Chapter 16
Framing the Portraits of Singapore Secondary Mathematics Pedagogy: An Outsider's Perspective

Wee Tiong Seah

Abstract Thirteen different research articles which report on a programmatic research on the enacted secondary school mathematics curriculum in Singapore have been perused in the preparation for this chapter. It considers the instructional practices associated with Singapore secondary mathematics teachers, and identifies possible contextual factors that facilitate these teachers' enactment of the mathematics curriculum, framed by the Social Cognitive Theory. These factors include teachers' content knowledge, trust in the leadership, students as disciples, societal valuing of excellence, and twenty-first century competency education. The role of teacher self-efficacy is also examined. An understanding of these contextual factors helps to frame the portraits of mathematics teaching and learning in Singapore secondary schools, and could also allow us to better assess how best to replicate particular instructional practices in other mathematics education systems. In particular, it appears that what works in practice reflects the harmonious interaction between teacher professionalism on the one hand, and policy and other contextual factors on the other hand, underlied by what individuals, institutions, and the society value now and over time.

Keywords Context · Experienced and competent teachers · Instructional practice · Secondary mathematics · Singapore

16.1 From Machine to Cup, from Plan to Lesson

Coffee is one of the world's most popular beverages, and some baristas are known for creating great cups of the liquid gold consistently. Yet, across different countries, these and other baristas are likely using similar or identical expresso machines. Thus, the acquisition of one of these expensive expresso machines does not guarantee great

W. T. Seah (✉)

Melbourne Graduate School of Education, The University of Melbourne, Melbourne, VIC, Australia
e-mail: wt.seah@unimelb.edu.au

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coffee; the human barista is as important in the coffee-making process. For this reason, a skilful barista is considered to have mastered the science and art of making the perfect brew, and they are often celebrated and hotly sought-after.

Enacting a (mathematics) curriculum is no different. When Brown (2009) described teachers' work interpreting and enacting the curriculum as a design activity, he too was highlighting the creative process involved in interpreting and customising mathematics learning for students. An important component of this creative design work—whether one is creating a perfect cuppa or designing for effective mathematics teaching—is decision-making. Remillard (2018) distinguished between planned decisions and in-the-moment-design decisions [IMDDs], and both types of decisions contribute to the enacted curriculum. It should be noted that any IMDD made "is not necessarily a reflection of poor planning or underdeveloped resources. Rather, they reflect the substantive distinction between the written, planned, and enacted curriculum" (Remillard, 2018, p. 491).

It is well-known that Singapore students consistently produce world-leading results in major international mathematics assessment exercises such as the Trends in International Mathematics and Science Study [TIMSS] and Programme for International Student Assessment [PISA]. This achievement has understandably attracted much attention from educators and researchers across the world. Not only have Singapore students been demonstrating excellent mathematical knowledge and skills (the focus of TIMSS), but they have also proven themselves at applying these knowledge and skills to novel mathematical problem situations (the focus of PISA). While the rigorous and forward-thinking national mathematics curriculum can lay claim to much credit for this achievement (American Institutes for Research, 2005; Schleicher, 2018), just like those state-of-the-art expresso machines, the roles played by Singapore mathematics teachers—akin to the barista masters—in enacting the curriculum are equally significant. It is thus no wonder that the Australian Association of Mathematics Teachers, for example, has been organising Exchange Study Tours for Australian educators and teachers to interact with Singapore teachers face-to-face in classroom settings.

In this context, the publication of this book 'Mathematics Instructional Practices in Singapore Secondary Schools' has been timely. The book chapters drew upon the findings of an extensive programmatic research project conducted in Singapore in 2016—2018 to investigate the enacted secondary mathematics curriculum in Singapore schools (thereafter called the 'enactment project' in this chapter). The pedagogical practices of thirty experienced and competent teachers were examined, and for some of these practices, more than 600 other teachers were surveyed to determine the extent to which they were commonly employed in the Singapore secondary school mathematics education system.

However, just like it is often wondered why it is almost impossible to replicate the 'perfect cappuccino/latte' in certain countries, it is important to identify the features of different socio-political/institutional/personal contexts which either facilitate or impede a teacher's master strokes. Thus, the purpose of this chapter is to take advantage of the author's positioning as an outsider to look in at Singapore's educational scene, to identify features which affect how local teachers enact the curriculum in rich and effective ways, but which have not all been explicitly identified amongst the chapters of the book mentioned above. For readers in Singapore, this chapter might identify some contextual features which are otherwise invisible. For other readers, this chapter might provide us with a more rounded portrait of the mathematics instructional practices in Singapore secondary schools. In so doing, this chapter responds to the question: What contextual features facilitate Singapore secondary school teachers' enactment of the mathematics curriculum?

The author is also a privileged outsider to the Singapore mathematics education system. He was teacher-trained in Singapore and taught secondary school mathematics there for several years in the 1990s across the spectrum of perceived student abilities. This experience and contextual knowledge should add strength to the analysis reported in this chapter, for it would have enriched the ways in which the author has understood and interpreted the enactment project from the outside in. In particular, this cross-cultural professional experience sensitises the author to the place-based nature of mathematics teaching and learning.

As such, the discussion in this chapter is framed by the Social Cognitive Theory which is outlined in the next section. The contextual features identified can be categorised generally into personal and environmental factors. The personal factor which will be featured in this chapter will be teachers' content knowledge. As for the environmental factors, this chapter will focus on: trust in the leadership, students as disciples, societal valuing of *excellence*, and twenty-first century competency education. The role of teachers' self-efficacy will also be included.

16.2 Social Cognitive Theory

Albert Bandura's (1986) 'Social Cognitive Theory' regards an individual's behaviour and action as part of a three-component, dynamic, and reciprocal model in which personal factors [P], environmental factors [E], and behaviour [B] interact with and influence one another on an ongoing manner. In this model, B would refer to the Singapore teachers' enactment of the local mathematics curriculum. The individual—which in this chapter refers to any of the Singapore secondary mathematics teachers—is an active agent whose practice represents an enactment of the intended curriculum. The cognitive, affective, and conative aspects of a teacher's functioning would constitute P, examples of which include their mathematics content knowledge and pedagogical content knowledge, the affective dispositions, and the professional motivations. For example, we can see in Chapter 7 how teachers' cultivation of students' non-cognitive traits [B] were guided by both teachers' own beliefs [P] and teacher-perceived students' abilities [P]. These would interact with E, the environmental factors, in bidirectional ways. This may not be explicit in the chapter understandably, given that it was not the focus of the study. Yet, we can imagine, for examples, how the mathematics topic of the day [E] might affect the extent to which particular attitudes are included in the lesson plan [B], how the cultivation of *perseverance* [B] might modify a teacher's perception of a student's ability [P], and how the sustained and successful promotion of *confidence* amongst students in a class [B] would redefine the classroom context [E] for future mathematics teaching. What these mean in our discussion in this chapter is that

> knowledge of the factors, whether planned or fortuitous, that can alter the course of life paths provides guides for how to foster valued futures. At the personal level, it requires cultivating the capabilities for exercising self-directedness. These include the development of competencies, self-beliefs of efficacy to exercise control, and self-regulatory capabilities for influencing one's own motivation and actions. (Bandura, 1989, pp. 7–8)

Thus, this triadic reciprocal causation model highlights the role of teacher agency in enacting the curriculum. A key component of human agency is self-efficacy (Bandura, 1989), where

> self-judgments of operative capabilities function as one set of proximal determinants of how people behave, their thought patterns, and the emotional reactions they experience in taxing situations. (Bandura, 1989, p. 59)

There is then a particularly important function for teachers' self-efficacy as it regulates—and is regulated by—their personal factors, environmental factors, and decisions and actions. As much as the enactment of the curriculum involves decision-making before and during class (as was discussed above), this too is a function of a teacher's judgement of their own capacity to deliver what has been planned.

16.3 Teachers' Content Knowledge

A significant personal factor which affects a teacher's enactment of the curriculum is their own level of content knowledge. Without an excellent knowledge of mathematics, any teacher would not be aware of all the possibilities which are available for the creation, adaptation, and modification of instructional materials, for the solutions to challenging tasks, nor for the ways of simplifying mathematics explanations. More generally, as Ball, Thames, and Phelps (2008) asserted, "teachers must know the subject they teach. Indeed, there may be nothing more foundational to teacher competency" (p. 404). Similarly, the Teacher Education and Development Study in Mathematics [TEDS-M] adopts the view that "knowledge of content to be taught is a crucial factor in influencing the quality of teaching" (Tatto et al., 2008, p. 19).

In the project that this book is based on, there are many instances when teachers' command of the mathematics content knowledge had facilitated their interpretation and transformation of the mathematics curriculum. In Chapter 11, for example, we see in the mixed methods study with more than 600 teachers in Singapore how these teachers selected and modified instructional materials for classroom use. More than 96% of the teacher respondents revealed that they made adaptations and modifications to their reference materials such as textbooks and school-based resources. Indeed,

> a vast majority of Singapore secondary mathematics teachers do not view their duty as merely 'lifting' items from reference materials to give to their students; rather, they see their role as

> necessarily one of mediation between the reference materials and student learning: they are required to value-add by modifying them. (pp. 205–230)

Furthermore, the pedagogical considerations which guide the adaptations and modifications have led to a development of a range of teacher strategies, namely, ‘modify’, ‘new’, and ‘smoothen’. Underlying the effective use of each of these strategies has to be good-enough knowledge of relevant mathematics. For example, when a teacher participant was observed to have modified a vectors addition item to increase the cognitive demand for their students, this teacher clearly understood the commutative law for vector addition to achieve their intention, rather than simply regarding vector addition as arranging vectors ‘end-to-end’.

In addition, as reported in Chapter 12, students across all three ability streams in Singapore are regularly exposed to challenging tasks. Similarly, Chapter 14 described how a Singapore teacher (Teacher 8) employed a range of design principles towards creating instructional materials with the aim of promoting students’ connection-making. The author has also often heard comments overseas that Singapore mathematics teachers are good at relating to their students by simplifying their explanations to their ability levels. All these teacher moves would not have been possible if the teachers involved do not know enough relevant mathematics content.

Singapore’s participation in the International Comparative Study in Mathematics Teacher Training [ICSMTT] (Burghes, 2011) had shown that Singapore’s pre-service secondary mathematics teachers’ content knowledge was one of the best in the world, having ranked fourth. At the same time, the National Institute of Education, Singapore’s provider of teacher education programmes, is also actively taking steps ‘to ensure and/or develop such [content] knowledge in prospective as well as practising teachers’ (Tay, Lim, Ho, & Toh, 2017, p. 130).

The significance of teacher content knowledge on teaching effectiveness is visible when we examine the practices of out-of-field mathematics teachers, for example. The shortage of qualified mathematics teachers in secondary schools in several countries such as the USA, Australia, and Ireland (Ní Riordain & Hannigan, 2009) have led to large groups of out-of-field mathematics teachers who generally lack relevant mathematics content knowledge and pedagogical content knowledge. For example, 21–38% of Years 7–10 mathematics classes in Australia are believed to have been taught by out-of-field teachers (Prince & O’Connor, 2018). Since a command of mathematics content knowledge is crucial to teacher quality in planning, facilitating, and assessing mathematics learning, then these out-of-field teachers will find mathematics teaching an extra challenge cognitively, since they need to interact with mathematics concepts and skills. McConney and Price (2009) reported how teachers who believed that they have some control over subjects they were teaching out-of-field also thought that they were better supported and more capable. This is perhaps why two professional development programmes catering to out-of-field teachers in Australia had prioritised acquisition of mathematics content knowledge over other forms of knowledge (Vale, 2010).

16.4 Trust in the Leadership

According to the 2020 Edelman Trust Barometer (Edelman, 2020), Singapore is one of only 7 out of 28 countries in which the government is trusted by a majority of its people. This is not unfounded. In less than a generation, the same government in Singapore had led a small island which has no natural resources through self-government to independence, and transformed it into a technologically advanced island state with one of the highest GDP in the world. For many Singapore teachers, their parents would have survived the early difficult days with the government, and as such, there is a sense of shared camaraderie. This trust in—and respect for—the government extends to the (mathematics) education system as well; Singapore's achievement in TIMSS and PISA since their respective inceptions would have further strengthened this trust in the country's education leadership. In the context of the enactment project, this trust thus constitutes a facilitating environmental factor which ultimately supports teachers' enactment of the curriculum.

In this positive environment of trust and professionalism, teachers, the teacher education provider, and the government can engage in productive dialogues which ultimately benefit the quality of teaching and learning. One area in which the education system would have benefitted from this productive relationship is the positive attitudes and mindsets which teachers, principals, policy makers, and educational researchers have for one another when they implement and evaluate new approaches to teaching (mathematics). This is not to say that teachers will enact in their practice what is 'given' to them without question. Rather, innovative pedagogical approaches which have been adapted for the Singapore context are more often assessed by the professional community with a more open mind. What we see as a result of this tripartite relationship is very often an informed and engaged implementation of new teaching approaches, which in turn facilitates higher probabilities of improving the quality of school mathematics education.

16.5 Students as Disciples

The same teacher teaching the same topic in different classes would not enact the curriculum identically, as the teacher attends to different student needs and demands. In other words, the enacted curriculum is co-constructed with students. Students thus constitute another set of environmental factors affecting curriculum enactment. While it was not the intention of the enactment project to focus on students, they do get mentioned since teachers' decisions and practice are intertwined with students' participation. The experienced and competent teacher featured in Chapter 9, Teacher 27, provided an example of how dialogic mathematics talk was able to take place with the engaged participation of his students. Yet, "instances of meaningful math talk in which students are actively engaged in and are transforming one other's thinking are rare" (pp. 163–181). Although the reasons for this phenomenon were not offered, understandably, the author wonders how the teachers felt when confronted with this phenomenon? Or, would this be expected in the student–teacher relationship in the classroom somewhat, so that the teachers' (lack of) response in turn reinforces the students' 'silence'? Indeed, to what extent has Singapore teachers' enactment of the mathematics curriculum taken into consideration (consciously or otherwise) the students' behaviour and expectations in class? How representative is the case in Chapter 4, when "students had little room to think independently. Instead, students mainly followed the teacher's 'planned frame' to learn what was prior determined by the teacher" (pp. 63–77).

Perhaps this reflects the cultural reality in Singapore, in which the student–teacher relationship continues to be perceived by the society as being essentially disciple-master in nature. In Confucius Heritage Cultures such as Singapore, the teacher is often regarded as the holder of knowledge, especially for subjects such as mathematics which is often perceived to have no allowance for 'grey areas'. In addition, Singapore scores highly along the 'power distance' dimension in Geert Hofstede's 6D Model (Hofstede Insights, 2020), which indicates a high "extent to which the less powerful members of institutions and organisations within a country expect and accept that power is distributed unequally" (Hofstede Insights, 2020). In the education setting, this would mean that we can expect to see students in Singapore schools respecting their teachers' authority, which in the local culture also implies not arguing back, not questioning, and not making disrespectful comments (see also Hogan, 2014).

16.6 21st Century Competency Education

One of the five inter-related components of the Singapore Mathematics Curriculum Framework (Singapore MoE, 2019) is named 'attitudes'. "Attitudes include one's belief and appreciation of the value of mathematics, one's confidence and motivation in using mathematics, and one's interests and perseverance to solve problems using mathematics" (Singapore MoE, 2019, p. 11). Thus, despite the label for the component being affective, it actually refers to the range of affective and conative—that is, non-cognitive—features of learning that are to be fostered amongst students. This is significant: even though 'productive dispositions' is one of the five identified intertwined strands of mathematical proficiencies in the influential report prepared by Jeremy Kilpatrick and his colleagues (US National Research Council, 2001), only a few countries appear to have incorporated it in their latest mathematics curriculum reform. The Australian Curriculum (ACARA, 2016), for example, features a set of four proficiency strands that are parallel to the four cognitive strands in the American report, but leaving out the 'productive dispositions' strand.

This expectation for teachers to cultivate 'desirable' affect and enabling conation amongst their mathematics students would have supported teachers' intentions and efforts to incorporate it in their instructional practice. In Chapter 7, the research with experienced and competent mathematics teachers revealed that they teach in ways which cultivate confidence, perseverance, appreciation, and interest. The fostering of student beliefs, however, was not observed. According to the research findings, the teacher's actions were not only supported by environmental factors, but also guided by the teachers' own beliefs as well as their perception of student ability, both personal factors.

It should be noted that Singapore's approach goes beyond making mathematics learning fun for students. The findings reveal that the non-cognitive traits that are promoted both deepen students' appreciation of the nature of mathematics (e.g. real-world applications), and develop students' personal competencies (e.g. perseverance). Similarly, in an earlier study, Toh, Cheng, Ho, Jiang, and Lim (2017) demonstrated how comics were used in mathematics lessons to promote interest AND to facilitate twenty-first-century skills. It seems that non-cognitive traits are not only developed to facilitate mathematics learning, but mathematics learning also has the responsibility of developing relevant traits amongst students as part of the country's holistic education process. As noted in a OECD (2019) report,

> the curriculum in Singapore … highlights that competencies are to be learnt with core values – care, integrity, respect, resilience, responsibility and harmony – at the centre of their learning framework. Singapore's Ministry of Education believes that 21st-century competencies are not learned in a vacuum, but in specific contexts …. These values are expected to be embedded into every subject. (p. 7)

16.7 Societal Valuing of *Excellence*

The Singapore culture values *excellence,* the spirit of which is best captured by a Hokkien dialect lexicon often used locally, 'zho sui sui' (literally: get it done beautifully and perfect). The term is found in the value statements and slogans of many institutions and companies. The Singapore healthcare system, one of the best in the world, has been described as delivering 'affordable excellence' (Haseltine, 2013). 'Excellence' is one of the six core values of the iconic Singapore Airlines. But it is not 'all policy and no action'. *Excellence* is a trait that has been built into the Singapore psyche, where 'okay is not good enough'. One will hardly ever hear anyone saying, 's/he will be alright!'.

The same trait is valued in the Singapore education system as well, in part due to the cultural influence of Confucianism in which academic excellence is revered. As Kaur (2004) asserted,

> [in relation to striving] towards excellence in the mathematics classroom [,] …. As the saying goes – good, better, best; never let it rest till good is better and better is BEST!, generally mathematics teachers in Singapore schools are poised to do the best they can for their pupils. (n.p.)

Thus, this creates an environment for Singapore teachers to expect nothing but the best of their teaching and of their students. When the teacher participants of the project this book is based on creatively designed or selected challenging tasks for their students (see Chapter 12), they were confident that their practice would be supported by the students' willingness to try and engage.

This cultural trait might explain why the mathematics pedagogical practice in Singapore continues to display a dominant performative orientation (see Chapter 2). Teaching for student mastery using worked examples and class practice was found to be not just a teacher move exercised by the experienced and competent teachers in Singapore, but one which defines the instructional practice of the 600+ teachers surveyed in the study noted in Chapter 5. This focus on mastery learning is indeed also an expression of the valuing of *excellence*.

The strive towards excellence does not need to come at the expense of developing other skills such as understanding. In the project this book is based on, while the teacher participants were engaged with teaching practices that promote mastery (see Chapter 5) and that introduce students to challenging tasks (see Chapter 12), they were also teaching in ways which promote conceptual understanding (see Chapter 4), mathematical reasoning (see Chapter 13), and connections (see Chapter 14).

16.8 Teachers' Self-Efficacy

Perhaps because the teacher participants in the Enactment Project were all considered experienced and competent, their instructional practice as reported in the various studies reflect high teacher self-efficacy. That is to say, to be able to plan and execute all that had been summarised in this chapter so far reflects teacher beliefs in their capabilities to exercise control over their respective enactment of the mathematics curriculum. Certainly, Singapore teachers' strong mathematics content knowledge, value alignment with the society, students' identity as disciple, and Singapore's achievement in TIMSS and PISA, are contextual features which would contribute to the teachers' self-efficacy beliefs to some extent. Since a teacher's identity as a professional is heavily related to their self-efficacy (Canrinus, Helms-Lorenz, Beijaard, Buitink, & Hofman, 2012), it is important that this particular form of teacher beliefs is nurtured and developed.

The high esteem with which the teaching profession is held in the Singapore culture (Dolton, Marcenaro, de Vries, & She, 2018; Tan & Liu, 2017) would also contribute to high teacher efficacy. In Singapore, teachers are respected for the crucial roles they play in educating the young generations, and this trust in their professionalism is expressed in the ways they are entrusted by the Ministry of Education to design and deliver lessons that cater to the capacity and needs of their own students. Schools and teachers are also encouraged and supported to take ownership over their professional learning, as reflected in such policies as 'Thinking Schools, Learning Nation' in the late 1990s and in the adoption of the Professional Learning Communities [PLC] (Hord, 1997) model in the early 2000s as the main means across all schools for teacher professional learning. For a teacher, the combination of such professional support, their trust in the leadership (see Sect. 16.4), and the respect they experience in school and in the society, all come together to strengthen their belief in their ability to teach and to enable student learning, that is, teacher efficacy.

Empirically derived knowledge regarding Singapore mathematics teachers' self-efficacy does not appear to exist, however. A study did find that Singapore secondary school teachers' self-efficacy was dependent on the educational streams of their respective students (Chong, Klassen, Huan, Wong, & Kates, 2010). Specifically, teachers in high-track schools displayed greater efficacy beliefs compared to their peers in other schools where there was a greater variety of student achievement types. This study did not break down its 222 teacher participants by the subjects they were teaching though, so it is not clear the extent to which a similar scenario might apply to mathematics teachers.

16.9 Conclusions

There is no doubt that teachers and educators around the world are interested to find out not just how Singapore organises her school mathematics curriculum, but also how Singapore teachers enact it in their instructional practices. The Enactment Project this book is based on has collected relevant data from a wide range of perspectives to shed light on how experienced and competent teachers have done this in their instructional practices, and also how representative these might be in the Singapore secondary teaching profession. This chapter complements these findings by suggesting how the teacher moves are to be understood in context, as unique teacher personal factors and environmental influences shape these moves while also being shaped by them. It identifies teachers' content knowledge, trust in the leadership, students as disciples, societal valuing of *excellence*, and twenty-first-century competency education as examples of such factors. The role of teacher self-efficacy is also examined.

Understanding these contextual factors allows us to better assess how best to replicate particular instructional practices elsewhere, amongst other possibilities. For example, foreign visitors to the Singapore mathematics classroom would notice pedagogical approaches and professional learning programmes that might be familiar in their home education systems, such as student-centred teaching (see Chapter 3 for details) and PLCs, and they may be left wondering what the secret ingredient to Singapore's success in school mathematics education is. It is hoped that the discussion in this chapter would remind these visitors that what works in practice reflects the harmonious interaction between teacher professionalism on the one hand, and policy and other contextual factors on the other hand, underlied by what individuals, institutions, and the society value now and over time.

Perhaps this is why, despite the best efforts of talented baristas elsewhere with the best espresso machines, there is something about latte in Melbourne, Australia which makes it one of the best—if not the best—in the world.

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Wee Tiong Seah is an Associate Professor at the Melbourne Graduate School of Education, The University of Melbourne, Australia. He is also an appointed Research Fellow of Zhejiang Basic Education Research Centre, China. He taught Mathematics and English Language in secondary schools in Singapore before embarking on an academic career in Monash University, followed by The University of Melbourne, both in Australia. In Australia, Wee Tiong teaches pre-, in-service as well as postgraduate courses in mathematics education and in research methodology, and supervises research students pursuing Masters and PhD degrees. His publication and research interests include the development of enabling valuing amongst students and teachers, self-efficacy, and the role of artificial intelligence programmes in complementing mathematics teachers' professional practice.