Education Innovation

Young Hoan Cho
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Authentic Problem Solving and Learning in the 21st Century

Perspectives from Singapore and Beyond

Springer

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Series Editors' Foreword

Foregrounding Authentic Problem Solving and Learning to Rethink and Transform Research, Policy, and Practice for Twenty-First-Century Learners

The twenty-first-century global landscape, where work and life situations are becoming more unpredictable and complex, entails individuals to be equipped with key competencies to help them cope with these rapid changes and thrive as global citizens and workers of the future. Problem solving is regarded as a fundamental competency that is entwined with other twenty-first-century competencies, such as critical thinking and creativity. Students should have greater exposure to solving real-life and nonroutine problems and take part in authentic practices that go beyond acquiring canonical knowledge. Conceptualized and developed with these needs as focal points, this book can help inform and transform research, policy, and practice to better prepare learners to face the challenges of the twenty-first-century knowledge economy.

This book is the eighth in the Springer Education Innovation series. Problem solving has always been recognized as one of the cornerstones of learning and schooling. This book chronicles empirically based perspectives and thought-provoking assertions about authentic problem solving and learning. It provides multifaceted and comprehensive ideas on authentic problem solving by covering various disciplines (e.g., mathematics, science, geography, and teacher education), levels (i.e., primary, secondary, junior college, polytechnic and higher education), and learning contexts (i.e., formal and informal). Utilizing varied frameworks (i.e., cognitive, affective, and sociocultural aspects), it affords wide-ranging insights on various elements of authentic problem solving: the design of problems and environments, implementations of such designs, and evaluation of outcomes. It underscores a wide array of key dispositions and skills relevant to authentic problem solving and learning, such as argumentation, play, thinking through tinkering, modeling, deep processing, invention, critical thinking, goal orientations, and collaboration. The contents of this book present empirical evidence upholding the potential benefits of

authentic learning and participation for diverse learners, including low-achieving students (e.g., applying business knowledge and skills learned in school at real workplace environment). Given the broad lens that this volume applies to describe the nature of authentic problem solving and learning, it thus serves as an invaluable resource for educators and policymakers to develop approaches and design environments that prime learners for tackling diverse types of problems—be it structured or ill-structured, routine or nonroutine, and familiar or unfamiliar—which resemble those that they (learners) would encounter in navigating their future workplace.

Moreover, this book also offers a distinct contribution to the extant literature on real-world problem solving by presenting contributions from Singapore-based researchers. In the recently released results of the 2012 Programme for International Student Assessment, Singapore emerged as the top performer among 44 countries and economies in terms of tackling real-life problems. Singapore's 15-year-old students were found to be strongest in dealing with problems that necessitate understanding and formulation or representation of new ideas. Singapore's strong performance on creative problem solving internationally in spite of her emphasis on high-stake assessment could be a testament to the possibility that development of high authentic problem solving proficiencies can be achieved within such educational culture. Gaining leverage from this positive development, this book allows researchers and educators from other parts of the world to glean on the nature of authentic problem solving and learning processes that take place in Singapore classrooms and potentially exemplify key elements of practice that propelled Singapore students' outstanding performance in international assessments, such as those in the realm of problem solving. These scholars can extract useful information, new insights, successful stories, and practical guides that they can apply in their respective educational settings.

Concerning policymakers and curriculum developers who are at the helm of education systems, they can acquire a better understanding of the benefits and challenges of enacting authentic problem solving activities and how authentic learning practices can run counter to other aspects of the traditional school systems, such as teachers' and students' beliefs, curriculum designs and assessment modes, and school culture. Although these contradictions may seed negative reactions from some sectors, they can create the impetus for reflections and changes in education policies and practices. This book presents diverse frameworks and multiple scenarios that can be used in identifying potential bridging strategies to analyze and reconcile such contradictions and streamline the process of adapting school systems to the needs of twenty-first-century learners.

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Foreword

Learning cannot be detached from problem solving. Learning in schools must prepare students for life in the real world that is filled with ambiguities and complexities, a world that is enmeshed with problems that lack the structure and elegance of archetypal classroom tasks. Problem solving skills are part and parcel of one's survival kit in the competitive and dynamic life arena that is continually shaped and transformed by rapid social, technological, and cultural advancements in the twenty-first century. This new world creates a multitude of difficulties for those who are ill-equipped, but brings rewards and a better quality of life for those who possess the necessary competencies.

This book serves as a comprehensive resource for readers who value the promotion of learning that is transferrable to real-world practice and who recognize the importance of authentic problem solving as a key twenty-first-century competency. The various chapters show diverse aspects of authentic problem solving and learning in different learning contexts across K-12 schools and higher education. A wide range of domains, including science, mathematics, geography, and teacher education are given attention by the contributors. The book focuses not only on authentic learning in school but also on participation in informal learning contexts. Although there are a few books about authentic learning or problem-based learning in school, they rarely involved both simulation and participation models for authentic learning focused on both formal and informal learning spaces.

Contributions from authors coming from different educational systems or instructional settings provide both theoretical and empirical perspectives on authentic learning, so as to guide teaching and learning innovations. The book describes innovative school practices in the design of problems, learning processes, environments, and ICT tools for authentic problem solving and learning. In addition, the book not only highlights key components of authentic learning activities but also describes how the components interact with each other in a dynamic system.

This book offers to provide the Asian perspective that is lacking in the current publications on authentic learning or problem solving that have been dominated by Western views. It highlights authentic learning theories initiated by Singaporean researchers (e.g., productive failure, cognitive function) and practices unique in

Singapore (e.g., retail experience for active learning, problem-based learning curriculum in Republic Polytechnic). Those who are interested in reforming school curricula and improving classroom practices, particularly for Asian learners, can identify success stories that bear some semblance to their own instructional settings. Moreover, this book describes possible challenges that educators may face when authentic activities are conducted in Asian classrooms. To reduce the gap between planned and enacted authentic learning activities, the book suggests professional development of teachers and coevolution of learners and authentic tasks.

Being a compendium of articles that focus on the confluence of theory, research, and practice, the book serves as an up-to-date and comprehensive resource on authentic problem solving and learning. It addresses a wide range of readers who are interested in developing and promoting instructional practices and learning environments that are essential for fostering the competencies to solve problems in real-world contexts. In particular, graduate students and researchers in Learning Sciences and Educational Technology will find the book beneficial in understanding both theoretical and practical aspects of authentic problem solving and learning. For teachers and school leaders, the book provides insights on developing school curricula, improving pedagogies, and planning professional development programs. The empirically based insights and thought-provoking propositions presented can help inform and transform practice to better prepare learners and teachers to face the challenges of the twenty-first century.

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Part I
Introduction and Overview

Chapter 1
Authentic Problem Solving and Learning for Twenty-First Century Learners

Young Hoan Cho, Imelda S. Caleon, and Manu Kapur

Abstract In line with the goal of developing learners for the twenty-first century, which is characterized by the emergence of knowledge-based economies, educators have strived to cultivate students' competence in authentic problem solving. This book documents innovative practices of authentic problem solving and learning in Singapore and other countries with regard to three main approaches: *authentic problem*, *authentic practice*, and *authentic participation*. Concerning authentic problems, this book introduces the role and design of authentic problems and problem-based learning environments. The discussions on authentic practice emphasize authentic experience, tool-mediated action, and culture more than realistic problems themselves. The last key theme in the book, authentic participation, elucidates informal learning out of school and learners' interaction with practitioners in a community of practice. Throughout this book, the dynamic interaction and tensions of authentic problems, learners, tools, and learning environments are discussed along with successful cases of authentic learning in K-12 school, higher education, and professional development. Blending contributions from Singapore-based and international authors, this book provides useful information, new insights, successful stories, and practical guides to school leaders, parents, teachers, and researchers who are willing to develop authentic learning environments for twenty-first century learners.

Keywords Authentic problem solving • Authentic learning • Twenty-first century competencies • Authentic practice • Authentic problem • Community of practice

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Authentic Learning for Twenty-First Century Learners

With the rapid changes in the social, political economic, and technological landscape around the world, learners face a more globally competitive job market after leaving school. The twenty-first century, which is characterized by the emergence of knowledge-based societies, necessitates learners to be comfortable in dealing with ambiguities and complexities in the real world and competent in using knowledge as a tool in their workplace. Despite complex demands of a new society, school education has emphasized acquiring knowledge for standardized tests that are usually separated from real-world activities and contexts. In addition, school tests usually include well-structured problems with all elements required for a single right answer (Jonassen 1997). Students can solve well-structured problems by applying prescribed processes and a limited number of concepts or rules without critical and creative thinking. To ensure high achievement of students in high-stakes tests, teachers tend to provide direct instruction of problem-solving processes with worked examples and have students solve practice problems in a textbook. However, these conventional problem solving and instructional practices have limitations in the twenty-first century in which people should flexibly solve novel problems with no single right answer and adjust themselves to a world of constant change (Thomas and Brown 2011).

Literature in the learning sciences and educational psychology has indicated the existence or proliferation of *inert knowledge* problem; that is, learners cannot recall and use their prior knowledge and problem-solving experiences while solving a new problem due to the change of contexts and surface features (Gentner et al. 2003; Novick and Holyoak 1991). For instance, people often fail in using knowledge of fractions they have learned in school when figuring out how much cottage cheese they need to have three-quarters of the two-thirds cup of cottage cheese in a diet program (Lave 1988). Brown and his colleagues (1989) also pointed out a common limitation of contemporary school systems: "Students may pass exams (a distinctive part of school cultures) but still not be able to use a domain's conceptual tools in authentic practice" (p. 34).

This inert knowledge problem is a critical issue in educational communities that seek for the development of twenty-first century competencies. Authentic learning models can provide a fertile ground to nurture key competencies identified as essential for learners of the twenty-first century, as well as help in tackling the inert knowledge problem. The United States National Research Council (NRC 2012) suggested three domains of twenty-first century competencies: cognitive (e.g., critical thinking, problem solving, argumentation), intrapersonal (e.g., self-regulation, adaptability, metacognition), and interpersonal (e.g., collaboration, leadership, conflict solution). In traditional classroom practice, students may not be able to sufficiently develop the twenty-first century competencies due to the lack of learning opportunities for making arguments to solve ill-structured problems, self-regulate learning processes, and collaboratively build knowledge with classmates. By contrast, it is highly plausible that authentic learning approaches help students to

develop the twenty-first century competencies. By working collaboratively to solve problems in an authentic situation, students are likely to engage in critical thinking, collaborative knowledge building, self-regulation, and developing knowledge and skills that are transferrable to a new situation (Hmelo-Silver and Barrows 2008; Kapur and Rummel 2012; Yew and Schmidt 2009). For instance, Hmelo-Silver et al. (2007) found that problem-based learning and inquiry learning are beneficial not only for knowledge acquisition and application but also for the development of problem-solving skills, reasoning skills, self-directed learning skills, and future learning. Thus, to help learners to develop twenty-first century competencies, it is imperative for educators to consider the utilization of authentic learning models.

In authentic learning models, learning occurs while people solve problems in authentic contexts and participate in the practice of a community. That is, authentic learning is closely related to problem solving and other practices in a community. Students learn by engaging in authentic activities defined as "ordinary practices of the culture" (Brown et al. 1989, p. 34) including interaction with practitioners, collaborative problem solving, negotiation of meanings, and reflection. Through these learning activities, students can develop knowledge, skills, and values in authentic contexts as practitioners like mathematicians, scientists, writers, and historians do (Cho and Hong 2015). Thus, authentic learning can help students to become a member of the culture and participate in meaningful practices.

Authentic Learning Models

Although there are a number of barriers in school (e.g., curriculum, examination, school culture) to authentic learning, several instructional models aligned with the principles of authentic learning such as anchored instruction (Cognition and Technology Group at Vanderbilt 1990), cognitive apprenticeship (Barab and Hay 2001; Collins et al. 1989), problem-based learning (Hmelo-Silver 2004), learning by design (Kolodner et al. 2003), and productive failure (Kapur 2012, 2013) have been developed and successfully implemented in K-12 and higher education. These models consider problem solving as a key learning activity in which learners collaboratively solve complex, ill-structured problems that are similar with those that practitioners encounter in the community of practice (i.e., authentic problems). While solving the authentic problem, learners may engage in the epistemic practices of using concepts, principles, rules, tools, and resources that have been iteratively developed in the culture (Bielaczyc and Kapur 2010). These instructional models are based on the epistemological assumption that learning cannot be separated from problem solving, which is an essential part of the practice in a community. Wenger (1998, p. 8) emphasized the integration of learning and practice: "Learning is an integral part of our everyday lives. It is part of our participation in our communities and organization."

Existing literature on authentic learning has indicated that authentic learning environments can be designed based on the simulation and participation models of

authenticity (Barab et al. 2000), although there is considerable debate about how best to structure and scaffold such environment (Kapur and Rummel 2009). In the simulation model of authenticity, learners are engaged in classroom activities that resemble real-world practices, and contexts. The participation model for authentic learning emphasizes ecological authenticity where learners participate in the practices of out-of-school communities and develop an identity as a community member.

Simulation Model for Authentic Learning

Instructional models with the simulation perspective involve problem-based learning, cognitive apprenticeship, and inquiry-based learning. In a simulation experience, an authentic learning environment serves as a context that mirrors the process of the utilization of knowledge and skills in real-world situations (Gulikers et al. 2005; Herrington and Oliver 2000). This environment resembles real-world complexity and offers myriad resources that enable analysis from various angles (Herrington and Oliver 2000). The degree to which the processes involved in these environments mirror those performed in real-world settings may be regarded as procedural authenticity. The authenticity of the tasks provided by these learning environments is associated with some key features (as summarized by Herrington and Oliver 2000): The tasks need to be ill-defined and complex, require a sustained period to resolve, afford an opportunity for learners to collaborate, and integrate various domains.

The simulation models feature a learning environment in which students can develop knowledge, skills, and values while solving authentic problems and carrying out authentic tasks. The problems and tasks usually do not present all the information needed to solve them, can be solved in multiple ways, often require the use of multidisciplinary approaches, evolve into different forms as more information is collected, and do not have an absolutely correct solution (Gallagher et al. 1995; Jonassen 1997). The benefits of authentic learning environments based on the simulation model have been well-documented in previous studies. For example, research on productive failure has shown how engaging students in the authentic mathematical practice of generating and exploring diverse solutions to a complex problem before learning the canonical concepts helps develop deep conceptual knowledge that can be transferred to novel contexts (Kapur 2014, 2015; Kapur and Bielaczyc 2012). This research also shows how collaborative discussions may initially diverge while exploring multiple representations and solutions when students do not know the correct solutions; yet, this process is key to deep learning (Kapur et al. 2006). Roth and Roychoudburry (1993) found that using authentic contexts for collaborative inquiry activities can facilitate the development of students' higher-order inquiry skills. In consonance with these results, Kuhn and Pease (2008) reported that prolonged engagement in collaborative inquiry activities,

which were set in real-world contexts and supplemented with computer-based scaffolds, helped in developing students' fundamental process skills such as interpretation of evidence, formulating appropriate causal conclusions, problem identification, and communicating findings. The problem-based learning (PBL) approach, which emerged from the experiential learning tradition, offers learners a rich opportunity to develop knowledge and life skills by engaging in guided collaborative problem solving (Hmelo-Silver 2004). Empirical studies, mostly involving mature learners, provide converging evidence that the PBL approach can cultivate flexible understanding, transferrable problem-solving skills, self-directed learning strategies, and effective collaboration skills (Hmelo-Silver 2004). A meta-analysis of 43 articles that focused on (PBL) as applied in tertiary education indicated consistent positive effects, especially on skills-related outcomes (Dochy et al. 2003). Although more studies are needed to ascertain the effectiveness of PBL in younger learners, existing evidence provide a strong support for the potential of PBL to foster competencies that are essential for current learners to adapt in a rapidly evolving technology-driven world.

Participation Model for Authentic Learning

The participation approach for authentic learning underscores the provision of opportunities for learners to directly interact with real practitioners in the context of their actual field of practice (Radinsky et al. 2001). Aside from factual, process, and task authenticity, participatory experiences also feature *ecological authenticity*: that is, the learner tackles real-life tasks within the actual context in which the task has meaning (Barab and Dodge 2007; Barab et al. 2000). The learner may assume the role of an apprentice who is being guided by a mentor engaged in professional practice. Using Lave and Wenger's (1991) perspective, the learner may learn through *legitimate peripheral participation*, which allows him or her to take part in simple low-risk activities and then gradually work on tasks with increasing significance in the community. This participatory experience, which physically brings learners into the real world, provides learners with optimum opportunities to learn about aspects of practice that cannot be acquired from and captured by simulation experiences (Radinsky et al. 2001). In Barab and Hay's study (2001), middle-school students took part in a short camp with real scientists. The students were given an opportunity to participate in real scientific projects that entailed them to "do science where scientists do science" and alongside practitioners of science (Barab and Hay 2001, p. 76). The students experienced authentic science practices and discourse in connection with domain-related dilemmas. They perceived themselves as doing legitimate science and contributing to the making of science. Lambson (2010) found that new teachers shifted from peripheral to more central participation in a teacher study group and took on the culture, practices, and language of the teacher community through regular discourse with more experienced teachers. These studies show that

authentic learning emerges within participatory experiences which enable novices to interact with practicing professionals and make meaning in a collaborative activity (Bielaczyc, Kapur, and Collins 2013; Rahm et al. 2003).

Authentic Problem, Authentic Practice, and Authentic Participation

We considered both the simulation and participation models for authentic learning in framing this book. Within the simulation model, we further distinguished an authentic problem approach from an authentic practice approach. The authentic problem approach focuses on complex, ill-structured, and realistic problems that may lead to learning through authentic problem solving. In PBL, for instance, all learning activities are organized around complex and realistic problems (Hmelo-Silver 2004). As an illustration of this point, Hmelo-Silver and Barrows (2008) engaged a group of students in a PBL activity which required the diagnosis and treatment of a medical problem involving a real patient afflicted with pernicious anemia. Initially, limited information from the patients' medical record was provided to the students. The students were allowed to ask questions and request for laboratory test results and were given the freedom to identify and research on the concepts that they need to learn to address the problem. They were also asked to generate hypotheses and reflect on them. To guide the problem-solving process, the students wrote facts, ideas, learning issues, and action plans on a whiteboard, which subsequently served as the focal points of the group discussions. After solving the problem, the students reflected on the lessons learned from the activity.

In contrast, the authentic practice approach emphasizes authentic experience, tool-mediated action, and culture more than realistic problems themselves. Within the authentic practice realm, even a simple problem can be useful for understanding how practitioners see the world, use tools, and take part in activities. For instance, Schoenfeld (1991) used a magic square problem (i.e., placing digits from 1 to 9 in a square box with 9 cells so as to make the sum of digits same along each row, each column, and each diagonal), which enables students to take part in mathematical practice and look at a problem as mathematicians do.

The authentic participation approach is divided into two subthemes. The first subtheme, which was described earlier, elucidates learners' interaction with practitioners in the context of their place of practice. The second subtheme focuses on the interaction among members of a community of practice as they engage in collaborative identification and solving of real problems that are present within their community. Illustrative examples of the second subtheme were mentioned by Darling-Hammond (1998) in relation to teacher learning and professional development: Teachers were engaged in collaborative research activities in which they identified and addressed classroom-based problems and issues, such as those pertaining to assessment practices and effective teaching approaches.

Therefore, this book is structured in regard to the three approaches – authentic problem, authentic practice, and authentic participation approaches– toward authentic problem solving and learning.

Authentic Problem Solving and Learning in Singapore

A key purpose of this book is to introduce authentic problem solving and learning practices for school stakeholders who are interested in reforming a school curriculum and improving classroom practices, particularly in Asian settings. Although the simulation and participation models of authentic learning environments have been examined in a number of studies, few books and articles have discussed authentic learning and authentic problem solving in the context of Asian countries. According to Barab et al. (2000, p. 42), "Authenticity emerges through meaningful relations among individual, community, and task." Authentic learning activities may be designed and implemented differently and have various meanings depending on learners and communities. For example, a group of teachers set up a classroom to resemble a bank, where there are tellers to attend to the withdrawals and deposits of existing depositors and account managers who are meant to entertain those who would open new accounts. If the students are not familiar with banks, the simulated environment may not appear as authentic to them. When educators design and build authentic learning environments in Asian countries, they should fully understand the dynamic interaction or tensions among authentic tasks, Asian learners, and culture of Asian communities. However, there are few design principles, cases, and empirical studies on authentic problem solving and learning for Asian learners who lack experience in student-centered learning. To fill the gap in the literature of authentic learning, this book aims to introduce innovative practices of authentic problem solving and learning in Singapore schools and learning communities. Singapore serves as a worthy example of an education system that is working toward the promotion of authentic learning experiences for students.

During the early 2000s, authentic problem solving was not explicitly utilized as a key learning activity in Singapore classrooms. Hogan and Gopinathan (2008) found that primary and secondary classroom practices mainly consisted of whole class lecture, whole class answer checking, and individual seatwork in their classroom observations during 2004 and 2005. They pointed out the following issues in Singaporean classroom practices:

> The enacted curriculum in Singaporean classrooms is characterized by limited disciplinarity as indicated by a limited focus on advanced concepts, knowledge application, validation of knowledge claims, and generation of knowledge that is new to students … Teacher-dominated instructional practices prevail within classrooms. (p. 370)

In order to overcome the limitation, the Singapore government has introduced educational policies guided by the vision of "a nation of thinking and committed citizens capable of meeting the challenges of the future, and an education system geared to the needs of the twenty-first century" (Ministry of Education 2008). In addition, the Ministry launched a new initiative, referred to as *Teach Less Learn More*, to de-emphasize instruction that is focused on tests and examinations and focus on the quality of learning and engagement of students. As results of the initiatives, Singapore schools began to increase student-centered learning practices and pedagogies to foster the development of twenty-first century competencies. Singapore's education efforts seem to have paid off as the city-state has shown

indications of achievement in line with fostering authentic learning and problem solving. According to the results of the Programme for International Assessment (PISA) survey, which was conducted under the auspices of the Organisation for Economic Cooperation and Development (OECD), Singapore students have fared very well when compared to their counterparts in 64 other countries: They ranked second in mathematics, fourth in science, and fifth in reading (OECD 2010). PISA, with its focus on "the extent to which students can apply the knowledge and skills they have learned and practised at school when confronted with situations and challenges for which that knowledge may be relevant," utilized assessment tasks framed in real-life situations (OECD 2012, p. 22).

Another development that is aligned with the Ministry's vision is the growing research efforts to explore the integration of authentic problem-solving activities as parts of learning activities in Singapore classrooms. Working under the purview of the Office of Education Research at the National Institute of Education, a number of researchers and teachers have collaborated to address this research agenda, with a particular focus on PBL, inquiry learning, productive failure practice, and participation in a learning community. We deem that the current compendium of studies carried out by Singapore researchers over the course of almost a decade is a valuable educational resource that warrants attention from educators, as well as researchers and curriculum developers, from other parts of the world. Information on authentic learning pedagogy coming from high-performing education systems, such as that of Singapore (OECD 2010), will provide fertile insights that can enrich extant knowledge of educators from other education systems around the world. This book also intends to explore how the innovative practices of authentic learning and problem solving have changed Singapore classroom practices and what kinds of challenges are are yet to be overcome in Singapore contexts. This book includes authentic problem solving and learning practices in diverse domains, educational levels, and learning contexts. Readers will easily identify successful stories that can be applied to their own contexts of practice and gain new insights into how to improve instructional practices and design school curriculum innovations.

Overview of the Book

Our hope is that this book will help readers understand authentic problem solving and learning and how it can be used to make a difference in their school or learning communities for the development of twenty-first century competencies. It describes innovative school practices on the design of problems, learning process, environments, and ICT tools for authentic problem solving and learning. In addition to the innovative practices, this book also aims to provide readers with theoretical explanation of authentic learning process and outcomes. For an in-depth understanding of authentic problem solving and learning, this book presents how students learn from generating and exploring solutions to complex problems and what cognitive functions are needed at different stages of problem-based learning.

Comprising 20 chapters, this book presents the three approaches (authentic problem, authentic practice, and authentic participation) about authentic learning along with theoretical explanation, successful cases, instructional design principles, and challenges encountered in K-12 schools and learning communities (see Fig. 1.1). The three approaches, which are presented in the core parts (II to VI) of the book, are embedded in between Part I ("Introduction and Overview") and Part VII ("Conclusion and Future Direction"). We describe our purpose and the overarching structure of this book in Chap. 1 ("Authentic Problem Solving and Learning for Twenty-First Century Learners") of Part I. Parts II and III focus on authentic problems. Parts IV and V include chapters that deal with authentic practice. Chapters under Part VI report studies on authentic participation. Part VII ("Conclusion and Future Direction"), which contains the last chapters provides a synthesis of the key learning points from the previous chapters and meaningful insights for future research on authentic problem solving and learning.

Part II, "Authentic Problems and Tasks," contains three chapters detailing how instructors can design and use ill-structured real-world problems and describing the role of authentic tasks for meaningful learning in school. Chapter 2, "The Role of Authentic Tasks in Promoting Twenty-First Century Learning Dispositions," shows that authentic tasks play a significant role in determining secondary school students' beliefs, motivational dispositions, and individual engagement when it comes to mathematics learning. To enhance the benefits of authentic tasks, teachers need to understand the nature of authentic problems and design them effectively based on theories and classroom contexts. Chapter 3, "A Design Model for Problem-Based Learning," introduces theories and empirical studies on designing real-world

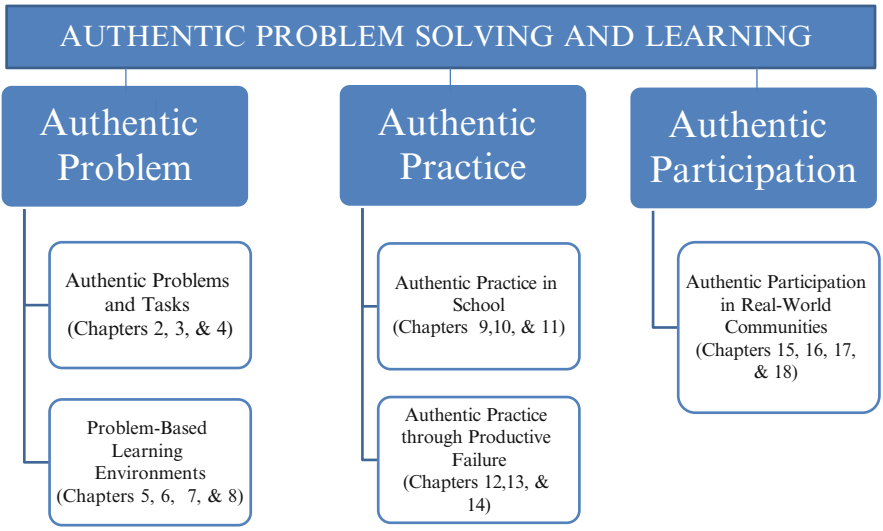

Fig. 1.1 Organization of the book in accordance with three approaches in authentic problem solving and learning

problems for PBL as well as practical approaches to designing and evaluating the problems. In addition, Chap. 4, "Mathematical Problem Solving Using Real-World Problems," shows the affordances and challenges of using authentic problems with young children in a primary school in Singapore. These chapters can be helpful for readers who want to understand the role of authentic tasks and design them for meaningful learning.

Authentic problems are essential in problem-based learning environments like PBL and inquiry-based learning. These learning environments provide instructional supports, resources, and tools that help learners to collaboratively solve authentic problems. Part III, "Problem-Based Learning Environments," includes four chapters that present a conceptual framework of PBL and classroom practices in Singapore. Chapter 5, "Problem-Based Learning: Conception, Practice, and Future," introduces PBL as a student-centered, problem-driven, and situated learning approach that is implemented in a variety of disciplines. The theoretical conception and design issues of PBL are discussed along with suggestions for future research. Chapter 6, "Using Problems to Learn in a Polytechnic Context," shows how problem-based learning environments have been effectively developed and implemented at a polytechnic in Singapore. The school not only modified its curriculum, assessment, and academic policies for PBL but also made efforts for professional development of teachers. Two chapters in this section show different approaches toward how students learn in problem-based learning environments. Chapter 7, "Pedagogical Interfaces in a Problem-Based Learning (PBL) Environment: Cognitive Functioning at PBL Stages," reveals cognitive functions at each PBL stage, whereas Chap. 8, "Finding Common Ground During Collaborative Problem Solving: Pupils' Engagement in Scenario-Based Inquiry," focuses on the sociocultural aspects of collaborative inquiry learning.

The discussion on authentic practice emphasizes authentic learning activities and experiences more than authentic problems. Parts IV and V both focus on the authentic practice. Although both sections underscore theory and practice to enculturate learners into the culture of real-life practitioners through authentic activities, the latter section focuses mainly on the practice of productive failure (see discussion in succeeding paragraph). The former section, "Authentic Practice in School," includes three chapters that show different conceptual frameworks and practices for authentic learning activities. The authors of Chap. 9, "Cultivating a Remix Movement in an East Asian Culture," argue that the activities of play, tinkering, and remix should be fostered to overcome the limitations of examination-oriented education in East Asian cultures. In addition, Chap. 10, "Authentic Thinking with Argumentation: Putting on the Thinking Caps of Scientists and Designers," provides a conceptual framework for authentic thinking with argumentation that is essential in the practices of both scientists and designers. Lastly, Chap. 11, "Using an Immersive Environment to Address Problems Associated with the Learning of Geography," presents a curricular intervention in which secondary school students develop geographical intuition and knowledge through experience in immersive learning environments. This section helps to understand emerging practices for authentic learning, which can be applied to K-12 education.

The next section, "Authentic Practice Through Productive Failure," focuses on research that revolves around productive failure. The productive failure learning design provides students with opportunities to engage in the practices of mathematicians by formulating and exploring solutions to novel problems in small groups before receiving formal instruction of canonical solutions. This section includes three chapters that introduce productive failure as authentic practice and explain what makes it effective for meaningful learning. Chapter 12, "Learning from Productive Failure," provides a conceptual framework of productive failure and key learning mechanisms in productive failure on the basis of empirical studies in Singapore schools. A growing number of studies have shown that learning through productive failure is more effective than that achieved through traditional direct instruction. Based on a quasi-experimental study, the authors of Chap. 13, "Discussing Student Solutions is Germane for Learning when Providing or Delaying Instruction," argue that productive failure is effective because learners can pay attention to key components of a canonical solution when it is compared and contrasted with their own solutions. In addition, Chap. 14, "Mathematical Skills and Learning-by-Invention in Small Groups," shows that the effectiveness of invention activities is, in part, determined by the composition of small groups. Group composition plays an important role in productive failure practice, which is usually carried out through collaborative, not individual, work. The authors underscored the findings that groups including both students with high and low math skills are likely to explore a broader range of solutions and higher-quality solutions, which is important for learning from productive failure.

The penultimate section, "Authentic Participation in Real-World Communities," includes four chapters that showcase specific cases and provide insights about how people learn by participating in informal learning activities and community practices. The section zeroes in on authentic participation, which assumes learners' direct interaction with real-world communities. Chapter 15, "Retail Experience for Active Learning (REAL) Experience," shows an innovative program in which secondary school students develop their business knowledge and skills by participating in an internship at local retailers in Singapore. In addition, Chap. 16, "Authentic Learning Experiences in Informal Science Learning: A Case Study of Singapore's Prospective Teachers," shows design-based research in which preservice teachers codeveloped an informal astronomy workshop and interacted with their expert mentors. Chapter 17 and 18 report on authentic participation of in-service teachers for the development of their competencies in a professional learning community ("Exploring the Process of Problem Finding in Professional Learning Communities Through a Learning Study Approach") and in a wiki-based learning community ("Problem Solving of Teacher-Generated Classroom Management Cases in Wiki-Based Environment: An Analysis of Peers' Influences"). The former chapter explores how biology teachers identify and define a problem that would be addressed in a professional learning community, and the latter investigates how secondary school teachers collaboratively solve their own classroom management issues in an online learning community. Teachers can develop their identity and professional competencies necessary in twenty-first century classrooms by actively participating

in the process of collaboratively identifying, analyzing, and solving real problems in their community.

The last section (Chap. 19, "Authentic Problem Solving and Learning: Lessons Learned and Moving Forward", and Chap. 20, "Authentic Learning Research and Practice: Issues, Challenges, and Future Directions") presents an integration and reflections on the key ideas that were underscored in the previous chapters and provides the readers with recommendations to transform current practices and advance research in authentic problem solving and learning.

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Part II
Authentic Problems and Tasks

Chapter 2
The Role of Authentic Tasks in Promoting Twenty-First Century Learning Dispositions

Jennifer Pei-Ling Tan and Youyan Nie

Abstract Authentic tasks are widely acknowledged by educators to foster desirable twenty-first century (21C) learning dispositions in students, particularly in terms of motivated and engaged learning. In mathematics education specifically, authentic tasks are commonly upheld as essential to the development of positive student affect towards mathematics, as well as mathematical problem-solving competencies and its encompassing socio-cognitive processes—reasoning, communication and connections—among learners (Beswick K, Int J Sci Math Educ, 9(2):367–390, 2011). Despite this widespread belief in the value of authentic tasks, there is surprisingly limited empirical evidence on the relationship between the use of authentic tasks in classrooms and productive learning dispositions (Pellegrino and Hilton (eds) Education for life and work: developing transferable knowledge and skills in the 21st century. National Academies Press, Washington, DC, 2013), particularly from the perspective of students as a critical stakeholder group. This chapter attempts to address this knowledge gap.

Drawing from a comprehensive study involving more than 4,000 students across 129 classrooms from 39 secondary schools in Singapore, this chapter foregrounds the extent to which the use of authentic tasks predict a suite of productive 21C learning dispositions. These comprise positive beliefs, attitudes and motivational dispositions that lend themselves towards deeper learning, namely, mastery-approach and performance-approach goal orientations, self-efficacy and task value and individual and collaborative learning engagement. Hierarchical linear modelling results underscore the significance of authentic tasks in predicting students' individual engagement levels and mastery-approach and performance-approach goal orientations, as well as the extent to which they consider mathematics to be interesting, useful and important. Authentic tasks, however, were not a significant predictor of students' collaborative engagement and self-efficacy in learning mathematics. The implications of these results are discussed, particularly in light of current understandings of Singapore secondary school students' self-reported dispositions towards learning mathematics and their strong global performance in international mathematics achievement tests.

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Introduction

Social commentators and futurists have produced a variety of characterisations of our current millennium. These include the Digital Age (Brown 2006; Thomas and Brown 2011), the Creative Age (Florida 2002) and the Conceptual Age (Pink 2005), just to name a few. Despite semantic differences, all of these labels acknowledge that our twenty-first century (21C) social and economic landscape has distinctive features that set it apart from preceding historical periods. Where standardisation and mass production used to be primary generators of economic wealth in the Industrial Age, the current 'digital revolution'—embodied in personal, mobile and networked technologies—has replaced manual and routine mental labour with personalised services, ideas and innovation. These are in turn argued to be key commodities that drive new economic growth (Freeman 2004; Perez 2002).

This significant epistemological and sociological shift is exerting substantial pressure on the social institution of schooling worldwide to evolve and respond in terms of what Harvard Professor Richard Elmore (1996) terms the 'core of educational practice', that is, 'how teachers understand the nature of knowledge and the student's role in learning, and how these ideas about knowledge and learning are manifested in teaching and classwork' (p. 2). While the specifics of school curriculum may remain contested, there now appears to be some convergence among global educational scholars, policymakers and practitioners around what constitutes 21C literacies and dispositions and the enabling pedagogical approaches that are likely to foster them (Hanna et al. 2010). The use of authentic tasks is widely acknowledged to be one such pedagogical approach. While commonly referenced '21C literacies and dispositions'—such as digital, creative and critical literacies, collaboration and lifelong learning aptitudes such as engagement, interest and self-efficacy—have always played important roles in the progress of human history, they have traditionally been viewed as 'expressive affordances' (Bernstein 2000). In a knowledge-centred economy, characterised by complexity and rapid change, exponential technological advancements, multiplying bandwidth and increasing global consumer demand, these individual and collective attributes come to play a more central role in determining access to and productive participation in local, global and virtual societies.

As highlighted earlier, however, a review of extant literature appears to indicate an incommensurate gap between (a) the advocacy of authentic tasks as a means to motivate and engage students towards deeper learning and (b) the availability of empirical evidence beyond assorted qualitative small-scale research examples that can provide robust insights into the relationships between authentic tasks and productive student learning dispositions, including engagement and motivation. While