

Introducing the Landscape of the Singapore Mathematics Education Journey

Mathematics education encompasses both practices and research. This book is a state-of-the-art review, though not an encyclopaedia or a handbook, of current practices and research studies in mathematics education and mathematics teacher education in Singapore. It traces the journey from the development of the Singapore mathematics curriculum in the 1950s to the present day and reports on how that curriculum is put into practice and what research can enlighten the readers about the effects of those practices. This review extends the first state-of-the-art review on mathematics education in Singapore published in 1991 (Chong, Khoo, Foong, Kaur & Lim-Teo, 1991). This former review was commissioned by the Southeast Asian Research Review and Advisory Group (SEARRAG), and it included only summaries of research studies but did not describe practices. During the intervening one and half decades, many changes have taken place in the practices of mathematics education in Singapore, including several revisions of the mathematics curriculum with reduction of topic coverage, infusion of Information and Communications Technology (ICT) into mathematics instruction, recruitment and training of trainee teachers and in-service teachers by the National Institute of Education (NIE), and the important roles of mathematics education within the national education system. The education research culture in Singapore has also blossomed with more mathematics educators at NIE participating in international comparative projects, an increasing number of research students in mathematics education at NIE (at the time of writing, there are 16 PhD students in mathematics education), higher expectations on mathematics educators at

NIE to conduct research and to publish, stronger funding of educational research from the Singapore Ministry of Education (MOE), in particular, the establishment of the multi-million dollar Centre for Research in Pedagogy and Practice (CRPP) at NIE, and a growing awareness and acceptance of senior education administrators and policy-makers of the contributory functions of high-quality research studies in the debates to formulate policies about critical education issues to prepare Singapore students for the uncertain future.

Members of the editorial team have duly recognised the above trends and needs, and have invited or commissioned mathematics educators and senior mathematics teachers in Singapore to contribute chapters on different aspects of this education journey. Each chapter has been reviewed by at least two editorial members. Collectively the chapters describe the mathematics education landscapes, relate personal experiences, peep into classroom snippets, offer historical sketches, tell well-worn or novel stories, report heavy statistics, and much more, including the important theme of students' learning in most of the chapters. These are idiosyncratic voices describing some features of the Singapore mathematics education landscape from the authors' perspective; they do not represent any official views. Nevertheless, we hope that the issues these authors so earnestly explore in this book will be of interest not only to local readers, in particular graduate students and researchers, but also to the international mathematics education community, because many local studies are not readily available in international publications. Policy-makers and readers outside of mathematics education may be able to tease out relevant lessons in their own domains beyond mathematics. However, we also wish to reiterate that what has apparently worked for Singapore mathematics education at a particular period in its history may not work elsewhere or at different times, a fundamental belief that has guided many of us in what we have learned and adapted from other countries and domains of knowledge.

There is no one "right" way to begin a journey, nor is there one "best" way to read a huge book like this one about an education journey. Nevertheless, when one embarks on a journey, it is prudent to have on hand a good map that indicates the major signposts of the terrain. These signposts can inform the travellers about the peaks and valleys, forests

and deserts, islands and currents along the journey. For many travellers, be they tourists or natives, such a map or guidebook, either printed or mental, also helps them to visualise the relationships among the objects and scenes encountered along the way. In the case of an abstract journey of how Singapore students have become very competent in mathematics or how Singapore has developed a world-class education system in the eyes of some international educators (e.g., Barber & Mourshed, 2007; National Mathematics Advisory Panel, 2008), there are actually many challenges along the timeline and in the curriculum space. The chapters in this book describe these challenges narrated in many cases by authors who have participated in national curriculum development, published mathematics textbooks, and conducted the research studies they are writing about. Furthermore, what the readers finally know about certain aspects of the journey depends to a great extent on who are the narrators; hence, the biographical data given at the back of the book should be read together with the respective chapters. The rest of this introductory chapter describes our mental map for the chapters.

The 23 chapters are divided into three main parts. Part I contains six chapters about the Singapore education system and mathematics teacher education. A good place to begin especially for readers who are unfamiliar with the Singapore education system is Chapter 1 by Wong and Lee N. H. This chapter traces the development of the Singapore education system and its mathematics curriculum over the past five decades. It explains the terminologies commonly used to describe this system and several major initiatives introduced by the Singapore MOE during this period. For example, terms such as *Special*, *Express*, *Normal*, *model drawing method*, *the Pentagon framework*, *PSLE*, and *clusters*, have specific local meanings and they will appear frequently throughout the book. Understanding this background information will help the readers follow the discussions in the other chapters of the book.

Singapore teachers have been known to work very hard, and a recent McKinsey report (Barber & Mourshed, 2007) has highlighted the important contributions of high-quality teachers in a world-class education system. Chapter 2 by Lim-Teo describes how mathematics teachers are trained at NIE in programmes that range from pre-service to in-service to graduate levels. The chapter also contributes to international

discussion about balancing the roles of mathematics content knowledge, pedagogical content knowledge, and theory-practice link in teacher education, in particular, drawing on some findings of a major study led by the author on mathematics pedagogical content knowledge (MPCK) among novice primary school mathematics teachers.

Helping teachers to develop through a learning community that stresses mutual support has been strongly promoted by many educators. Chapter 3 by Chua P. H. explains several measures undertaken in Singapore along this path, giving details about Learning Circles, action research, and the functions of the Centre of Excellence on Mathematics at the East Zone. An emerging form of such a learning community in Singapore is the adaptation of “lesson study” that has its origin in Japan but has since spread to several countries. In Chapter 4, Fang, Lee C. K. E., and Sharifah document their experiences in trialling this form of professional development in a primary school, working on lessons in long division, area and perimeter, and equivalent fractions at Primary 3 and 4 levels. Another way to bring about teacher change in pedagogy is to engage them as collaborators in research. Yeap and Ho in Chapter 5 explore this approach by describing three case studies and situating it within their 4-I Model of teacher change. Singapore MOE recognises the need to appoint Master Teachers who have shown very strong pedagogical practices in the disciplines, as catalysts to promote teacher professional learning by organising various activities. Currently there are only two Master Teachers in mathematics, and in Chapter 6, Ng J. D. and Foo K. F., as Master Teachers at the primary and secondary level respectively, explain the nature of this scheme and sketch their own personal journeys as teacher leaders and curriculum leaders at the cluster level.

Mathematics teaching and learning covers numerous features and this diverse topography adds richness to the journey. Part II consists of 12 chapters that offer interesting details (as in close-up shots) and more macro descriptions (as in medium shots) of these features.

A unique Singapore mathematics landscape is the model drawing method. It was created in the 1980s to help students solve so-called “challenge problems” or algebra word problems without the use of algebra. This systematic method has now attracted some attention from

the international community. However, the experience of teaching this method in primary schools over the past twenty years has raised several issues in curriculum design, assessment, and instruction (see Chapter 1) that have attracted the attention of several researchers. There are two chapters about this model drawing method: Chapter 7 by Ng S. F. and Lee K. takes a pedagogical perspective drawing on a series of studies of students' work in solving algebra word problems, and Chapter 8 by Lee K. and Ng S. F. examines the role of working memory using functional neuro-imaging technologies to conclude that symbolic algebraic method demands more of working memory than the model drawing method. This latter research attempts to link problem solving behaviours to physiological basis, a path of applying neuroscience to study important education problems.

The next two chapters (9 and 10) deal with two specific mathematics topics and the studies were conducted by recent PhD graduates. In Chapter 9, Wu and Wong provide data about the performance of a large sample ($n = 907$) of secondary school students in graph reading, graph interpretation, graph construction, and graph evaluation. A concern is that many students could not explain their statistical reasoning with statistical graph items. In Chapter 10 about another large-scale survey ($n = 1002$) of Primary 6 to Secondary 2 students, Jiang presents the problem solving strategies used by these students to solve three word problems on speed and their common errors. Indeed, there are many more studies of problem solving heuristics, learning difficulties, and errors among Singapore students that have not been included in this book. Nevertheless, to provide further glimpses of this part of the terrain, Foong in Chapter 11 provides a narrative review of more than 60 studies about mathematics problem solving, conducted mostly by graduate students. It is not possible to give a one-line summary this complex landscape, and it suffices here to just highlight the need for researchers to work closely with teachers to address their beliefs, practices, and dilemmas to teach mathematics via problem solving or to teach about problem solving.

In line with international trends, Singapore has invested billions of dollars into equipping schools with essential and adds-on ICT resources, developing e-learning materials, training teachers to integrate the

technologies into mainstream teaching, and introducing policies of ICT use, for example, allocating 30% of curriculum time to embed ICT. International findings about ICT use in mathematics education have been equivocal, and large-scale studies tend to report lack of impacts of ICT on student achievement (e.g., Dynarski et al., 2007). In Chapter 12, Ng W. L. and Leong describe the Singapore practices and report some findings on how ICT has been harnessed in mathematics teaching and learning. They take note of the many unresolved issues about ICT use down the technological path and stress the need to use ICT not as a technological toy but as a tool that can promote active learning.

Although the learning of mathematics involves mainly cognitive processes, there is convincing evidence and strong theoretical arguments to show that emotions, attitudes, values, and other affective characteristics held by the students can influence the effectiveness of their learning. Two chapters address this issue. Chapter 13 by Yeo reports a weak correlation of 0.39 between mathematics anxiety (as measured by the Fennema-Sherman Mathematics Anxiety Scale) and test anxiety (as measured by the Test Anxiety Inventory) among a group of 621 Secondary 2 students. In Chapter 14, Lui, Toh, and Chung describe a relationship between the perceptions held by about 700 Secondary 2 students about the social climate of their classrooms and their self-concept in mathematics. In a follow-up action research project, two groups of Secondary 2 students engaged in several cooperative learning activities, and their feelings were generally positive. Studies that extend from those reported in these two chapters should examine the relationships between affective variables and mathematics achievement at different grade levels.

Students differ widely in their aptitude for mathematics. Singapore has followed international practices to develop special curriculum for the gifted and for those who need special assistance. Khong describes in Chapter 15 several programmes that cater to the needs of the gifted and the talented in mathematics. The key approach is through curriculum differentiation, and 11 types of differentiation are briefly explained, ranging from using challenging problems to out-of-class activities. On the other hand, in Chapter 16, Cheam and Chua W. L. J. explain the Learning Support for Mathematics (LSM) framework that MOE has

developed in the past few years to include the types of experiences to be offered to lower primary pupils who have been identified through normed tests to need special remediation in mathematics. This framework is a 4-pronged intervention approach covering cognition, metacognition, motivation, and environment. These “special needs” students might have missed crucial learning and development experiences in kindergartens and pre-schools, which are not part of the national, formal education system. Sharpe in Chapter 17 describes three studies about numeracy at these early years, showing that some kindergarten teachers were not knowledgeable about how young children think about number work. She proposes several activities that are more developmental in nature. Indeed, there is only sketchy information about the terrain of early numeracy in Singapore.

Ever since Singapore students achieved top performance in mathematics in the TIMSS series of international comparison in 1995, 1999, and 2003, a constant stream of overseas educators and delegations has visited Singapore trying to find out the factors that might contribute to this success. However, within Singapore, the main education stakeholders, namely, students, parents, teachers, schools, and ministry officials, do not place much emphasis on TIMSS findings to set the benchmarks for success of the education system. The local stakeholders are more likely to use as main indicators the performance of students in the public examinations, namely, the Primary School Leaving Examination (PSLE), Singapore-Cambridge General Certificate of Examinations at Ordinary level, Normal level, and Advanced level. This book does not provide any in-depth analysis of these important examinations, but the interested readers can locate the examination results from the *Singapore Education Statistics Digest* at <http://www.moe.gov.sg/>. The evolution of the Singapore examination systems is clearly explained in the recently published book by Tan, Chow, and Goh (2008). Set against this national examination system, Quek and Fan argue in Chapter 18 for the need to devise a new examination paradigm to encompass what is now known as “alternative assessment.” They then describe a large study that incorporated four types of alternative assessment (journal writing, self-assessment, oral presentations, and projects) in classroom lessons.

The five chapters in Part III cover four international comparative studies that Singapore has participated in. The performance of Singapore students in TIMSS is dealt with by Kaur in Chapter 19. Although Singapore students scored very well in many TIMSS items, Kaur cautions that a sizeable proportion of these students are still weak in solving problems unfamiliar to them in terms of context, language, and format. She proposes no fewer than nine possible factors of success, but TIMSS analyses conducted to-date have not been able to provide convincing direct links or effects between these factors and mathematics achievement. In the case of background variables, Boey in Chapter 20 provides some findings from TIMSS 2003 on seven categories that cover students' attitudes toward mathematics, home resources, and school environments.

Besides TIMSS, mathematics educators in Singapore have also participated in smaller comparative studies. Chapters 21 (Kaur and Yap) and 22 (Kaur, Koay, and Yap) describe two longitudinal studies undertaken in the past decade. The Kassel project, reported in Chapter 21, followed more than 2000 students from Secondary 2 (13+) in 1995 to Secondary 3 (14+) in 1996, whereas the International Project on Mathematical Attainment (IPMA) (see Chapter 22) tracked the mathematics performance of about 800 students from Primary 1 (6+) in 1999 to Primary 5 (10+) in 2003 on a yearly basis. Longitudinal studies are rare in education, so these two chapters should be of particular interest to mathematics educators. Unlike the other studies that concentrate on students' mathematics performance, the last chapter in Part III by Wong, Kaur, Koay, and Jamilah reports on students' perceptions about their "best" mathematics teachers using the relatively new "Draw a teacher" technique, supplemented with written responses.

With this necessarily brief introduction, we invite you to embark on the Singapore mathematics education journey, beginning with the terrain that best captures your interests or needs. Bon voyage. In the final concluding chapter, we will discuss new landscapes that invite local explanation and international collaboration.

Editorial Board
May, 2008

References

- Barber, M., & Mourshed, M. (2007). *How the world's best-performing school systems come out on top*. London: McKinsey & Co.
- Chong, T. H., Khoo, P. S., Foong, P. Y., Kaur, B., & Lim-Teo, S. K. (1991). *A state-of-the-art review in mathematics education in Singapore*. Singapore: Institute of Education.
- Dynarski, M., Agodini, R., Heaviside, S., Novak, T., Carey, N., Campuzano, L., Means, B., Murphy, R., Penuel, W., Javitz, H., Emery, D., & Sussex, W. (2007). *Effectiveness of reading and mathematics software products: Findings from the First Student Cohort. Report to Congress*. Washington, DC: U.S. Department of Education, Institute of Education Sciences. Retrieved August 31, 2007 from <http://ies.ed.gov/ncee/pdf/20074005.pdf>
- National Mathematics Advisory Panel (2008). *Foundations for success: The final report of the National Mathematics Advisory Panel*. Washington, DC: Author.
- Tan, Y. K., Chow, H. K., & Goh, C. (2008). *Examinations in Singapore: Change and continuity (1891 – 2007)*. Singapore: World Scientific.