Chapter 1
Introduction

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1.1 Introduction

In the last century, nations, such as Britain, Germany and France, the United States and Japan, have made significant economic progress due to having critical masses of people who are well educated in mathematics and science. Today, technology continues to shift power and centres of economic dynamism. In recent years, countries, such as Singapore, South Korea, Japan, Finland, Estonia, Switzerland, the Netherlands and Canada, have been able to innovate their societies and industries based on good education that is grounded on the strong foundations of mathematics and science. The Fourth Industrial Revolution, powered by the phenomenal advances of digitalisation, has made it even more pressing for countries to prepare their

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people with the basic knowledge, reasoning and thinking in mathematics and science. This is, of course, even more accelerated by other crises, such as the Covid-19 pandemic, which has caused nations to seriously consider what the future of education and society would be like in a new norm. Furthermore, improved access to new technologies, such as mobile Internet services and Artificial Intelligence programs, not only provide for new opportunities but also call for education to ensure that the new generation are well equipped to cope and thrive in the new economy.

The results from the 2018 Programme for International Student Assessment (PISA) implemented by the Organisation for Economic Co-operation and Development (OECD) were released in late 2019. Andreas Schleicher (2019), Director for the Directorate of Education and Skills, made this remark in his insights on and interpretation of the results:

> The aim with PISA was not to create another layer of top–down accountability, but to help schools and policymakers shift from looking upward within the education system towards looking outward to the next teacher, the next school, the next country. (p. 3)

PISA has helped in the policymaking strategies of many nations (e.g., Stacey & Turner, 2015). We observe that PISA has moved in tandem with the advancement of knowledge in education research and rapid technological developments to bring about changes in the organisation of the mathematics and science disciplines. In addition, the processes of knowledge building and the interaction of theories with applications have also been enhanced.

While certain education systems that had initially performed poorly in PISA but have looked to systems that did well have benefitted, systems that had thought they were doing well had a rude reality check (Center for Global Education, 2019; Goldstein, 2019). In the specific case of the US, it was not that specific schools or state systems were not doing well individually. It was that PISA results showed the image of the country's education system being an excellent overall system was only a perception that was perhaps inaccurately correlated to its economic and political success. "[Seemingly] successful school systems have many internal measures, but without greater context, it is difficult to understand what the 'best' really is. International benchmarks show what is truly possible in education; they can be a healthy driver for reform efforts worldwide" (Centre for Global Education, 2019).

Amidst significant protests against the use of PISA to guide policy (e.g., D'Agnesi, 2018), Schleicher (2019) made this fair comment:

> Some people argued that the PISA tests are unfair, because they may confront students with problems they have not encountered in school. But then life is unfair, because the real test in life is not whether we can remember what we learnt at school, but whether we will be able to solve problems that we can't possibly anticipate today. (p. 3)

Indeed, to be fair, PISA was never intended to be the only source to motivate and spur educational improvement efforts. This is because large-scale assessments have their limits. The inclusion of assessing values and twenty-first century competencies for future-ready learners has been debated on for some time now. We recognise that quantifying these is not as easy as marking a mathematics or science test. Much more than that, the skills needed for the workforce changes more quickly than we can develop assessments. In its two most recent *Future of Jobs* reports (2016, 2018), the World Economic Forum (WEF) listed two slightly different sets of top-10 skills that are priorities for employers (see Table 1.1). In just 2 years, employers have re-ordered what was of priority, replacing 2015's Items 6 (quality control) and 9 (active listening) with 2020's Items 6 (emotional intelligence) and 10 (cognitive flexibility).

Thus, even though PISA "goes beyond assessing whether students can reproduce what they have learnt in school [and assesses their ability] to extrapolate from what they know, think across the boundaries of subject-matter disciplines, apply their knowledge creatively in novel situations and demonstrate effective learning strategies" (Schleicher, 2019, p. 3), it can only *assess beyond* to a certain extent. Instead, PISA and other international benchmarks should spur us to think apart from the traditional and into the future. In this case, PISA would have a greater impact on the way we look at the concept and structure of education, which includes assessments, curriculum, syllabus and knowing the purpose and role of education in any nation.

Yet, there are many other factors that influence education. Urban migration, climate change and equity issues all call for education to prepare for the next generation with greater numeracy and scientific literacy. OECD Secretary-General Angel Gurria observed that whilst some countries have made significant improvements in certain areas, "it is disappointing that most OECD countries saw virtually no improvements on the performance of their students since PISA was first conducted in 2000" (Horobin, 2019); still, expenditure per student (primary and secondary) rose by some 15% over the same period.

How can we ensure a real and positive system transformation that is sustainable? What are the strategies to establish strong mathematics and science foundations that will build the capacity of people? How do we have scalable and effective implementation of future-orientated mathematics and science curricula?

Table 1.1 Top-10 Skills in 2016 and 2018 *Future of Jobs* reports

2015	2020
1. Complex problem-solving	1. Complex problem-solving
2. Coordinating with others	2. Critical thinking
3. People management	3. Creativity
4. Critical thinking	4. People management
5. Negotiation	5. Coordinating with others
6. Quality control	6. Emotional intelligence
7. Service orientation	7. Judgment and decision-making
8. Judgment and decision-making	8. Service orientation
9. Active listening	9. Negotiation
10. Creativity	10. Cognitive flexibility

1.1.1 Singapore Education System and Education Demographics

Singapore has been participating in PISA since 2009, making the 2018 participation its fourth time. Its education system has had multiple decades to evolve. Specifically, its primary level (elementary) spans from Years 1 to 6 and its secondary level (high school) spans from Years 7 to 10 (Ministry of Education, Singapore [MOE], 2020). While the primary level is already fully into subject-based banding (SBB), the secondary level will be progressively fully SBB by 2024. The current three-levels streaming system (Express, Normal [Academic] and Normal [Technical]) was relevant in the past as it helped align students' academic progress and abilities.

It is, however, with the new education phase or reform, called the "Learn for Life: Remaking Pathways" education phase, that Singapore is striving to seek a balance between the rigour of education and the joy of learning. One avenue is the SBB, where for each subject, students will be able to choose which level suits them best: G1, G2 or G3. G1 is suitable for advanced learners and G3 is suitable for students less inclined to that subject. Unlike the three-level academic streaming system where all students of one class take the same level for all subjects, students under SBB may choose a level more suitable to himself or herself and those of the same level go to one class for that one subject. For example, a student may choose to take two G1-level subjects, three G2-level subjects and one G3-level subject. Yet, another in the same class may choose three G1-level subjects and three G2-level subjects. This flexibility allows them to be agents of their own learning, preparing them to be lifelong learners, self-directed learners and self-regulated learners.

Singapore schools are meant to provide a rich variety of holistic learning experiences from building a strong foundation in literacy and numeracy to the physical, aesthetic, moral, social and emotional (MOE, 2020). These are embedded throughout the curriculum, whether through the academic or non-academic. There are also opportunities to contribute to the communities and the society through Values-in-Action programmes. Students also experience Applied Learning where they learn by doing, learn about the real world and learn for life. At the corner of the education system is the bilingual policy where students must take the English language and an ethnically ascribed mother tongue language. This enables them to connect with people from different backgrounds and is especially needed in a multiethnic and multicultural country such as Singapore. This also gives them a competitive advantage in a globalised world, where Singapore students are able to appreciate their heritage and the culture of others.

In 2018, there were 356 schools, of which were 186 primary schools, 139 secondary schools, 15 junior colleges (JC), and 16 mixed-level schools (which comprise schools from primary 1 to secondary 4/5, and from secondary 1 to JC 2; MOE, 2020). In the same year, there was a total of 428,773 students, where the average class size was 32.4 students across all levels. There was a total of 33,671 teachers, school leaders and education partners (which include administrators, executives, allied educators, etc.). This meant that the ratio of teaching staff to primary school pupils was 14.8 while to secondary school students, it was 11.6.

Following the launch of the PISA 2018 results, the first editor of this volume, Professor Tan Oon Seng, was asked to make a commentary on how countries, such as Singapore, were able to consistently improve their performances. Singapore was able to ensure that her proportion of top performers increased, and that the weakest performances achieved new heights. At the 2019 OECD Conference, Professor Tan emphasised two key points: Singapore teachers and the Singapore curriculum.

Singapore is endeavouring to ensure that its education system is holistic and future-ready. We have often said that our teachers are nation-builders and our students are the contributors of the future. It is with this vision in mind that we endeavour to go beyond any one part of the education system. In our new education phase, called "Learn for Life: Remaking Pathways", we are recalibrating our emphasis on assessment in order to balance it with bringing out the joy of learning (MOE, 2019).

Singapore's achievement in mathematics and science education as reflected in international assessments is well recognised. In the 2018 results, Singapore was second for reading, mathematics and science (Schleicher, 2019). Advancement of knowledge and new frontiers in research as well as rapid technological developments have brought about changes in the organisation of the mathematics and science disciplines, processes of knowledge building and the interaction of theories with applications. Singapore, especially, has in place a set of educational policies for developing, supporting and sustaining the ongoing development of school teachers and students, that also encourages innovative practices in pedagogy and learning at a systemic, country-wide level.

1.1.2 PISA Criticism and Going Beyond

Although we had mentioned above that some education systems have been able to improve their systems as reflected in their PISA rankings, the PISA international benchmark is not without its critics. While some have sought to improve PISA, others have had negative reactions to it. Zhao (2020) cited many likeminded others who are adamantly against PISA though they do not seem to be averse to international benchmarking exercises. Zhao compiled criticisms that include how the PISA survey is flawed, promotes a distorted view of education to produce economically effective citizens, does not have the most rigourous research standards and promotes a propaganda of ranking. Zhao further posited that PISA is adversely influencing policymakers and leading them down the wrong path. He proposed PISA makes an erroneous assumption that the PISA targeted group (i.e., 15 year olds) are all preparing for the same challenges and need identical skills and competences even though they come from different societies which have many cultural, political, religious. Zhao claimed that PISA assumes that there is a universal set of valuable skills and knowledge for all countries, and claimed this is an overtly monolithic and primarily Western view of societies.

While the editors of this volume understand Zhao's concerns, we recognise that PISA is still improving its methodology and processes. We are also interested in the key features that drive the development of PISA which are briefly policy orientation that identifies characteristics of education systems that have high-performing standards, innovative "literacy" concept which looks at student capacity to apply knowledge and skills to solve and interpret problems, relevance to lifelong learning, regular progress monitoring and a breadth of geographical coverage and collaboration (Schleicher, 2019). The strength of PISA is that they are also moving away from just looking at ranking student achievements and looking at issues of embodied in the titles of their three publications, namely, what students know and can do, where all students can succeed, and what school life means for students' lives. These look into equality related to socio-economic status, gender and immigration background, into school climate, teacher attitude and practices, student well-being, and many others (OECD, 2019), and have been doing so for some time. These are issues that are related and may affect or be affected by academic results.

Comparing one education system with another does not necessarily fall into the trap of an overemphasis of ranking. In the PISA 2018 results, we see that China (represented by the four provinces of Beijing, Shanghai, Jiangsu and Zhejiang) is ahead of Singapore in reading, mathematics and science, being the first of all participating countries. This is, of course, a change from the 2015 results where Singapore was first and the four provinces were ranked 10th. This would lead us, in friendly competition and even more curiosity, to ask how did they improve. Would there be any lesson we could learn from them? But it is not just limited to who is above Singapore but also those who are close to Singapore, geographically and in terms of ranking. It would also be interesting to learn from places such as Estonia that has been making education waves in its increase over the past few PISA exercises. Or even from Hong Kong which is extremely close to Singapore not only in terms of education, but also in terms of having historical, economic and geographic similarities although having distinct differences such as political and social approaches. We may also learn lessons from those that are maintaining their ranking or even decreasing in ranking.

Yet, these comparisons should not confine Singapore or, for that matter, any country seeking to continuously improve its education system in order to benefit its citizens. In our opinion, international benchmarks have their uses and they are very beneficial if used properly, astutely and wisely. Governments, however, should not be swayed by the organisations that lead these international benchmarking exercises or that advocate any other international approaches for the simple fact which Singapore has always recognised: they need to be discerned well, understood thoroughly and contextualised to local needs. A country's approaches are native to their geographical or social circumstances which are different, no matter how ironically similar they are from those of ours. PISA is not everything but neither is it nothing. It is not a focus on the ranking that we are emphasising but the lessons and opportunities that come with such benchmarking exercises. No two societies are exactly the same and thus, there is a need to understand international standards, contextualise them and go beyond.

And going beyond just using international standards is what is described in this volume. It aims to provide insights to policymakers, leaders of science and mathematics education, and practitioners on big picture thinking and multiple perspectives that are key to how Singapore brings about effective science and mathematics education across all levels. In the light of twenty-first century competencies, how do we innovate the curriculum for life and ensure societal relevance? Given the knowledge explosion, what constitutes the basic threshold, fundamental and core knowledge in the fields of mathematics and science? In Singapore, purposefulness, connectedness, pragmatics and future orientation characterise and shape the multifarious factors to enhance science and mathematics education. Issues addressed in this volume include teacher education, pedagogy, curriculum, assessment, teaching practices, applied learning, ecology of learning (e.g., science centres), talent grooming (e.g., Olympiads), culture of science and mathematics, vocational education, and STEM (science, technology, engineering and mathematics).

The mathematics chapters in this volume complement those in the recently published Springer volume, *Mathematics education in Singapore* (Toh, Kaur & Tay, 2019). Firstly, they allow a common perspective of Singapore mathematics education through the lens of PISA. Chapters 4 and 7 are prime examples of this approach. The international comparison perspective allows readers unfamiliar with Singapore to benchmark against situations more accustomed. Well-known PISA goals also set up a common arena to view Singapore's challenges. Thus, and secondly, the chapters have a forward-looking perspective. Instead of dwelling on past achievements, these chapters highlight challenges and possible solutions to Singapore mathematics education. They run the gamut of classroom practices, pre-service teacher education and professional development, excellence in mathematics available for all, and developing teacher-researchers.

The science chapters in this volume augment the discourse in the Springer volume, *Inquiry into the Singapore Science Classroom: Research and Practices* (Tan, Poon & Lim, 2014). Whilst the earlier publication focused on the design and implementation of the inquiry-based science curriculum in Singapore, these chapters discuss the broad range of factors that contribute to the success of science education in Singapore, including the future-oriented mindset of policymakers, adaptability of teachers, quality of teacher preparation and professional development programmes, and commitment of time and resources to education research. The chapters may also be read alongside another recent Springer volume, *Science Education in the twenty-first Century: Re-searching Issues that Matter from Different Lenses* (Teo, Tan & Ong, 2020), as they present, in effect, Singapore-based case studies that complement the findings of science education research from different countries expounded in the latter.

In Chap. 2, Oon Seng Tan posits that Singapore's stellar PISA achievements is a corollary of continuous incremental improvements plus quantum leap changes in the Singapore mathematics and science curricula ecology. This chapter aims to provide the big picture of how mathematics education and science education in Singapore ride on waves of change to equip learners with the kinds of thinking needed for the future world of work. Beyond the rigour of well-planned and resourced syllabuses rich in fundamentals and heuristics are the pedagogical approaches of process thinking and applied learning. The aligning of learning with applications in an ecology of inquiry and authentic experiences at every level has been catalytic for the success of Singapore learners. In the light of all these is the teacher policy factor that results in the mathematics and science teachers who can bring about student engagement and agency in their pursuit of STEM aspirations.

The PISA and TIMSS mathematics and science results have been extrapolated to imply successful STEM education as these two disciplines are core subjects in most school systems around the world. However, the local and international STEM community remains divided in their understanding of STEM and STEM education. In Chap. 3, Tang Wee Teo and Ban Heng Choy shed some insights on their understanding of this acronym and provide an overview of STEM education in Singapore. The chapter further discusses the work of different organisations towards STEM education in Singapore. These are the research centre the Multi-centric Education Research and Industry STEM Centre at the National Institute of Education (meriSTEM@NIE), the outreach centre the Science Centre Singapore, and the elite specialised STEM schools. The authors raise four key issues and challenges which STEM education stakeholders have to confront for STEM education in Singapore to take the shapes and forms that meet its intended purposes.

Chap. 4 by Berinderjeet Kaur details the attainment of Singapore students in Mathematics to give a background to Singapore's efforts to improve its education system. The mathematics attainment data after every cycle of TIMSS and PISA is often of interest to mathematics educators in Singapore and elsewhere. Kaur gives interesting examples of how the data collected from different systems of schooling of the participating countries and economies offer opportunities for policymakers, educators and researchers to use the data to benchmark school mathematics curriculum against international standards, identify gaps in curriculum plans, envision future goals of the curriculum and help contribute towards excellence in education internationally.

Singapore inherited its education system and curricula from its colonial British masters. The early years since independence in 1965 did not see much change. However, change picked up in the early 1990s in response to the fast-changing world and the needs of Singapore. Kai Kow Joseph Yeo and Lu Pien Cheng in Chap. 5 attempt to describe how the mathematics curriculum in Singapore has innovated and responded to such changes. In particular, the chapter has chosen three out of many major innovations in Singapore mathematics education and discusses them in relation to school mathematics: Problems in Real-World Contexts (PRWC), Learning Support Programme for Mathematics (LSM), and Improving Confidence and Numeracy (ICAN). These innovations are discussed with reference to three questions Serdyukov would ask regarding innovations: What is this innovation for? How will it work? What effect will it produce?

As a small nation with scant natural resources other than human resource, education has played a crucial role in the economic survival, prosperity and progress of Singapore since her independence. Singapore's science curriculum aims to help the young develop and realise their potential amidst a flexible and broad-based educational landscape. Centred on the theme of science as inquiry, the science curriculum, from primary to pre-university levels, puts particular emphasis on the knowledge, skills and processes, and ethics and attitudes of science, as well as the understanding of the impact of science in daily life, society and the environment. In Chap. 6, Jennifer Yeo and Kim Chwee Daniel Tan describe the evolution of the science curriculum in Singapore, and how it supports students in developing the scientific literacy, competencies and values necessary for them to take on challenges, and thrive in an ever-changing world. They attribute the success of science education in Singapore to three key factors: (1) the responsiveness and adaptability of policymakers and teachers, (2) fidelity of implementation, and (3) partnership with industry and institutions of higher education.

In Chap. 7, Weng Kin Ho and Eng Guan Tay, examine the K-12 School Mathematics Curriculum. In Singapore, nationwide educational policies and movements have taken place frequently and within a short space of time from each other. In turn, such educational initiatives get translated into changes in curricula of every school subject – mathematics inclusive. In this chapter, the authors attempt to make explicit the connection between Singapore students' PISA performance and the curricular shifts by highlighting the major changes that have taken place in K-12 Singapore school mathematics curriculum, analysing them in terms of the shifts in curriculum ideologies. The authors also map each of the dimensions of the PISA assessment framework with the components of the Singapore Mathematics Curriculum Framework to further substantiate the claim that "the [Singapore] education system and school mathematics curriculum contribute in part towards the success of Singapore's students in … PISA" (Kaur, Zhu & Cheang, 2019, p. 134). Additionally, they give some answers to challenges posed in "Ten Questions for Mathematics Teachers … and how PISA can help answer them" (OECD, 2016) that are relevant to the Singapore context. Based on the twenty-first century competencies identified respectively by OECD and MOE, the chapter explores possible new directions for the national mathematics curriculum.

In Chap. 8, Tin Lam Toh discusses how Singapore strives for excellence in mathematics education in various ways. The chapter begins with the importance that Singapore has placed in identifying and developing its mathematically talented students for the prestigious mathematics competitions. It also illuminates concurrent movements of local mathematics communities that help popularise mathematics competitions within the more interested student population, and even attempts to align mathematics competitions with the school curriculum to benefit more in the general student population in a variety of ways. The chapter continues to discuss the expansion of mathematics competitive activities to include mathematics research and real-world problem solving in order to identify and nurture a much wider group of mathematics talents among the Singapore students. At the systemic level, various attempts to develop and stretch our talents are emplaced, such as the Gifted Education Programme and the Integrated Programme. Within the curriculum structure, much has been done to provide differentiated instruction for students from primary to pre-university education. This culminates in the imminent SBB, which will be implemented in full scale in the near future.

In Chap. 9, Yew Hoong Leong reflects on an interesting perspective about how mathematics education research influences classroom practices. Beginning with an argument on the value of mathematics education research, he illustrates how understanding research contributes to actual classroom practice. His examples include “Model Method”, mathematics problem-solving, and the concrete-pictorial-abstract instructional heuristic.

In Singapore, informal science education is recognised by schools as an important avenue for providing stimulating and enjoyable learning experiences that complement and extend what is taught in the science classroom. A wide range of informal science education destinations are available in Singapore; these include not only institutions that reach out to students as part of their mission, such as the Science Centre, zoo, and natural history museum, but also industrial establishments like semiconductor and soft drinks factories. Schools have been able to leverage the diversity of such platforms to organise field trips for their students. Chapter 10, by R. Subramaniam and Yin Kiong Hoh, explores the state of informal science education in Singapore and shows how the informal science education destinations contribute to raising science literacy levels in the country. They also highlight the necessity of government support in the creation of institution-based destinations for informal science education, such as the Science Centre and the Singapore Zoological Gardens.

With scientific inquiry as its pedagogical underpinning, the Singapore Science Curriculum aims to instil curiosity, perseverance, creativity, and critical thinking, and develop communication, collaborative, and inventive thinking skills in students. Structures have been put in place to encourage teachers to try out different inquiry-based activities that develop these twenty-first century competences. In Chap. 11, Jennifer Yeo, Wenli Chen, Timothy Ter Ming Tan and Yew-Jin Lee present three innovative approaches – Image-to-Writing (I2W), a model-based inquiry; Spiral Model of Collaborative Knowledge Improvement (SMCKI), an argumentation-based approach; and Microbial Fuel Cell (MFC), a design-based pedagogy – and discuss how these approaches contribute to the development of the above competences. The I2W approach focuses on developing deep conceptual learning. The SMCKI, on the other hand, focuses on the social and cognitive aspects of knowledge construction, and the MFC prioritises inter-disciplinary learning. These examples show how different models of inquiry can each support students in developing twenty-first century competences in its own way.

In Chap. 12, Kit Ee Dawn Ng and Eng Guan Tay discuss how mathematical literacy in Singapore is linked to twenty-first century competencies. They present arguments on tensions that could arise from philosophical as well as pragmatic perspectives whilst acknowledging that twenty-first century teacher professionalism requires specialist knowledge and skills in mathematics. Apart from curricula alignment, it is teachers who will ultimately bridge the learning gap, such as paving the way for “Mathematical Literacy in the 21st Century” calls for innovation in pre-service Mathematics Education, professional development and professional networks. The chapter presents a multi-faceted and multi-dimensional framework which synergises teacher education, MOE, and professional teacher organisations in providing teacher education for a twenty-first century mathematics teacher in

Singapore from pre-service through to life-long professional development. The discussion covers Singapore's pragmatic approach in preparing teachers who can adapt to the constantly changing education landscape and provides directions for future developments towards life-long, life-wide, life-deep, and life-wise learning.

The quality of teachers is the major determinant of how well a science curriculum is enacted. Chapter 13 by Aik Ling Tan, Dominic Jing Qin Koh and Xin Ying Lim provide details of the two key teacher education programmes at NIE in Singapore – the 16-month Post-Graduate Diploma in Education and the 4-year Bachelor of Science (Education) programmes – and explain how these programmes prepare future-ready science teachers for the education system. Anchored on the core values of learner-centredness, a strong sense of teacher identity, and service to the profession and community, courses in the four-year programme equip preservice science teachers with content knowledge, pedagogical knowledge and knowledge of learners. Practicum experiences are also provided for preservice teachers to apply their theoretical knowledge in actual classrooms. Four success factors for pre-service science teacher education in the twenty-first century are identified: meaningful practicum experiences, opportunities to carry out academic and education research, good academic and practicum mentors, and a supportive multi-party teacher education ecosystem involving the NIE, schools, MOE, and other organisations.

In Chap. 14, Yaw Kai Yan and Kok Siang Tan discuss the pre-service and in-service programmes at NIE, and explain how these programmes equip and support student- and in-service teachers for the implementation of Singapore's inquiry-based science curriculum. NIE's content-pedagogy integrated Initial Teacher Preparation (ITP) programmes emphasise Pedagogical Content Knowledge (PCK), innovative pedagogies, and the imparting of values and life skills through science lessons. At the same time, in-service science teachers are encouraged to participate in a wide range of continuing Professional Development (PD) courses to upgrade and update their science content knowledge and pedagogical skills. Five pertinent aspects of pre-service preparation and continuing professional development of Singapore science teachers include (1) content knowledge upgrading, (2) updates on pedagogical innovations in the teaching of specific subject areas, (3) new competencies to meet changing societal needs and demands, (4) new developments and initiatives in education, and (5) research and management skills.

In Chap. 15, Kim Chwee Daniel Tan and Jennifer Yeo elucidate Singapore's science education from a research perspective set in the twenty-first century. Science education research involves systematic inquiry into the teaching and learning of science. Research can be utilised to solve problems in the science classroom, for example, educational researchers seek to determine how to help students learn difficult concepts or how to facilitate students' engagement in scientific inquiry and argumentation. Research findings can be disseminated through the publication of books, journal papers and articles for teachers, as well as presentations during conferences, workshops and formal courses. Teachers who have read the publications or attended the presentations may gain new perspectives and understandings, and these may encourage the teachers to examine and rejuvenate their practices. When teachers engage in research themselves or collaborate with educational researchers, they may also gain new experiences and insights which can impact how they think and act. Thus, the impact of research on science classroom practices can be considerable, especially in Singapore, where there is close collaboration in the research-practice enterprise between the researchers from NIE, schools and MOE.

In Chap. 16, Tang Wee Teo and Aik Ling Tan offer insights into how the Singapore science teaching fraternity builds up its human capabilities through committing time, effort, and many other resources into engaging teachers in research to support their evidence-based practices. In the process, these science teachers progressively develop into established professionals. This chapter focuses on the repertoire of opportunities available to Singapore science teachers to support them in their progression into established professionals. Besides short-term courses, obtaining a Master's degree is yet another way to build the professional capacity of the teaching workforce. Investing time to pursue a Master's degree requires commitment and, more importantly, support from the school leaders and MOE. Singapore provides different routes to obtaining a Master's degree and the different funding sources available to them. Bespoke professional development programmes for teachers also come in the form of research partnerships that empowers teachers more than mere participation. In this chapter, the authors describe the different projects that science teachers have embarked on to gain first-hand experience in research. Action research is popular among science teachers and have created opportunities for them to present at professional meetings such as conferences.

Finally, in Chap. 17, Ban Heng Choy and Jaguthsing Dindyal expound on the need to see teachers as more than just instructors in the classroom. There is a growing trend to position teachers as agents of change, who collaborate with different stakeholders to innovate and improve their teaching practices. These changing demands of educational systems have placed increased emphasis on developing teacher-researchers who are able to adopt an inquiry stance in their mathematics teaching. An overview of the crucial role of teacher-researchers is presented here by drawing on relevant literature and looking back at the key shifts in teacher development. The authors then describe some key competencies of a teacher-researcher and how mathematics teachers could attain these competencies. These would be necessary considerations for mathematics educators in developing mathematics teacher-researchers.

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