the teacher knowledge space. Our community works in a borderless world and there are multiple opportunities and resources to access and contribute to. The second half of the 21st Century is arguably an exciting period for mathematics educators in the Asia-Pacific rim countries to come together and explore useful paths for identifying mathematics talent and to better support our mathematics teachers of the future.

CONCLUSION

In this plenary, I have argued that current models of PD programs for mathematics teachers could be made to be more effective by directing our resources to attract high quality applicants for teaching positions, programs that target teacher learning and tasks that foster the development of a robust body of knowledge base. While there are several models of such knowledge, I suggest that the MKT model provides a powerful framework for conceptualising and assessing teacher learning in the context of providing more effective PD experiences. Future work in this space could aim to generate and analyse MKT sensitive activities for PD programs and their efficacy. Equally, mathematics teachers should beinvited to engage in action research about the viability of this approach to better support their continuous growth as professionals. Towards this end, public universities such as UiTM, could assume a more central role in setting the agenda for policy making and generate innovative programs for future mathematics teachers.

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