Chapter 1
Introduction

Science Education Research and Practice in Asia

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Abstract The purpose of this book is to highlight the current status of Asian countries with regard to science research, teaching, and learning and the potential problems Asian countries face as they take their place as leaders in science education. As such, this introduction provides the background for the discussions that follow in this book. This book comprises 31 chapters separated into five sections: overview of science education in Asia, content analysis of science education research, assessment and curriculum, innovative technology in science education, and teacher professional development and informal science learning. Included in this work are six commentaries from internationally well-known science education scholars who provide in-depth analyses of the current issues facing science education research and practice.

1.1 Introduction

Asia has been experiencing spectacular economic growth over the past three decades, and important lessons can be drawn from this region (i.e., China, Hong Kong, Japan, Singapore, South Korea, and Taiwan; Lohani 2014). According to the World Bank's Knowledge Economy Index (KEI), countries that score higher on the KEI have higher levels of economic development and vice versa (World Bank 2007, as cited in Asian Development Bank 2014, p. 4). In other words, they found a positive correlation between KEI and GDP. However, as for the education and skills subindex score, Asia and the Pacific received an average score of 4.66, which is far below the average Organisation for Economic Cooperation and Development (OECD) score of 8.01 (Asian Development Bank 2014). Despite considerable progress in increasing access to education, many Asian economies still have education systems that lag behind those of more advanced nations (except Japan, Korea, and Taiwan, whose education scores were above average). A recent report

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M.-H. Chiu (ed.), *Science Education Research and Practice in Asia*,
DOI 10.1007/978-981-10-0847-4_1

from the Asian Development Bank claimed "Developing countries in Asia are uniquely positioned to use the knowledge-based economies (KBE) as a platform for sustainable growth and innovation in a way that may well change the global competitiveness landscape of the future" (p. 6). Therefore, KBE should be beneficial to all countries that intend to connect to, and make a difference in, the global world.

In addition, several reports on Asian economies indicated a high graduate unemployment rate (in one Asian country, over one-third of the graduating population is unemployed, and in another, research shows that over 10 % of the unemployed population are high school graduates), and 45 % of employers surveyed in Asia reported difficulty in filling positions due to a lack of suitable talent in their markets. This is compared to a global average of 34 % (e.g., Manpower Group 2012; Mourshed et al. 2012; Xinzhen 2009, as cited in Asian Development Bank 2014, p. 32). In 2015, the global average increased to 39 %, which underscores the need to identify and address the challenges teachers, researchers, and policymakers face in educating their local populations (Mourshed et al. 2012). It is not enough to prepare students for employment, but they must be prepared for "employability" (Asian Development Bank 2014, p. 32). Does science education prepare students by equipping them with the knowledge and skills required in the twenty-first-century marketplace? What are the implications of KBE for a nation's educational system?

The following sections present recent statistics showing what has already been accomplished and what challenges we may face in the future so that readers can draw their own conclusions from the chapters in this book.

First, according to the results from the Trend of International Mathematics and Science Study (TIMSS) and Programme of International Students Assessment (PISA), a number of Asian countries have outperformed on both the TIMSS and PISA over the past few decades. The TIMSS is designed to investigate science and mathematics performance by fourth (around 9–10 years old) and eighth (around 13–14 years old) graders across the world. The PISA examines scientific literacy of 15-year-old students. Although these two tests assess different competencies in science for different age groups, both attempt to compare educational outcomes in order to improve each participating country's educational achievements. As a result, for the past few decades, it is no surprise to many educational researchers, governmental agents, and policymakers that Asian countries have outperformed other nations. The major findings from these assessments include the following: (1) Asian countries outperform other countries on the TIMSS and PISA; (2) the leading Asian countries tend to have low interest in science; and (3) the leading Asian countries tend to have high-stakes entrance examinations.

The attributes of the high-stakes entrance examination system might partially explain why these countries experience high performance but low interest in science. However, countries without high-stakes entrance examinations also demonstrate top academic performance (such as Finland). As such, we cannot simply attribute the outcomes of these countries to their examination systems as there are likely other elements (e.g., teacher quality in Finland; Lavonen and Laaksonen 2009) that influence these outcomes. Additional longitudinal investigations are needed to better understand the impact of science curriculum and science education policies on science outcomes in countries with different economic and cultural characteristics.

Second, according to a report based on the data from the Survey of Adult Skills (a product of the OECD Programme for the International Assessment of Adult Competencies, PIAAC), there is a positive relationship between performance on the PISA and the corresponding age group's performance on the Survey of Adult Skills. This analysis was done specifically for mathematics and reading competence because scientific literacy was not tested until 2006. The report revealed that 15 year olds in Finland, Japan, Korea, and Sweden performed above average in 2000. Twelve years later, adults 26–28 years old in these same countries also performed above average on the Survey of Adult Skills. In other words, it is likely that countries whose 15-year-old students demonstrate high performance will be the same countries whose young adults (around 26–28 years of age) will also perform well (OECD 2013). Students near the end of their compulsory schooling who perform at high levels tend to maintain their lead after they transition from school into young adulthood. Therefore, according to the OECD (2013), "School systems need to ensure that their students perform at a high level by the time they complete compulsory schooling and that these skills are maintained and further developed thereafter" (p. 1). A related area that requires further study is the manner in which, and degree to which, individual countries are equipping their individuals with core skills *after* they leave school (OECD 2013, p. 4). Countries with compulsory education that goes beyond 15 years have more opportunities to prepare their citizens for the changing world.

Although PISA science has not been investigated by the PIAAC, we anticipate a similar result would be revealed. In recent years, it has become increasingly clear that basic reading, writing, and arithmetic are not enough. The importance of twenty-first century non-cognitive skills—broadly defined as abilities important for social interaction—is attracting growing attention and is increasingly recognized as influencing citizens' abilities to use their knowledge and skills to make a better life. So, what should we teach in and out of school during the K-12 years and even beyond so we can equip our students for the next era? How should students be assessed in order to measure their competence in school?

Finally, in addition to the international studies on student performance, the scholarly performance of science educators has also been investigated. Based upon a series of content analyses on research trends in science education from 1998–2007 (i.e., Chiu et al. 2015; Erduran and Mugaloglu 2015; Lee et al. 2009; Sozbilir et al. 2015; Tsai and Wen 2005), in addition to the English-speaking countries (such as Australia, Canada, UK, and USA), several Asian countries increasingly published in the internationally well-known journals, such as *International Journal of Science Education (IJSE)*, *Journal of Research in Science Teaching* (JRST), and *Science Education*. For instance, Taiwan was ranked 6th in 2003 and 2004 and then 5th in 2005 and 2007, and Israel was ranked 4th for 2003 and 2005, 5th in 2004 and 2006, and 7th in 2007. However, Turkey was not among the top 10 until 2006 and then was ranked 9th for the period between 2003 and 2007. Given that English is the dominant language for publishing professional research in international journals, this presents barriers and challenges for researchers whose mother tongue is not English (Bencze et al. 2012; Chiu and Duit 2011).

However, it remains a dilemma whether to publish research locally in one's native language or in English for worldwide readers. This is no doubt a situation that many non-native English speakers face when they consider publishing their research. On the one hand, the research is likely contextualized to reflect the needs of the society and educational system in which it was conducted. Therefore, the outcomes of the research should provide feedback for that specific context. On the other hand, lessons learned in one context often have implications for other contexts, both similar and divergent, and contribute to the new global knowledge base. Going forward, English is likely to remain the dominant language. As such, how do international scholars face the dilemma of where to publish throughout their professional careers? From my observations, when a junior faculty member needs to be promoted in academia, publishing articles in international journals becomes a "must do" action to take. For senior researchers, it is a channel to connect to the entire professional society. But, on the other hand, senior scholars have social and academic obligations for sharing the outcomes of their research with local science teachers, graduate students, and policymakers and also must act as mentors for younger scholars by sharing their academic products. This type of contribution of translating research outcomes into tangible benefits for the local society represents a model of sharing and mentoring with younger scholars in order to further the research agenda and improve the overall quality of research in the field.

Should the science researcher of today focus globally or locally? The answer is "glocally" (both globally and locally). In other words, one needs to be globally oriented and simultaneously contribute back to one's own society. How can Asian countries catch the global wave of science education reform and also go beyond what has been presented above? There is no simple answer for this dilemma, but paying more attention to the impact of publishing in international journals and encouraging researchers to find a balance between globalization and localization is the future of science. It is with this understanding that we have poised this book to help the reader discover new avenues for pursuing science education on a glocal scale.

1.2 Background of This Book

The Asian countries/regions presented in this book were chosen because of their geographic locations. The nations/regions included in this book are China, Hong Kong, India, Israel, Japan, South Korea, Lebanon, Macau, Malaysia, Mongolia, Oman, Russia, Singapore, Taiwan, Thailand, and Turkey.

1.3 Structure of This Book

This book includes five sections: overview of science education in Asia, content analysis of science education research, assessment and curriculum, innovative technology in science education, and teacher professional development and informal science learning. The wide range of topics covered in this book provides a thorough description of the state of science in Asia today. A short description about each chapter is presented below.

1.4 Section 1: Overview of Science Education in Asia

The first section includes two parts. The first part contains five chapters that describe the general development of science education in several Asian countries to present overviews of what have been accomplished in the field, and then one commentary chapter.

Chapter 2 concerns science education in China and was coauthored by Wang, Zhu, and her colleagues at Beijing Normal University. Their chapter touches on a wide range of topics (e.g., curriculum and textbooks, nature and history of science, students' alternative conceptions and reasoning ability, and teacher professional development) in chemistry, physics, and biology education. The authors highlight the emerging need to publish papers in international journals, discuss how science education research has rapidly grown over the past decade, and point out that science education researchers in China are actively participating at international conferences to contribute to the future of this research.

In Chap. 3, Boujaoude and El-Hage describe the history and structure of the science education system in Lebanon. They identify several challenges for science education in their country. For instance, the assessment of student achievement focuses mainly on pure academic knowledge rather than on the active use of knowledge in everyday contexts. Also, the language of instruction of science in Lebanon is a foreign language (mainly English or French rather than Arabic, which the majority of Lebanese students use), resulting in students having lower than desired knowledge and skills in science. This is not unique to the Lebanese educational system. Later, we will read Chap. 5 for Malaysia whose country share similar problems in terms of balancing dual languages (mother tongue and English) in science classrooms and daily life. More importantly, several higher order skills (e.g., information and communication skills and problem-solving skills) are not yet integrated into the science curriculum.

In Chap. 4, Wei describes science education in Macau and presents the results of an in-depth study that examined science education in the country using questionnaires, classroom observations, interviews, case studies, and document analyses. He found that the use of science textbooks was influenced by the neighboring regions, with Mainland China being the most influential. He also found that according to students, neither the regular classroom environment nor the laboratory environment was fully consistent with the tenets of constructivism. In particular, science teaching was not highly relevant, and learning was passive. Therefore, Wei comments that although student achievement in Macau is above average according to the OECD, it is not good enough, and the nation requires large-scale support in order to improve the professionalism of the country's science teachers.

In Chap. 5, Halim and Meerah depict how science and technology became a vehicle for improving the global competitiveness of Malaysia. In particular, they address the impact and usefulness of research outcomes in informing practice and science education reform. They also indicate that special emphasis was given to the acquisition of science knowledge, mastery of science and thinking skills, and acceptance of the moral obligation of being responsible for the planet. More importantly, the understanding that the country would require skilled workers in the science and technology field led to the initiation of programs related specifically to STEM education in Malaysia. However, in such a multicultural society, the students speak in their mother tongue at home but use English in learning science and mathematics, which creates a barrier to learning science knowledge in an effective way and results in unsatisfactory performance in international comparative studies (such as TIMSS).

In Chap. 6, Nookoo elaborates on science education in Mongolia since 1911 and describes how the first integrated science curriculum for primary and secondary schools was developed in 1925 and then separated in 1938 into three subjects (physics, chemistry, and geography—unlike other countries that included biology as their third scientific subject). Although the political and economic situation has changed over the past few decades, Mongolia still struggles with a shortage of experienced science teachers and limited support for conducting science education research.

In Chap. 7, Treagust and Tsui provide their comments on the five chapters that provide comprehensive and developmental reviews of science education research in those 5 countries/regions. Also, they highlight the language issues in teaching science subjects as the main theme across some chapters. As for multiple languages countries/regions, it becomes a challenge for teachers and students to switch between two languages, and such switching often becomes a detrimental factor in students' science achievement.

The second part of this section includes five chapters and takes readers on a journey to Oman, Singapore, Taiwan, and Thailand.

In Chap. 8, Al-Balushi draws our attention to the limited science education research being conducted in Oman and the limited number of science education researchers in the country. There is an emerging need to recruit more graduate students for science education research, perhaps by providing them with scholarship opportunities.

In Chap. 9, Tan and Teo illustrate the impact of the use of information, communication, and technology (ICT) on science education in Singapore. A thematic approach (e.g., diversity, cycles, systems, energy, and interactions) has been adopted in the primary science grades to present an integrated perspective on scientific ideas. As for the lower secondary science curriculum, an inquiry-centric approach, including the exploration of big ideas and important concepts from overarching themes, is the key element in science teaching and learning. Until the upper secondary and preuniversity levels, science is an elective subject aimed at equipping students with the scientific knowledge, skills, and attitudes to become confident citizens in a technological world. To ensure that the general population is scientifically literate and able to thrive in the twenty-first century, the emphasis needs to be on rapid scientific and technological advances as well as teacher development policies and practices.

In Chap. 10, Guo and Chiu provide a comprehensive review of the development of science education research sponsored by the Ministry of Science and Technology (MOST) in Taiwan. Based on the book, *Science Education Research and Practice in Asia: Challenges and Opportunities*, they pinpoint how receiving financial support for conducting research in science education was a privilege that led to the country's increased prominence in the international science community. It turns out that even though English is a second language for Taiwanese researchers, they conquered this language barrier and made Taiwan a competitive country in the science education field.

In Chap. 11, Faikhamta and Ladachart explicitly describes the influence of Western science education in Thailand. The Thai science curriculum was initially developed in an effort to decentralize the education system and to utilize a standards-based curriculum. Each school needs to develop its own school-based curriculum according to the national science standards. However, even though there were attempts to reform science education in Thailand, student performance has not significantly improved since 2008. Therefore, the Faikhamta states that although ICT and STEM are priorities, the science teacher preparation programs both for preservice and inservice teachers need to improve teachers' pedagogical content knowledge in order to improve the quality of science instruction.

In the last chapter, Lavenon summarizes the key issues about each chapter in this second part of this chapter and then helps readers to draw conclusions relevant for their local and global contexts. Lavenon draws several points from the four previous chapters for readers to ponder, such as external funding for supporting research, new research methodologies, communication and evaluation of research outcomes, collaboration among international scholars, and recruitment of doctoral students for conducting research, which can all play central roles in improving science education across the region.

1.5 Section 2: Content Analysis of Science Education Research

Content analysis in science education shows the trends and themes that have been published in professional journals and sheds light on the future direction of science research (e.g., Lee et al. 2009; Tsai and Wen 2005). This section's five chapters examine and comment on the research topics and fields published by researchers in certain countries in Asia as revealed from the content analysis methodology.

In Chap. 13, Chiu, Lin, and Chou describe their review of 365 articles on conceptual change in selected international science education journals. Seventy-eight of the 365 articles were published with Asian science education researchers either as the first author or the correspondence person. They also found that the most cited article across the world, including Asia, was Posner et al. (1982). However, the order of the next 25 most impactful articles was different for Asia compared to the rest of the world. In addition, there was no single author from Asia who was among the top 25 most impactful authors internationally, but three researchers from Taiwan were included among the top 25 most impactful authors in Asia.

In Chap. 14, Choi and Choi first briefly introduce the history of science education research in Korea, identifying a growth period from 1992 to 2003 followed by a maturity period from 2004 to 2013. They further describe their investigation of science education research in the *Journal of Science Education* published by the Korea Association for Science Education during the maturity period. They found that 23.2 % of the articles emphasized teaching, and 20.3 % of the publications emphasized learning in context, while only 6.7 % of the articles examined students' conceptions. This result was inconsistent with the Lee et al. (2009) study and suggests that international differences exist in publishing trends.

In Chap. 15, Erduran and Mugaloglu describe their analysis of research trends in Turkey in the key journals International Journal of Science Education (IJSE), Journal of Research in Science Teaching (JRST), and Science Education for the period of 1998 to 2012. From their analysis of the articles by Turkish scholars, they found that Turkey's contribution to science education research has grown dramatically during the past decade and that most of the publications were empirical research rather than theoretical pieces. To maintain the momentum of publishing articles in well-known international journals and equipping researchers with the competence to conduct research, they advocate for the importance of forming teams of science educators who encourage collaboration among senior and junior researchers, teachers, and postgraduate students in an apprenticeship model to develop respective expertise for science education.

In Chap. 16, a similar research methodology to content analysis was applied by Sozbilir, Akilli, Yasar, and Dede in Turkey. The authors investigated 1338 research articles published in peer-reviewed journals and describe the growth in the number of Turkish publications in international journals. One of the factors contributing to this outcome is the requirement that researchers publish internationally in order to obtain academic advancement. These authors found that not only were Turkish authors publishing in international journals, but they were publishing *high-quality* research papers in *respected* international journals. They encourage policies that would help researchers address educational problems by making nationwide data accessible. However, they suggest taking action against the trend of publishing research in international journals and, instead, focusing on finding solutions for needed science education reforms.

In Chap. 17, Parchmann raises several crucial issues for readers to consider in terms of the future direction and purpose of science education research. She frames her chapter by asking three reflective questions: (1) How do research emphases develop, and how do we set standards without restricting the broadness of the research field in science education? (2) How well do research communities cooperate and take each other's perspectives and findings into consideration? (3) How can policies help to develop a field of research, and how can research support the development of policies for improvements of practice? Parchmann describes how education researchers often do not get credit for their work because their publications had not appeared in international journals; this can lead researchers to lose interest in supporting their local education systems, which in turn may lead to their research findings not being used to support the development of science practice.

1.6 Section 3: Assessment and Curriculum

This section's four chapters relate to assessment and curriculum. Each chapter discusses the alignment between curriculum, instruction, and assessment that curriculum developers should take into serious consideration when designing science activities. The authors also concur that the quality of instruction should be reflected in students' assessments.

In Chap. 18, Cheung describes his investigation into secondary school students' beliefs about school-based assessment (SBA) of chemistry in Hong Kong. From his research, Cheung found that the most powerful predictor of student beliefs about SBA was the formative functions of SBA in Hong Kong. The introduction of SBA can enhance the validity of external examinations and encourage teachers to provide their students with opportunities to carry out various types of practical work to improve learning. For instance, Cheung claims that students would benefit if their teachers implemented inquiry-based laboratory experiments within regular chemistry lessons.

In Chap. 19, Fortus takes another perspective and describes how TIMSS and PISA testing influence teacher practices in Israel. He comments that despite the country's refocusing on science and technology in order to maintain and improve the level of science education in Israel, the nation's assessment system has not received enough attention from policymakers. Teaching to high-stakes tests has become the dominant force in school teaching and student learning, resulting in students being over-tested and under-motivated in science. Fortus advocates for the need for policies that direct teacher instruction and student learning in science, instead of allowing teaching to the test.

In Chap. 20, Teleshov and Zhilin introduce the long history of didactics in chemistry education in Russia and criticize the slow development of, and lack of innovative ideas for promoting, chemistry education. They pinpoint not only the need to accumulate teaching methods but also the need to improve teaching practices with evidence-based tools. More importantly, empowering science teachers with creative thinking for instruction remains a central task of science education reform.

In Chap. 21, Lederman states that assessment is mainly for measuring learning, teaching, and curriculum, while evaluation is for seeing how well science education programs meet their goals and how effectively policy is improving science education. Lederman challenges readers to ponder whether assessment has moved science education forward (like in Russia) or backward (e.g., lowering students' motivation and interest in learning science and entering technological fields).

1.7 Section 4: Innovative Technology in Science Education

The five chapters in this section discuss possible channels for the use of technology in science education. Although each chapter emphasizes a different approach for promoting science teaching and learning, the strategies provided in these chapters make good use of modern technology and try to infuse innovative technology into the curriculum for better delivery to learners. While technology has been quietly immersed into our lives, the answer for "how can we take advantage of this device for school learning and teaching" might be found in the following chapters.

In Chap. 22, Fujii and Ogawa design a chemistry lesson for sustainable development that links science, technology, society, and environment (STSE) as a new approach for students in Japan and Korea. The approach they use provides opportunities for students to view science as an integral part of their everyday lives.

In Chap. 23, Agarkar introduces an open educational resource via a Web site in the regional language (Marathi) as a means for enabling students, teachers, and parents to meet the diverse needs of school systems in India. Agarkar argues that one has to be aware that merely uploading materials on a Web site does not guarantee improvement in science education.

In Chap. 24, Chang, Hsu, and Hung describe their investigation of how students and teachers used Web-based Inquiry Science Environment (WISE) as a vehicle to develop integrated understanding of science concepts and to formulate scientific explanations in Taiwan. The authors found that the positive impact from the use of WISE allowed students to engage in scientific activities rather than teacher-centered activities.

In Chap. 25, Wang and Yang suggest the use of technology to enhance science teaching and learning in various ways. However, they also point out that although technology has greatly advanced over the past few decades, the topic of how technology influences learning continues to be debated. There is no doubt that the development of ICT creates new opportunities for school science practice. The authors propose a model with three key elements for effective learning with technology (i.e., nature of ICT, transforming, and mediation model) that allow for reflection on how to design an appropriate technology curriculum for science education.

In Chap. 26, Liu comments that although the Education for Sustainable Development (ESD) agenda has been discussed and made progress in its theories and practices in environmental education in the past few decades, ESD has not been recognized as a core vision in science education curriculum reform. Therefore, he advocates not only to help citizens construct the knowledge of ESD but also to help them take action in order to enhance the capacity of citizens to deal with science- and technology-related situations in their everyday lives for ESD. Finally, he summarizes the three previous chapters by highlighting the four interrelated dimensions for successful scale-up: depth, spread, sustainability, and shift in ownership. Each is elaborated in depth in the chapter.

1.8 Section 5: Teacher Professional Development and Informal Science Learning in Science Education

This final section with five chapters examines teacher professional development and informal science learning and includes a final chapter on the importance of science education for all. Chapters 27 and 28 discuss teacher professional development and highlight the need for high-quality science education in order to catch up with the need for globalization. Chapters 29 and 30 extend the content from formal schooling to informal science learning and broaden our view about the value of science education through lifelong learning. Chapter 31 summarizes the current state of science education in various contexts, as well as what lies ahead for the field.

In Chap. 27, Mamlok-Naaman, Katchevich, and Hofstein describe the centralized approach for science education in Israel. To advance science education and improve teacher practices and student learning, Israel introduced four models of high school science teacher professional development (i.e., leadership workshops for teachers, action research, evidence-based professional development, and teachers as curriculum developers). The authors describe each model; in particular, they highlight the importance of sharing instruction-related knowledge between experienced teachers and novice teachers as well as treating teachers as equal partners in decision making about their own profession development.

In Chap. 28, Isozaki describes the Japanese approach to science teacher professional development and relates this to the issue of globalization. The author also discusses issues of cultural context in order to help non-Western countries reflect on their research and practice in science education.

In Chap. 29, Tal discusses an avenue for science learning from schools to nature. She provides a comprehensive review on the history of out-of-school learning in Israel and comments on the shortage of students' hands-on learning experiences, which prevents students from appreciating the learning of science. To conquer this problem, the author offers a professional development program aimed at helping teachers to lead outdoor inquiry activities. The inclusion of outdoor activities can help shift the focus from teacher-centered to student-centered learning.

In Chap. 30, Dahsha and Pruekpramool explore how to make good use of community resources to promote science learning in Thailand. The authors describe how to identify and maximize one's own local cultural resources. They also describe the use of learning stations to share and discuss knowledge acquisition and completeness.

In Chap. 31, Calabrese Barton uses a story about Quentin's invisibility and marginal situation to elaborate on how to provide quality and equality in science education for disadvantaged children. This highlights the value of teacher professional development once more.

1.9 The Goals of This Book

The purpose of this book is not to provide rigid answers to the diverse questions introduced throughout. Instead, this book is intended to present the reader with the background necessary to understand the challenges that lie ahead for science education across the globe. The chapters presented here highlight science research and practice in different contexts. Furthermore, they present a variety of strategies and programs that can be adopted for different contexts and cultures in order to ensure the next generation is well equipped to be scientifically literate.

I hope this book provides explicit directions and profound reflections for readers who are interested in conducting science education research or promoting science education in practice. I also hope researchers, educators, and policymakers will take away from this book various channels for promoting scientific literacy to a variety of students in a variety of locations. Finally, I hope this book ignites people's interest in promoting science education not only locally and regionally, but also globally, and that this work contributes to making a better future for the generations to come.

Acknowledgments I am grateful for the commitment of all of the authors who contributed to this book and who persisted through several revisions, after both internal and external reviews. I also appreciate the contribution of Leonard Liaw, who assisted with some of the editing of the chapters. In addition, I thank the Ministry of Science Education and Technology for the long-term financial support for me to carry out various studies that have provided me with great opportunities to share knowledge and outcomes generated from the research with global scholars. Finally, I dedicate this book to my husband, Bing-Jyun Wang, and children, Nadia Yuting Wang, and Hsin-Wei Wang, for their long-term support, love, and immense patience while this book was brought to light.

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