Each volume in the 7-volume series The World of Science Education reviews research in a key region of the world. These regions include North America, South and Latin America, Asia, Australia and New Zealand, Europe and Israel, North Africa and the Middle East, and Sub-Saharan Africa.

The focus of this Handbook is on science education in Asia and the scholarship that most closely supports this program. The reviews of the research situate what has been accomplished within a given field in an Asian rather than an international context. The purpose therefore is to articulate and exhibit regional networks and trends that produced specific forms of science education. The thrust lies in identifying the roots of research programs and sketching trajectories—focusing the changing façade of problems and solutions within regional contexts.

The approach allows readers to review what has been done and accomplished, what is missing and what might be done next.
World of Science Education
World of Science Education

Science Education Research in Asia

Edited by

Yew-Jin Lee
National Institute of Education, Singapore

SENSE PUBLISHERS
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CONTENTS

Preface.......................................................................................................................... ix

Introduction .................................................................................................................. 1
  Yew-Jin Lee

PART I: COUNTRY REPORTS, PERSONAL JOURNEYS

1. Science Education in Bangladesh............................................................................. 17
  M. Shahjahan Mian Tapan

2. Science Education Research in Taiwan................................................................. 35
  Chin-Chung Tsai and Ying-Tien Wu

  Aik-Ling Tan

  Zhixin Liu

5. The Changes in Science Curricula in China after 1976: A Reflective Review......................... 89
  Bing Wei

6. Thai Science Educators’ Visions of Reform: Personal Journeys................................. 103
  Vantipa Roadrangka, Naruemon Yutakom, and Deborah Tippins

7. Science Education for Young Children in Taiwan.................................................... 121
  Yen-Ting Chen, Jyh-Chong Liang, Meng-Lung Lai, and Fung-Yuen Chang

PART II: CURRICULUM, TEACHING, AND POLICY

8. Qualitative methods in Asian science education research: Toward a cultural-historical and dialectic approach to research objects........................................ 137
  SungWon Hwang and Wolff-Michael Roth

9. Rethinking the Context and Social Foundation of Science Education ................. 155
  Jinwoong Song
CONTENTS

10. “Science-educationizing” Schools: Extending School Science Activities beyond the Science Class ................................................................. 171
    Masakata Ogawa

11. Toward an Expansion of Science Education Through Real-Life Activities in Japan ............................................................................. 187
    Katsuhiro Yamazumi

12. Any Language Can Be the Medium of Instruction of School Science, But...: An Anti-Essentialist Investigation of Science Education ............. 203
    Ken Kawasaki

    Benny Hin Wai Yung, Fei Yin Lo, Siu Ling Wong, and Dong Sheng Fu

14. Addressing the Challenges of the Assessment Reform in Secondary Science in Hong Kong ........................................................................ 239
    May Hung May Cheng

15. A Blow to a Decade of Effort on Promoting Teaching of Nature of Science .......................................................................................... 259
    Siu Ling Wong, Benny Hin Wai Yung, and Maurice Man Wai Cheng

16. Digitizing Scientific Boundaries: Enlisting Interactive Digital Media to Expand and Extend Participation in Ecologies of Scientific Learning ........ 277
    Steven J. Zuiker

17. Analysis of Web-Information Searching Behaviors of Taiwanese Students in Science Courses ................................................................. 299
    Gwo-Jen Hwang, Pei-Shan Tsai, and Chin-Chung Tsai

18. Development of an Entrepreneurial Science Thinking (ENSCIT) Module for Secondary Science Education in Malaysia .................................. 315
    Nor Aishah Buang, Lilia Halim, T. Subahan M. Meerah, and Kamisah Osman

19. Situating Science Inquiry in a Knowledge Creation Metaphor of Learning ................................................................................................. 335
    Jennifer Yeo and Yew-Jin Lee

PART III: EQUITY AND SOCIAL JUSTICE

20. Education for Disadvantaged Students in Thailand .......................................................................................................................... 357
    Thasaneeya Ratnaroutai
21. Combating Learning Hurdles Arising out of Social Deprivation ...............371
   Sudhakar C. Agarkar

22. Seeking for Empowerment and Social Justice through Science Education
    in Nepal .................................................................393
    Bhaskar Upadhyay, Jagdish Chandra Regmi, and Uttam Sharma

23. Community Immersion as a Context for Relevant Science Teacher
    Preparation in the Philippines: An Ecojustice Perspective.................415
    Deborah J. Tippins and Vicente C. Handa

Index.......................................................................................................................427
PREFACE

With so few collections documenting the work of Asian science educators, this particular Handbook stands out as an important landmark in the literature. By bringing familiar Asian names in the science education circuit, freshly-minted scholars, classroom practitioners, and curriculum experts together in one edited tome, it helps to literally rewrite the intellectual terra incognita that has characterized much of science education research in Asia. Not by a long shot is this task complete for the difficulties in obtaining thorough, equitable, and up-to-date representation by science educators here have been formidable and would have probably made a mockery of our production timelines. Considering the vastness and heterogeneity of education systems in the Asian region, the descriptions of research programs in science education, local adaptations of curricula, home-grown innovations and theory generation, and accounts of experimental research are a real treat and one that leaves the reader spoilt for choice. Apart from looking backwards into the past and assessing what has been done well, or not, the contributors to this Handbook also speculate on what are the possibilities and threats in one of the most dynamic regions in the globe. Of course, present frustrations in educational development are not ignored as the contributors can ratify but all readers will definitely learn something here just as Asian science educators will benefit from dialog and cross-fertilization of ideas from other regions. Finally, editing this Handbook has only been possible due to the support of my wife and two young sons who have permitted me, if not tolerated, spending long stints at my desk in silence. And because of the many new friendships that have been made during the course of this 24-month-long project, it has also been an incredibly fulfilling accomplishment—Jai Ho!

Singapore
August 2009
INTRODUCTION

It is indeed a great privilege and honor to be the editor of the Asian volume in the *World Handbook of Science Education*. An ambitious undertaking, this multi-volume series aims to capture the state of the art in research in science education within particular geographical regions as well as offer first-hand accounts of some of the key problems that have occupied local. Whether applying theoretical frameworks that are already well-established or some avant-garde ideas still struggling to find acceptance, contributors here are united in addressing the concerns of teachers trying to make sense of and attempting to improve classroom teaching. Above all, this project makes thematic the subtle differences that science education has assumed in the international landscape, complex modulations and emphases that reflect how the enactment of science education by researchers, teachers, and learners fall at the intersections of history and society, or what we usually lump under a recognizably useful albeit highly nebulous term—culture.

Seen in this light, that frequently-asked question, “What works in science education?” no longer can assume complete desirability or legitimacy in an era defined by the “posts-.” More significantly, we will be perpetually disappointed as educators searching for that one “best” curriculum, that one “killer-app” or instructional principle that will somehow revitalize our programs and entice youth to study a subject, which we think is so integral to their lives as learners and as citizens. We have, as shown repeatedly, to be content with the fact that what actually works always depends (Honig, 2009): Culture often undermines or nuances the global/universal in education just as humble though powerful street-level bureaucrats reinterpret whatever has been handed down from above (Alexander, 2001). As science educators seeking to make the world a more just and livable place for this and subsequent generations, it is therefore necessary to understand how science education implicates or shapes culture, and conversely, how culture nourishes and configures multiple manifestations of science education. There will be many consequences for how we do our work now as our twin goalposts comprising theory and practice will shift in unexpected ways, new challenges and questions sprout up like weeds instead of being answered and put aside, and auxiliary assumptions and caveats will be tagged onto existing bodies of educational wisdom.

Because culture and education intertwine and defy any artificially imposed boundaries between them, they create intellectual excitement as well as pose obstacles to those engaged in policy and politics. And if we are told that culture is a “sphere of practical activity shot through by wilful action, power relations, struggle, contradictions, and change” (Sewell, 1999, p. 44) then we should likewise expect no less from (science) education. Educational solutions that seem to have

Y.-J. Lee (Ed.), *World of Science Education: Science Education Research in Asia*, 1–14.
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worked so marvelously well in certain contexts experience what Seymour Sarason called “predictable failure” (Sarason, 1990) when grafted without careful thought onto other systems. Too often, the breakdown of prescriptive policy mandates, quick-fix packages, and so-called teacher-proof materials simply confirm the primacy of culture writ large on science education: “[P]olicy…affect[s] practice…but practice has…an even greater effect on policy” (Cohen, 1990, p. 311). This is, of course, most infuriating yet acknowledging that the successes of our educational practices always “depend” due to the pervasiveness and mediation by culture—even implicated as a “national script” in studies such as the Third International Mathematics and Science Study (TIMMS)—is perhaps our most accurate theory of action and a somber message demolishing the hubris endorsed by hard positivism in earlier years of educational research. It is thus with these understandings (most likely encountered as perplexities) that I open this introductory chapter: I remind readers why it is imperative for Asian science educators to contribute to the international conversation as process and outcome of cultural enactment. Next, I suggest some possible reasons for their relative absence from these discussions and argue that despite these large or oppressive forces that militate against (science) education in Asia, one has to continue to exercise multiple forms of agency here. Finally, I offer an overview of the 23 exciting chapters written by a mixture of newly-minted scholars and familiar names.

An Argument from Cultural Sociology

One of the most pertinent reasons for a greater Asian presence in the international discourses on science education is based on culture, or more precisely, cultural sociology: Culture comprises many nested fields, of which science education is but one of them (Roth, Hwang, Lee, & Goulart, 2005). Moreover, these fields are not static monoliths but are transformed with every enactment of social practices—within and across fields—thereby nudging them in small and large directions that either reinforce existing practices or depart from them. When Asian (and other regional) science educators are under-represented in dialog, there is an overall loss of learning and development for the collective in terms of its human, material, and symbolic resources (Tobin, Elmesky, & Seiler, 2005). In other words, there is a decrease in the general possibilities of action and the room to maneuver not just for Asian educators but also for everyone.

Action possibilities always are collective; but individuals concretely realize actions. But each action has an outcome and as such produces new growth points for future actions, thereby both reproducing existing possibilities and opening up new ones—learning therefore is inherently a dialectical process. (Lee & Roth, 2007, p. 104)

For instance, East Asian pedagogies have long been dismissed as ineffective, stifling, and cultivating extreme deference to authoritative sources such as teachers or textbooks. New research has shown that this is not entirely true and that there are possibly key elements of East Asian pedagogies that can be accommodated within different educational settings thereby transforming and enriching otherwise
INTRODUCTION

stagnant fields (e.g., Mok, 2006). Lesson Study, which originated from Japan, has now migrated into new cultural settings unimagined by its founders at the same time as the envelope is altering for what is canonical Lesson Study. While less felicitous scenarios do appear such as when new pedagogies from elsewhere create contradictions within Asian science classrooms, they nonetheless offer the possibilities of radical change once these barriers are overcome (Lee, in press, 2008a). It is this dynamic process of expansive learning between individuals and collectives, and, between fields (e.g., within Asia, between Asia and the rest of the world), which causes the co-evolution of culture and science education that all educators can and must participate in the dialog with confidence.

An Argument from Demography

Another related argument for better Asian inclusion comes from demography—nearly 60% of everyone on this planet calls Asia his or her home while the combined populations from China, India, and Indonesia alone comprise a third of the world’s inhabitants. Nonetheless, Asian science educators or research findings based on Asian subjects have not been featured much among the three top-ranked ISI science education journals (Lee, 2008b). Save for small regional journals or those outlets that accept articles in the vernacular languages, Asia’s representation has never exceeded 15% of total published articles per year among each of these prestigious journals (Tsai & Wen, 2005). In the field of psychology, the figures are even more dismal with about 1% Asian representation (i.e., as first author or second author university affiliations) in the six top journals of the American Psychological Association (Arnett, 2008). Not unlike science education, psychologists from English-speaking countries (e.g., the UK, Canada, Australia, New Zealand), especially those from the United States, enjoy the lion’s share of publications and have dominated editorial boards and editorships of special issues in journals. As Arnett (2008) put it, what we have with regard to knowledge of the human sciences is therefore “an understanding…that is incomplete and does not adequately represent humanity”, which was expressed with incisive poignancy by him as “the neglected 95%” (p. 602). My argument here is thus an extension of the previous rationale from cultural sociology: Expansive learning for all comes with greater participation that ultimately will enrich the field(s) of science.

Asia as Multiple Paradoxes

The problems that confront science educators, indeed all who are involved in schooling in Asia are formidable: Widespread poverty, growing divides (e.g., ethnic, income, digital), climate and geography, overpopulation, armed conflict, and political turmoil to name but a few (Sachs, 2005). Once globalization and its close companion neoliberalism are added to this stew, it is no surprise that Asia presents to most outsiders a puzzle inside a riddle wrapped in an enigma as Winston Churchill once declared of Soviet foreign relations. In this book, I have defined Asia as that region stretching from Afghanistan to the Central Asian Republics and encompassing
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Table 1. Table showing various human development data from Asian nations (with a seat in the United Nations) that are represented by contributors in this book compared with the United States of America. [Note. “—” represents missing or unavailable data; Bd=Bangladesh; Ch=China; Hk=Hong Kong SAR; In=India; Jp=Japan; Kr=Republic of Korea; M=Malaysia; Np=Nepal; Ph=Philippines; Sg=Singapore; Th=Thailand]
INTRODUCTION

Northeast Asia down to countries whose borders terminate before the Antipodes. Other than this criterion of location, the states that call themselves Asian are incredibly heterogeneous in terms of size, colonial histories, economics, politics, religion, ethnicity, language, and a host of other characteristics. To give some indication of what I mean, Table 1 shows some human development statistics from some Asian countries represented in this book in comparison with the United States (United Nations Human Development Report, 2007/2008).

Insofar as the equality of representation among Asian science educators has been achieved in this volume, Table 1 is also revealing of the lack of participation by the least-developed countries in the region. Granted that the state of science education research is unlikely to approach that of the developed world in these places, it was disappointing to discover the near total absence of local nationals working in this field from the published literature or through Internet search engines. Having nearly 50 countries and thousands of indigenous tongues and dialects circulating here have similarly compounded the difficulties in identifying potential contributors not to mention the subsequent editorial process for this volume. At other times, requests for funding were made to the editors to facilitate the writing of a chapter, which we were unable to accede. In some countries, Internet connectivity was either too expensive or non-existent while telephone landlines and electrical supplies sporadic and unreliable, which again severely crimped our pool of authors. Well-stocked libraries of any kind, let alone academic ones, remain unattainable dreams for many here, just as many Asian educators are forced to take on two or more jobs to supplement their shamefully meager incomes. What one observes in this volume is hence a rather narrow membership by wealthier states, an inadvertent selection effect: Development, wealth, local capacity, and research productivity correlate almost perfectly in Asia (Lee, Hung, & Cheah, 2008). This partly arose too through our snowballing technique of obtaining names from established science educators (e.g., Reinders Duit, David Treagust, Ken Tobin) who were working with colleagues in Asia. Their generous sharing of contacts, though wide-ranging, tended to revolve around the same set of educators, which is understandable given the above reasons. The final line-up of chapters (and the intentionally moderate editing adopted that eschews deficit perspectives) thus function as an object lesson in itself, clearly demonstrating the realities of doing science education research in Asia.

Championing Human Agency

Rather than abandoning hope in the face of such massive challenges, the creative power and unexpected surprises of human agency need to be encouraged if we are consistent with a cultural approach toward science education. Though the iron cage is admittedly strong, it is not without cracks that afford passage—structure, just like culture, is never immutable (Rubinstein, 2000). The direct and indirect benefits of the microcredit loan scheme started by Muhammad Yunus are deservedly well-known although we can also learn richly from similar examples of positive agency in science education in Asia (e.g., Lee, 2008a; Lim, Lee, & Hung, 2008; Zahur,
Barton, & Upadhyay, 2002). One particular issue that is close to my heart is the almost inexorable rise of urban centers in Asia and the uneven basket of good and evil that accompanies it (Ness & Talwar, 2005; Pink & Noblit, 2007; Seabrook, 2007). For example, urbanization will enable ruling authorities to deliver goods and services more efficiently although access remains patchy and problematic for the marginalized (e.g., transient laborers, women, lower castes). The latter will try in resourceful ways to make do, to subvert, and possibly thrive in the midst of oppression although this process is always tenuous (Woronov, 2004). Science teachers in Manila enjoy better access to educational resources than their rural counterparts yet class sizes in public schools often exceed 60 (due to the burgeoning number of migrants from the provinces seeking jobs) thereby erasing any possible gains in learning. Lest I am misunderstood, conditions in the capital city are still very Spartan compared to those in the developed world; one teacher has told me of flooding in her classroom every time it rained due to the holes in the classroom walls while textbook ownership by students is low in general. Suffice to say that science education in Asia very soon might require forms of teaching and learning that bear resemblances to strategies adopted in urban America while deviating from it as well if we recall the argument that culture laminates over all our practices. The accounts that the reader is now about to read will exemplify what William Sewell once said: “Personal agency is, therefore, laden with collectively produced differences of power and implicated in collective struggles and resistances (Sewell, 1992, p. 22). More than anything, it is my wish that these 23 chapters will assist in the cross-fertilization of ideas and become catalysts for further agency among science educators everywhere.

CHAPTER INTRODUCTIONS

Section I: Country Reports, Personal Journeys

Given the glut of information available, review articles are necessary to synthesize and map the terrain in specific domains. What is additionally praiseworthy in the trio of country review chapters by Shahjahan Mian Tapan, Chin-Chung Tsai and Ying-Tien Wu, and Aik-Ling Tan is that they shed light on what previously had been almost opaque to outsiders. Tapan, for instance, describes in detail the primary concerns of education in his country—providing education for all, improving retention rates, and creating basic infrastructural support. Recognized as important for modernization, science has taken a more functionalist or applied role although research in science education remains at rudimentary levels. In the latter, research has focused on curriculum, teaching, and textbooks, which address the urgent needs of this young state. Vital here, as in many countries in South Asia, is the work of Non-Governmental Organizations (NGOs) that often provide, not just augment, essential services that governments are unable to supply or choose to ignore. Gender equity, bridging rural-urban divides, and helping the marginalized and indigenous peoples are some of the themes that we will revisit in the last section.
INTRODUCTION

The national concerns raised by Tsai and Wu and Tan are different: With basic provisioning needs satisfied, issues of educational quality (e.g., especially that ill-defined set of attributes known as 21st century skills) are uppermost in both Taiwanese and Singaporean systems. In the former, this is reflected by the increasing visibility of Taiwanese researchers publishing and being cited in the top-tier science education journals. In tandem with the international research community, learning conceptions and contexts have been favored areas of investigation although we are seeing a shift towards work in teacher education, informal science learning, and scientific literacy. Of note, the National Science Council in Taiwan has recently sponsored an international science and mathematics journal (*International Journal of Science and Mathematics Education*) that has appeared on the radar of many Asian science educators. What has happened in Taiwan has been undergirded by forward-looking planning, hard work by dedicated academics, and generous funding over at least twenty years, learning points for nations intending to repeat this feat. In my own domicile, Tan shows how science education research has a closer link with national educational policies (e.g., critical thinking, creativity, technology advocacy) and slogans rather than following wider trends: Research has trailed behind policy-making and has generally been confined to small-scale projects by individual researchers in Singapore. It has been, as expected, difficult to discern any obvious patterns in science education research here, which presents an interesting situation given the reputation that has accrued to Singaporean children in international achievement tests. Whether or not recent proposals to concentrate on conceptual learning, teacher education/learning, and informal science learning will succeed remains to be seen. And while there are abundant sources of funding and official proclamations of support, the lack of trained science educators and graduate students comfortable with research is a major bottleneck that another island with five times her population (i.e., Taiwan) does not appear to lack.

Two complementary chapters follow that chart the historical milestones and lived experiences of chemistry education in China: Zhixin Liu’s chronological timeframe stretching five decades while the lenses chosen by Bing Wei comprise the sociopolitical, international, and individual since 1978. Both authors provide fascinating yet distinct accounts of the growth of Chinese chemistry education against a sociopolitical backdrop that was undergoing major revolutions. Indeed, curriculum development here has come a long way from strict postwar implementation of syllabi and work plans undertaken without question to various attempts at building a home-grown chemistry curriculum. The system has also moved away from the initial reliance on Soviet educational psychology to very targeted borrowing of ideas from the West in recent years. Never completely isolated from the rest of the world, chemical educators in the Middle Kingdom have likewise grappled with fundamental issues regarding: Linking theory with practice (a tenet from Maoist ideology); emphasizing skills (process skills, practical work etc. though conceptualized in a unique way) versus content mastery, and, maintaining the scientific “pipeline” as opposed to teaching science for everyday relevance and Science-Technology-Society sensibilities. I found much
resonance with my cultural stance in the conclusions of Wei’s chapter for he believed that developing countries should prepare their own curricula without obliterating or disrespecting local knowledge and culture. Liu’s chapter, itself translated from Chinese as a labor of love by two who knew him well, acknowledges and confirms his status as the father of Chinese chemistry education.

Drawing on life-history and narrative methods, six Thai educators explore the challenges and tensions in local science education reform in the chapter by Vantipa Roadrangka, Nuruemon Yutakom, and Deborah Tippins. Wide-ranging in coverage but personal in nature, they spoke about making science relevant for learners, creating meaningful contexts for instruction, the salience of thinking scientifically and being literate in science, and building bridges between science educators and scientists. In Thailand, unequal power differentials have traditionally kept apart teachers, academics, and policymakers, which is not terribly unusual a situation although some changes are afoot here to minimize these barriers. Furthermore, it is heartening to note that just as in China, there is local capacity building in the area of science education whereby royal patronage plays a critical role (e.g., model villages that integrate scientific farming techniques with local community knowledge). After reading this chapter, there was a palpable sense that these interviewees were individuals with high degrees of commitment and purpose, agentic traits of the very kind promoted earlier. With equal enthusiasm and concern for young people (in elementary grades), Yen-Ting Chen, Jyh-Chong Liang, Meng-Lung Lai, and Fung-Yuen Chang bring to our attention how science education has been handled for this relatively neglected cohort in Taiwan. According to the authors, research on teaching methods took central place about a decade ago while studies on curriculum development, concept learning, and professional development gained prominence in more recent areas. As a whole, we are told that science educators in Taiwan have been much influenced by constructivism although much less by social constructivism, which is a stepping-stone towards appreciating the interpenetration of culture and science education. One also discovers that early years science is even more obscure a domain in Taiwan although this is by no means uncommon (Michaels, Shouse, & Schweingruber, 2007).

Section II: Curriculum, Teaching, and Policy

SungWon Hwang and Wolff-Michael Roth set the stage for the second and biggest section revolving around curriculum, teaching, and policy: Theirs is the only chapter in this handbook that deals exclusively with research methods and they employ a sophisticated argument based on cultural-historical and dialectical approaches. They take issue with how qualitative research has generally been conducted in Asia, which has confused and obliterated the particularities of the research object. However, the overarching point they make is that theory-generation has taken a back-seat because data are largely in the service of proving some theory rather than the other way around. Two inherent strengths of qualitative research are at distinct risk now, which Hwang and Roth unpack from two case studies of ethnomethodological transcription: “A deeper understanding of the
particular and the general simultaneously (i.e., the dialectic of the particular and the general) and second...opportunities for culturally reflexive interpretation (i.e., the dialectic of subjectivity and reflexivity).” Being convinced of their method of dialectical praxis that considers the interdependency of explanatory concepts and the research problematic, I join these authors in persuading readers to think more critically about their own research toolbox. As my former course instructor in research methods loved to say, if one really wished to prove or discover something from the data, success was a surety. This is essentially an identical warning that Hwang and Roth are articulating albeit using different language.

Jinwoong Song and his group in Korea have also done us a favor by attempting to devise indicators of science culture at the personal and societal levels where science culture was defined as “all modes and values of life which individuals and society share in relation to science and technology.” From earlier studies, they had found that there was an emphasis on the physical and personal contexts of content learning as well as the textbook and laboratory contexts of learning science. In other words, school science in Korea was presented as the learning of facts with application to everyday life through textbooks and practical work as the vehicles of that instruction. When their indicator instrument was modified to assess the degree of science culture in a few Korean cities, Daejeon city led the pack as it was a special municipality with many research institutions and a science museum. Again, Song and colleagues insist on values and personal interest, that is, affect, as the basis for learning science for young people. Unless this is clarified right at the beginning and revisited by teachers, it seems unlikely that students would ever accept our word that science is fun nor co-opt science as a resource for their own everyday purposes, which I enthusiastically agree.

I am pleased that the following three chapters delve into how science learning is not delimited by the apparently water-tight confines of school subject matter (Masakata Ogawa), institutional frames (Katsuhiro Yamazumi), and language (Ken Kawasaki), thereby reinforcing Song’s appeal for increased science literacy in modern society. Questioning if school science is only taught within formal science classes, Ogawa replies in the negative, at least in his analysis of the Japanese upper secondary curriculum. He takes pains to show how the aims of science as described by experts are actually spread in varying degrees across many school subjects (e.g., language learning, humanities, home economics). For Yamazumi, he describes a hybrid and emergent intervention project called New School that smudges the lines between school and the wider community. By drawing upon third generation activity theory plus ideas from progressive philosophers, we see how young children in Osaka learn more about science, the environment, culture, and history when they get personally interested in a local food plant that nearly went extinct. In Kawasaki’s case, he argues from an axiomatics model of science education that any language can be the medium of instruction for science—Standard Average European languages for teaching Western Modern Science (WMS) should not be privileged hence making it possible to have a relativistic view towards science and science education. By means of an excerpt where Japanese children were trying to sort fish according to their gender, Kawasaki demonstrated how using their first
language to enact science conflicted with aspects of WMS. If we take what Ogawa, Yamazumi, and Kawasaki are proposing seriously, then schools and the community are more “science-educationalized” than what we are currently led to believe and that worldview education displaces hegemonic forms of science education, which assumes familiarity with the Greco-Roman heritage. All these tactics, though ingenious for liberating science education, will nonetheless pose expected challenges in execution including the comfort levels of non-science-trained teachers explaining difficult concepts, the traditional balkanization of school subjects, and breaking the stranglehold that WMS has on practitioners.

In another coincidence, the next three chapters come from Hong Kong (and China) and are exemplary projects in science research with close involvement of school teachers. Taking advantage of cross-cultural nuances in teaching, Benny Yung, Fei-Yin Lo, Siu-Ling Wong, and Dong-Sheng Fu designed a teacher development project named Parallel Lessons whereby science teachers from Hong Kong and China taught in each other’s schools. Through the discrepancies that emerged in terms of choice of teaching strategies, student learning, and student-teacher interactions, it was believed that critical forms of teacher reflection and learning would follow. It helped that the latter was done via means of critical discourses within a supportive community of fellow teachers, curriculum experts, and the research team. From the preliminary results, it was found that Hong Kong teachers, while the more proficient in inquiry science techniques, tended to benefit less from Parallel Lessons than their mainland counterparts. Although both parties were equal partners in the study, the authors attributed this outcome to the “highly institutionalized teacher development practices and the culture of collegial and public conversation about teaching in China.” Apart from the comparative case studies that lay bare pedagogical content knowledge in science, the authors suggest a number of useful implications for teacher development.

Although achieving some successes, the stories concerning assessment reform (May Cheng) and teaching the Nature of Science (NOS) (Siu–Ling Wong, Benny Yung, & Maurice Cheng) are tempered by local resistance and sociocultural factors reported in East Asian settings. Cheng reports that alternative forms of assessment (e.g., performance, outdoor learning tasks) were avoided by many teachers in Hong Kong and even when some teachers were taught how to conduct authentic assessment in the form of scientific investigations, it demanded drastic and discomfiting shifts in instructional modes. A follow-up study that examined how teachers could use assessment rubrics to enhance student performance was more positive; a two-stage, progressive building up of confidence and experience in process skills and experiments was central for students together with joint support for teachers. If anything, Cheng’s patient work shows that for reforms to be sustainable, indeed even being implemented with some fidelity to the philosophy of the change, a tremendous amount of personalization, precision, and professional learning has to occur (Fullan, 2008). Nothing is guaranteed as Wong, Yung, and Cheng’s research warn us: The authors express great outrage over the “blow to a decade of effort on promoting teaching of Nature of Science.” One of the most troublesome areas to teach effectively, NOS capacity building was given due
diligence in the form of preparing video resources and intensive teacher workshops covering local topics of interest such as Disneyland, consumption of shark fins, the Severe Acute Respiratory Syndrome (SARS) epidemic and so on. While having guarded optimism that teachers would slowly embrace NOS teaching in time, there was an unexpected decision by the examination board to award only 2% (or less) of marks to NOS issues at the secondary level science examinations, a move certain to be negatively consequential in a high-stakes testing environment.

It is fitting that Steven Zuiker clarifies the learning issues surrounding the use of Information and Communication Technologies (ICT) or what he defines more broadly under Interactive Digital Media (IDM) in science education for there is a strong temptation among educators to be (blindly) enamored with technology. There are, in his opinion, two core processes in IDM, which educators can fruitfully leverage—digitizing boundaries (new media that facilitate new physical, informational, and participatory dimensions in everyday life) and open(ing) ecologies (inter-community or institutional exchanges). Coupled with the idea of boundary objects, Zuiker argues that these enable scientific learning to be an amalgamation of the physical and social “through a concrete process of building conversational realities.” Again, this is not without tensions and conflict such as our wish as instructors to receive correct answers as opposed to allowing misconceptions to arise as the inevitable outcome of increasing epistemic agency and identities as learners. Moreover, in his research involving computer games among secondary school children in Singapore, there seemed to be a trade-off between celebrating individual agency and having sufficient reflexivity to move group discourse, an observation too often reported by educational researchers.

Eager to determine the web-searching behaviors of Taiwanese students in science courses, Gwo-Jen Hwang, Pei-Shan Tsai, and Chin-Chung Tsai used the Meta-Analyzer software to capture these over 13 quantitative indicators such as the total time for web page selection, number of browsed and non-adopted pages, number of revisions on the science question, and so forth. From their study of 617 elementary school students, it was found that older learners were more skillful in finding and using information they found on the web, which could be explained by a number of reasons. As a whole, students also stated that the software helped them concentrate on the science problem better and improved their problem-solving abilities. Another finding that raises concern was that children in rural areas had less confidence in collecting and comparing information than those in the city, which points to the latent existence of a digital divide here.

Together with ICT, cultivating new skills for living in the new millennium takes center-stage in many education systems, of which Malaysia is no exception. Nor Aishah Buang, Lilía Halim, Subahan Meerah, and Kamisah Osman have thus designed what they call an Entrepreneurial Science Thinking (EnSciT) curriculum to foster the purposeful application of scientific knowledge to make new products or ideas. This is in keeping with fanning interest in science-related careers in Malaysian education as well as turning what may remain just as dreams into concrete realities and profit. Responses to this prototype curriculum have varied according to the types of learners; it was well-accepted by high- and medium-achievers regardless
of gender whereas children who had experienced less success in science found it hard to appreciate. It is envisaged that refinements to this ongoing project would definitely aid students to find greater personal meanings between science and everyday living. For Jennifer Yeo and Yew-Jin Lee, what is critical for the education of children now is Knowledge Creation, which incorporates and extends the well-known metaphors of learning as acquisition and participation. Embedding their arguments in the contexts of science inquiry learning, they suggest that these modes are consistent with theory-building practices in science as well as the collaborative nature of constructing knowledge. Through Knowledge Creation, therefore, the knowledge in a community is advanced and refined rather than merely reproduced or transmitted. From their intervention project in Singapore, we see how primary school students doing investigations on photosynthesis increased the breadth and depth of handling scientific concepts.

Section III: Equity and Social Justice

The last section of the handbook is concerned with equity and social justice, topics less visible till recent years in the science education community although of great relevance in Asian contexts (Anderson, 2007). Thasaneeya Ratanaroutai, as a science teacher-educator working among the urban poor, gives an overview of the conditions that disadvantaged children have to endure in Thailand and the various efforts by the government to mainstream some of them. For developing countries, these challenges are very persistent and multifactorial in nature so the kinds of sacrificial work by Ratanaroutai and her colleagues are to be commended. In a similar vein, Sudhakar Agarkar describes intervention programs in science among children from the lower castes and poor indigenous populations in Maharashtra, India. An impressive and systematic program spread over many years, there were many strategies that together contributed to its success including improving literacy and numeracy, supplying reading materials, question-answer sessions, teacher development, science clubs, peer tutoring, opportunities to conduct and plan scientific investigations and others. Despite how it is almost impossible to disambiguate which of these interventions was the most effective or if there were any interaction effects among these, it should not detract from the fact that some of these children did perform better in the Indian terminal examinations than they would have had there been no involvement by Agarkar’s team (see Chauhan, 2008).

In a fascinating piece of ethnographic research conducted by Bhaskar Upadhyay, Jagdish Chandra Regmi, and Uttam Sharma, they shone the spotlight on innovative forms of teacher agency and resistance to social inequalities in Nepal. Being members of the lower caste in that country, the two teacher-participants here overcame many barriers, which now were sources of inspiration for children, showing how things could be otherwise, and more importantly, that science could be one of the weapons that they could utilize. Interrogating what we as science educators consider as the purposes of studying science, these teachers walked a fine ideological line between preparing children for examinations (science is after all a form of powerful knowledge), and something that youth could themselves
embrace as immediately relevant and motivating. Again, as is so typical of development work, there are more questions than solutions. In our final chapter by Deborah Tippins and Vicente Handa, we learn more about community immersion as a means of science teacher preparation in the Philippines. Adopting ecojustice theory and collaborative action ethnography, the authors describe with much vividness and emotion how preservice teachers “become informed about local communities such that they might participate more fully as decision-makers and advocates for the local community and its environment.” Expecting black-and-white answers initially, the teachers came to realize that there were none to be offered as they continuously struggled through ethico-moral issues arising from their attachment in the villages, which I believe converges ultimately onto exploitative economic formations tied to environmental misuse.

REFERENCES


PART I: COUNTRY REPORTS, PERSONAL JOURNEYS
1. SCIENCE EDUCATION IN BANGLADESH

EDUCATION IN BANGLADESH

The People’s Republic of Bangladesh is a South-Asian country north of the Bay of Bengal. The country is surrounded by India in the West, North, North-East, and Myanmar to the South-East. A close neighbour to Nepal, Bhutan, China, and Thailand, it has an area of 147,570 km² and a population of nearly 140 million with a population density of 948 persons/km², one of the highest in world. Independent in 1971, Bangladesh is an ethnically homogeneous country: Bangalees comprise 98% and the remainder are mostly Chakmas, Santhals, Garos, Oraons, Biharis and Mundas. Variations in Bengali culture and language do exist, of course. According to a 2001 census report, the population was 89.58% Muslim, 9.34% Hindu, 0.62% Buddhist, 0.31% Christian and 0.15% Animist. Fifty percent of the population live below the poverty line while life expectancy for males and females are 60.8 years and 59.6 years respectively. The literacy rate is 68% (15 years and above), GDP-real growth rate at 6.05% (in 2008) and per-capita income is US$599 (in 2008). In this chapter on the state of science education in Bangladesh, I first describe education in general before speaking about science education and some of its challenges in the country.

General Education

The present education system in Bangladesh may be broadly divided into three major levels: Primary; secondary, and, tertiary education. Primary education (grades 1-5) is managed by the Ministry of Primary and Mass Education (MOPME) and secondary (grades 6-12) and higher education are under the administration of the Ministry of Education (MOE). In terms of curriculum, the post-primary stream of education is further classified into four types: General education; technical-vocational education; madrasa (Islamic religious schools) education, and, professional education. The first level of education comprises five years of formal schooling (grades 1-5). This stage is called primary education, which normally begins at six years of age. The main providers are the government primary schools, kindergartens, primary madrasas, and NGO (Non-governmental organization)-operated non-formal schools. At present there are 80,397 primary schools, 344,789 teachers, and 1,622,658 students at the primary level. The percentage of girls at the primary level enrolment is 50.1%.

The second level of education comprises seven years of formal schooling. The first three years is referred to as junior secondary (grades 6-8), the next two years
are the secondary (grades 9-10) while the last two years are called higher secondary (grades 11-12). Secondary education has three streams: Science, Humanities, and Business Education, which start at grade 9.

In 2005, Bangladesh had 9,444 secondary schools with 73.98 million students and 238,158 teachers. At the end of grade 10, students have to take the Secondary School Certificate (SSC) examination. In higher secondary stages, the course is of two-year duration (grades 11-12). The minimum requirement for admission here is the SSC or equivalent. It is offered by intermediate colleges or by intermediate sections of degree or master colleges. At the end of grade 12, students are to take the HSC (Higher Secondary Certificate) examination. Students may choose any of the streams from science, humanities or commerce.

The higher education (graduate and post-graduate levels) is the third stage of education, which comprises two to six years of formal schooling. The minimum requirement for admission at this stage is the HSC. Students can enroll in three-year degree courses or in four-year bachelors’ degree honours courses in degree level colleges or in the universities. Master’s degree courses are of one year duration for honors bachelor degree holders and two years for pass-grade bachelor degree holders. After completion of masters’ degrees, students may take up M.Phil and Ph.D degrees. The average duration for the M.Phil is two years and for the Ph.D three to four years. There are 74 universities in Bangladesh and out of these 21 universities are in the public sector while the other 53 are in the private sector. In 2005 there were 10,339 teachers and 207,577 students at the universities of Bangladesh (Bangladesh Bureau of Educational Information and Statistics [BANBEIS] Report 2006).

This educational track starts from the secondary level at the end of grade 8. The certificate courses prepare skilled workers in different vocations, which may last one to two years. There is a vocational course of two years duration at the higher secondary level. Diploma courses prepare the diploma engineers at the polytechnic institutes. This course lasts four years after passing the SSC (general or vocational).

National Science and Technology Policy

The Science and Technology (S&T) policy of a country is the policy formulated for science education, research and training, and the process to implement them for the technological, economic, and social development of the nation. During the colonial period (under the British rule), science education was very much neglected. Therefore, there was no specific policy for science education and technological development. Before independence, efforts had been made to prepare skilled technicians but not scientists. Parents encouraged their children to learn science in order to get good jobs and to have a chance to go abroad for higher education or for a job (Ministry of Education [MOE], 1986).
After independence, discussions related to development of a S&T policy was initiated. In 1976 a National Council for Science and Technology was established with the President of the country as its chairman and an outline of S&T was proposed but the proposed outline was not materialized. In 1980 Bangladesh formulated a draft National Science & Technology Policy and that was finalized and gazetted in 1986. The policy was designed to fulfill the following aims: To attain scientific and technological competence and self-reliance; to help increase production and employment in various sectors and sub-sectors of the economy; to be in consonance with the socio-economic, cultural, educational, agricultural, and industrial policies of the nation; to contribute to the world-wide pool of scientific and technological knowledge; to seek out and recognize high talents in various areas of science and technology; to strengthen cooperation in science and technology between developed and developing countries, and particularly among developing countries themselves, and, to provide guidelines for institutional arrangements or rearrangements in the research and development (R&D) structure (including education and training) for attainment of the above objectives (Ministry of Education, 1986).

With a view of towards policy formulation in S&T and their cultivation and application in various sectors, the Government of Bangladesh constituted the National Committee on Science and Technology (NCST) on 16 May, 1983. The NCST was also headed by the President and was formulated for the following purposes: To organize and coordinate all R&D works concerning science and technology in the country; to establish scientific and research institutions/laboratories/Centers for improvement of standard of scientific knowledge at all levels from the school to the university; to promote research and strengthening the competence and capability of research institutions; and to train personnel and specialized scientific and technological staff and encourage innovative activities, and, also creation of scientific awareness among the broad masses of people (Ministry of Education, 1986).

NATIONAL CURRICULUM AND TEXTBOOKS

Science at the Primary Level

At this age every children is curious and influenced by observing different events or phenomena in his or her immediate environment. At this level, therefore, introduction to the everyday environment has been given more emphasis and science is taught as environmental studies. In grades 1 and 2, natural and social environments are taught together and there are no textbooks for the children of these grades. The teachers have to teach the subject following the teacher’s guide on environmental studies developed by experts and published by the National Curriculum and Textbook Board (NCTB). In grades 3 to 5, science is taught as environmental science and there are separate textbooks for each of the grades (Ministry of Education, 1974). In my opinion the decision for introducing environmental studies at the primary level was an excellent one because the country is suffering from natural disaster and other environmental degradation.
Science at the Lower Secondary Level

The lower secondary age group of pupils in Bangladesh is from 11 to 14. In this stage science is taught as a compulsory subject entitled General Science. The syllabuses of the subjects had been prepared keeping in view the recommendations of the Bangladesh Education Commission Report in 1974 and also keeping in mind the previous experiences that the lower secondary students acquired due to the exposure to Environmental Studies (Science) at the primary level. The Bangladesh Education Commission Report of 1974 recommended that there must be a well-integrated course for the different branches of science at grades 6 to 8 and biology, physics, and chemistry should receive priority in the course. Following the recommendations of Education Commission Report, the syllabuses included topics in physics, chemistry, biology, geography, hygiene, food and nutrition, population education, and environment. The curriculum had been developed in 1976 and implemented from 1981. In the lower secondary science curriculum, a start had been made in 1981 to break away from some of the traditional features of science education in the last decade or so. The new curriculum and the textbooks gave recognition to the elements of enquiry, observation, and experimentation within science education. Much emphasis was put to “learning by doing” and in all chapters of the textbooks different interesting activities of science were included with the name of “Let’s do.” The science textbooks for grades, 6, 7, and 8 were introduced in 1981, 1982 and 1983 respectively.

The implementation of new curricula had, however, not been very successful because there were many complaints from teachers and parents about the lower secondary science textbooks. The teachers thought that they were unfamiliar with some new and modern concepts that were in the text. The orientation or training given on how to teach these books were not adequate especially in the use of activity-based methods in teaching science. There have been complaints from the teachers about syllabuses being too heavy and overloaded with lot of activities, which could not be performed in the present classroom situation of the secondary schools especially in the absence of indigenously produced equipment. Teachers’ Guides were not supplied in time and in some of the schools it was not supplied at all.

The Bangladesh National Education Commission of 1988 (Ministry of Education, 1988) urged that science education at all stages of school be strengthened and made a required subject for all pupils at the secondary stage. A report on modification of the science curriculum at the lower secondary level was submitted to NCTB in 1990 by a team of experts. They had prepared a revised sample curriculum and model teaching units for new textbooks for grade 6 to 8 and submitted to NCTB but no action had been taken up to 1995. In 1995, NCTB published new curriculum report and new textbooks (NCTB, 1995a, 1995b, 1995c) were introduced at this level in 1997 deviating from “hands-on practice” for the students. Hands-on practice is the practice of activities by the students themselves which was theoretically taught or demonstrated in the class. In my opinion deviation from this was a blunder as it is the root of all science education. If we properly implemented those textbooks of 1981-83, the situation
of science teaching-learning would have been better and the science education would have improved greatly. Their rationales for deviation were that although the curriculum and syllabus were much improved but in the practical situation the standard of science education was not improved due to the following reasons:

– Most of the teachers were not acquainted with the new content and concepts introduced in this curriculum due to lack of appropriate training
– The assessment and examination system were not appropriate and consistent with the requirement of the new curriculum
– The textbooks were extremely activity-based which were not consistent with the resources available in the schools in terms of lack of trained and qualified teachers, lack of appropriate physical facilities and science teaching aids in the classroom (Bangladesh National Curriculum Committee Report, 1995).

The new curriculum of 1995 for the lower secondary level was introduced by revision of the curriculum of 1976. These revisions of science curriculum were done because of the above weakness of the previous curriculum but with this change they could not achieve the goal and in my opinion, science education in Bangladesh was not improved but deteriorated. The faults were not with the textbooks but with implementation process because NCTB could not prepare teachers through proper training.

Science at the Secondary Level

Before 1960, no significant emphasis was given to science education at the secondary level in the then East Pakistan. General science was introduced at the primary level in grades 4 and 5 in 1951. In the lower secondary level, elementary science was then just initiated. *Elementary scientific knowledge*, an optional subject was offered at the secondary level. At that time science was taught as an additional/optional subject up to grade 10 and multi-stream courses were used to commence from grade 11.

Before independence, the major change in science curriculum was made in 1961. This was done following the recommendation of the Pakistan National Education Commission Report of 1959 (Ministry of Education, 1959). For the first time, science was made compulsory up to grade 10. Beside this a multi-stream system was introduced from grade 9. The courses were divided to different groups such as science, humanities, commerce, agriculture, home economics among others. The students of all but science group had to read a general science as one of their compulsory subject.

After the independence of Bangladesh, a National Curriculum and Syllabus Committee (NCSC) was set up in 1975, following the recommendations of the Bangladesh Education Commission Report 1974. The NCSC was entrusted with the responsibility of reviewing, redesigning and improving curricula and syllabuses up to higher secondary level. The NCSC accorded special emphasis to modernize science education of the country with reference to content, teaching strategy, evaluation and application of science and developed a new set of
curricula and syllabuses from primary to higher secondary levels during 1981-84. The curricula for higher secondary level were not implemented at that time. In 1995 on the basis of the National Education Commission Reports (MOE, 1988) that curricula was modified.

On the basis of the National Education Commission Report in 1974 and the Curriculum Committee Report in 1976, two textbooks—General Science Part I (Physical Science) and General Science Part II (Biological Science)—were introduced for grades 9 and 10 in 1983. Physical Science covers physics and chemistry while biological science covers botany, zoology, agricultural science, sericulture, apiculture, horticulture, fisheries, poultry, farming, nutrition, population, public health and pollution and so on. According to the recommendations of the Education Commission Report of 1974, science was made compulsory for all students at the secondary level. The books were accordingly prepared and introduced by NCTB in 1983. But due to resistance from different sources such as teachers, school authorities, guardians, and students, science was made elective by the government in the same year. The reasons provided at that time were that all secondary schools were not capable of teaching science as a compulsory subject because of lack of laboratories, equipment, teaching aids and trained teachers. Also, the teachers needed more time to be oriented with the texts. The students taking general science as their elective subject were treated as science-group students and the rest were treated social-science group students. The social-science group students could or could not take a paper on science. A book entitled *Modern Science* was prescribed by the NCTB as an elective subject for the social-science group students. The general science textbooks introduced in 1983 for grades 9 and 10 had been redesigned and modified on the basis of a nationwide evaluation of the trial edition introduced in 1983 by the science evaluation committee (1984) constituted by the MOE under NCTB. This revised edition was made effective from 1988. After revision no major changes in secondary science textbooks were brought about but some minor corrections were done with the help of experts.

The major change in secondary curricula was made in 1995 following the recommendations of National Education Commission Report of 1988. Just like in 1961, science was made compulsory up to grade 10 and a multi-stream system in general education was introduced from grade 9, the courses being divided into three groups—science, humanities, and business education. Physics, chemistry, mathematics, and biology were taught as separate disciplines in the science group. For other groups, general science was introduced as compulsory subject. The changed secondary science curriculum of 1995 was an updated one and was capable of maintaining standard of other developed and developing countries. It was comparable to O-level/GCSE curricula.

On the basis of changed curricula of 1995, textbooks in physics, chemistry, mathematics, and biology were developed keeping in view the standard and style of textbooks at O-level/GCSE level. The teachers, especially those in rural areas, are facing many difficulties teaching these subjects as they are not oriented with the modern and updated contents and their presentation style.
Science Curriculum and Textbooks at the Higher Secondary Level

Before revision of the science curriculum at the higher secondary level, science was taught according to the curriculum of 1959. It became obsolete in respect to subject matter as well as teaching approach and method. The National Curriculum and Syllabus Committee (NCSC) revised the curriculum in 1977 but it was not implemented. In 1995 new science curriculum was developed and introduced in 1997.

The physics curriculum was revised keeping in view the need for students who will study physical science and engineering in future and also for those who will take it as terminal education in their life. In the new syllabus, a new portion named Modern Physics has been added so that the students acquire concepts of some important inventions of physics and their applications. In mathematics teaching, vectors and calculus were introduced the first time. In the new syllabus, less emphasis was given on descriptive knowledge but more emphasis was given on mathematical and logical structure in teaching-learning physics and the importance of using equipment and experimentation. One of the main aims of this curriculum is that for those will not continue physics education in future, they will also be able to use the knowledge and skills of physics in different areas of their life. The objectives of teaching physics are mainly the extension of objectives of physics at the secondary level. The textbooks on physics were developed as per standard of A-level physics and modern treatments of different aspects of physics were provided. The objectives for chemistry and biology teaching-learning are similar to the objectives of SSC level chemistry teaching-learning with more rigorous and exhaustive treatment in comparison to secondary level. Textbooks are developed in such a way that they are comparable with A-level textbooks. Teachers are still facing difficulties in teaching with these books as some topics are new to them and the old topics are treated in a new and updated style with which they are not familiar. Some orientation for teachers were given by the NCTB but those were very inadequate.

Laboratories, Equipment, and Teaching Aids at the Secondary Level

The requirement for practical examinations at the secondary level is to perform at least one experiment for each of the subjects (physics, chemistry, biology). Twenty-five out of 100 marks are allotted for practical examination in each of the subjects. Therefore, each secondary school offering science should have a laboratory or science room and some equipment. Most do not have separate laboratories but some of them have a science room with inadequate equipment and furniture.

The new secondary science courses demand a more practical approach to teaching, which requires a minimum package of simple and unsophisticated equipment, teaching aids, and consumables such as chemicals, raw materials, and specimens. There is a general shortage of science equipment in secondary schools and colleges and most of the non-government institutions lack facilities for science teaching through practical work. Hence the opportunities for students to perform practical experiment themselves are very limited. There are two other
issues and problems in science education at the secondary level, namely that of the non-government secondary schools and higher secondary colleges at the rural areas do not encourage many students to take science as an elective subject because of financial costs. Most of the secondary science teachers are also not trained or oriented with the new science curricula and the textbooks so they find difficulties in teaching science at these levels.

Levels of Student Achievement in Science at the Secondary Level

In this age of S&T, it is alarming and discouraging that student enrollment in science at the secondary and higher secondary levels are declining. The number of science students at the secondary and higher secondary levels were 264,100 and 126,315 respectively in the year 2001. These numbers declined to 202,048 and 82,199 respectively in the year 2006 (BANBEIS, 2006). The percentage drops are 28.9% and 33.4% for males and females at the secondary level and 41.9% and 42.3% at the higher secondary level. The causes of this drop are because humanities and business education courses are easier in comparison to science and that there are more job opportunities for business education graduates rather than science graduates.

Science at the University Level

In most of the public universities there are faculties of physical science and biological science. Here, science is taught as physics, chemistry, botany, zoology, geography, biochemistry, pharmacy, and others. In the private universities, emphasis has been given to technology and engineering such as computer science and engineering, electrical and electronics engineering, civil engineering, environmental engineering, chemical engineering, industrial and production engineering, mechanical engineering, telecommunication engineering, textile engineering and others as these fields are job oriented and most in demand nowadays. The number of science students is also declining at this level.

INNOVATIONS IN SCIENCE CURRICULUM AND TEXTBOOKS

Bangladesh is the victim of global environmental problems, climate changes, and natural disasters. Besides, there are problems of environmental degradation relating to land, water, forest, and other natural resources. Above all, the lack of environmental education at all stages are the important causes of environmental degradation. The introduction of Environmental Studies at primary level is an innovation in primary curriculum. In the secondary curriculum, some environment-related topics have been dealt with in the science and social sciences as part of population education that was integrated into the course contents in 1970s.

Before 1976, all the reports of curriculum committees included objectives and content for each subject. In my opinion, these were innovative for they also included teaching-learning methods, teaching aids to be used, and assessment for
Each topic along with objectives and content to be covered. In the science curriculum (with special reference to that of the lower secondary) of 1976, it was proposed that there had to be well integrated courses from the different branches of science at grades 6, 7, and 8 and that biology, physics, and chemistry should receive priority. But this course had to be devised to enable the pupils to learn the application of science in their daily lives and to develop the ability to think logically and encourage an active approach to learning. Much emphasis has been placed on learning by doing. This is a change in the direction from the “process to product” in place of the traditional type of chalk and talk approach.

The new textbooks for science for grades 6 to 8 which was introduced in 1981-83 was an innovation in the area of science textbooks in Bangladesh which had the following features:

- Use of activity-based approach, with emphasis on low-cost improvised equipment made locally
- Inclusion of extra optional activities to extend the highly motivated and intelligent pupils
- A bigger variety of written exercises to include problem questions as well as recall questions
- A reduced number of technical names and terms.

In these books, each chapter contained some activities for the learners in the name of “let us do ourselves.” Teachers’ guides were introduced for the first time which contained:

- Suggestions on how to teach each part of the course and organize each lesson in terms of activities, time, and so on
- List of equipment and material required for each activity and how to make certain improvised items of equipment
- Answers to questions in text and additional background information on certain topics for the teacher.

INNOVATIONS IN TEACHING METHODS AND ASSESSMENT

No major change has been found up till now with regard to the teaching-learning methods of science in Bangladesh and the main problem is probably related to the teachers: They are inclined to teach the same things in the same way they were taught when they had been students. With the introduction of new textbooks at the lower secondary and secondary level in 1981-84, a teacher’s guide was developed (I was one of the authors of textbooks and also for the guide) and many innovative teaching methods were suggested here. The teachers were very reluctant to use those innovative methods due to lack of interest, motivation, and proper training. Even now, science is taught everywhere in Bangladesh using traditional teacher-centred methods with less importance paid to student participation. The teachers encourage the students in rote learning.

Similar to teaching methods, no major changes have occurred in the assessment system. With the introduction of new textbooks in 1981-84, assessment of student learning in science were proposed with both subjective (essay) and objective
(Multiple Choice Questions [MCQ]) test items and these type of test were incorporated in the exercises in each chapter in the science textbooks. However, these were not reflected in the questions set during different examinations. In the Secondary School Certificate (SSC) examination of 1992, MCQ items were set for the first time with the essay items. But it was criticized by parents and some educationists for reasons that it would help rote learning. The MCQ format is now being used to assess student learning not only at the SSC examination but in other grades of primary and secondary levels. But due to lack of qualified and trained science teachers it is not yet possible to get good MCQ items for assessment of student learning in science. Although the curriculum has been updated, the evaluation system has not been changed to meet the expectation of new curricula.

RESEARCH IN SCIENCE EDUCATION

At the postgraduate level, research in pure and applied science are conducted in different public universities in Bangladesh but research in science education are rare in Bangladesh. The students in the Science, Mathematics, and Technology Education department of the Institute of Education and Research (IER), University of Dhaka (DU) conduct research in science education for the partial fulfillment of their master’s degrees. The students at the Educational Research and Evaluation department also conduct a few studies in science education. Besides, M.Ed. students of public teachers training colleges conduct one or two studies in science education every year. The total number of research in science education in Bangladesh is very low in comparison to other developing countries and more effort and emphases should be given. The research done in science education in IER can be divided into the following categories (Begum & Tapan, 1992):

– Educational technology. Research in educational technology was mainly on instructional material development and their validation and effectiveness. A good number of modules were developed on the content of science and pedagogy of science teaching and they were experimentally validated to examine their effectiveness.

– Science teaching-learning. Research in this area are mainly on identification of teaching methods used by the teachers at different levels of education from primary to university level. Some studies were conducted to compare the effectiveness of different teaching methods. A few studies were on classroom culture of science teaching and identification of essential competencies for science teachers.

– Science curriculum. Research in this area mainly focuses on development and implementation of curriculum and evaluation of impact of curriculum and instructional materials. Besides, some studies were done on identification and evaluation of objectives of teaching physics, chemistry, and biology at the secondary level.

– Achievement of science and its correlates. A few studies were done on development of achievement tests and their validation. Some research were done to identify the correlates of achievement in science. These correlates are mainly academic motivation, socio-economic status of students, and gender.
– *Environmental education.* Several studies have been done on environmental studies. These include evaluation of teaching-learning materials and methods at the primary level, achievement of students, implementation and their impact, and identification of skills of primary teachers to teach environmental studies.

– *Assessment of science education.* A few projects were conducted on the development of assessment tools and to determine their reliability and validity. One study was conducted on effects of formative evaluation on student achievement in science (Khanam, 1994).

– *Textbook evaluation.* A good number of studies have been done on evaluation of science textbooks at primary and secondary levels. The environmental science textbooks developed by NCTB and some NGOs were evaluated and compared to determine whether they are consistent with the national curriculum.

– *Physical facilities.* A few studies have been conducted on physical facilities available for science teaching in rural and urban secondary schools. These are mainly related to the science laboratory and science corner.

Descriptions of some research performed by masters’ students in IER are given below. The author guided some of these while he was serving in IER, University of Dhaka. Siddiq (1976) conducted a research study to determine the effectiveness of self-instructional modules as a strategy for teaching science at grade 6. From her study she reported that the module was effective for science teaching at this level and the students possessed positive attitudes towards the modular instruction. From his study, Haque (1976) reported that about 88% of science teachers in Dhaka city had general academic qualifications but 55% of them had no professional qualifications. Most of the schools had science laboratories but with very limited equipment, which is very low in comparison to international standards. The teachers had to teach about 27 classes every week and each section of class has 47 students. He recommended professional development for the science teachers and teaching loads of 18 classes a week for teachers with class sizes of 30 students. These recommendations have not been implemented yet and the teachers are still over-loaded.

Begum (1981) conducted a study to determine the attitudes of grade 5 students towards environment studies. She reported that most of the students had positive attitudes towards the study of environmental studies. Parvin (1982) developed a curriculum on environmental education for grade 7 students and evaluated it with input from curriculum developers, subject specialists, and school teachers. She found that it was appropriate for the grade but recommended experimental verification using different teaching methods. Siddiqua (1982) found correlations between academic motivation and academic achievement of secondary science students. She selected 467 students from grade 9 and 10 as the sample for her study and found significant positive relationship between the score of academic motivation and score in science subjects.

Khatun (1983) identified the teaching skills needed by the teachers to teach biology at the secondary level. She listed the skills related to biology teaching at the secondary schools and evaluated these on the basis of expert opinion. She found that secondary biology teachers should have the following skills: (1) using
necessary apparatus and chemicals; (2) developing audiovisual equipment and their proper use, and, (3) collecting, storing and demonstrating the specimen for science teaching. Begum (1984) studied the present evaluation system of science faculty of Dhaka University (DU). From her study she reported that the students in the science faculty of DU are assessed through written and oral tests, which consist of tutorial, assignments, term papers, practical work, and regular attendance. The result was reported in terms of marks and alphabet grades. Further, there was no definite principle for distributing marks in written and oral tests and only 30% of marks were allotted for practical examinations. Khaleque (1984) and Chowdhury (1984) developed modules on grade 6 biology and grade 7 general science respectively and evaluated their effectiveness through comparison of mean achievement of experimental and control group students.

Banu (1984) conducted a study to determine students’ knowledge of environmental science at the primary level. From her study with a sample of students from eight primary schools she reported that the students had deficiencies in knowledge on environmental science and their achievement differed from school to school, between urban and rural students, and girls and boys. Devi (1985) found significant positive relationship between socio-economic status of the students and their achievement in science. The relationship is similar for both urban and rural students but there was significant difference between mean achievement of urban and rural students and between girls and boys.

Rashid (2001) conducted a study on “Assessment of Training Needs of Secondary School Physics Teachers.” She reported that secondary school physics teachers needed training in science content, practical work, teaching methods, and assessment. Mondal (2001) tried to identify the sources of physics teaching aids and found that most of the schools do not have adequate teaching aids and they do not know from where they can collect/produce them. A few teachers said that they bought them from school budgets and sometimes the students and teachers produced improvised teaching aids. Some government projects rarely supply some teaching aids.

Roy (2003) tried to find out the “Effect of Learners” page in daily newspapers on student learning in science and mathematics and found that these learning pages could not fulfill the needs of the students and recommended providing more materials on recent discoveries in science. Hassan (1985) studied the use of NCTB suggested teaching aids at the lower secondary level at Dhaka city schools. He found that most of the schools do not use NCTB suggested teaching aids. In most of the cases they do not use any teaching aids except the textbook.

Rana (2005) compared primary level science textbooks of NCTB with the education program of Bangladesh Rural Advancement Committee (BRAC), a NGO in Bangladesh. From the evaluation of both the textbooks with the help of the experts, he found that both the textbooks did not fulfill the criteria of good science textbooks. Bari (2007) conducted a study on utility of teaching aids developed by the Directorate of Environment to teach environmental science at the primary level and found that in most of the schools these teaching-aids were not available and those schools where these were available were not usable due to absence of
proper storage. The schools which are using it properly they found it very effective. Besides the above research, students at the IER have conducted some other studies such as causes of failure in examination in science subjects (Banu, 1993), suitability of primary science text materials (Bhuiya, 1990), determination of minimum continuum of biology at the secondary level (Das, 1984), problems of biology teaching at grades 9 and 10 (Khandakar, 1992) and comparison of achievement of girls in physical and biological science (Nahar, 1991).

WORK AMONG INDIGENOUS AND MARGINALIZED PEOPLE

There are indigenous people in Bangladesh: They are aborigines residing in the hilly areas of Chittagong, Mymensing, and Sylhet and are called Sauntal, Marma, Chakma. Being disadvantaged, they are largely deprived of education. Efforts are being made by the government agencies and NGOs to educate these tribal peoples. The schools situated in those areas teach science at the primary and lower secondary levels but at the secondary level, science education is taught as general science and teaching facilities for science-group students rarely exist. No special efforts have yet been taken to provide proper science education for students of these indigenous groups.

There are many children in this country who are disadvantaged and underprivileged. They get less opportunity to get education due to several reasons. Those who are enrolled in primary or secondary schools often drop out before completion. They are very poor and have to earn their livelihood from young. Some NGOs such as Proshika, BRAC and Under-privileged Children Education Program (UCEP) offer educational programs for out-of-school children and the students with incomplete schooling. BRAC and Proshika runs primary education program with science as a compulsory subject with the emphasis on environmental studies (science). The UCEP provides education up to lower secondary levels (grade 8) with more emphasis on S&T. After grade 8, these children are offered programs on technical trades such as automobile repair, knitting and sewing, printing, carpentry, electronics and electricity so that graduates can get a job and earn a livelihood.

According to the UCEP website (www.ucepbd.org), UCEP currently operates 43 integrated general & vocational schools (feeder schools) in urban slums of Dhaka, Chittagong, Khulna, Rajshahi, Sylhet, and Barisal. The feeder schools follow the curriculum and textbooks prescribed by NCTB incorporating basic elements of technical education and provide basic education up to grade 8. The prime objective of the Integrated General and Vocational Education (IGVE) curriculum is to prepare the students to follow a high quality of technical education. The service of UCEP is meant for the poor working children living in urban slums. The major work categories of such children are domestic servants, day labourers, factory workers, hawkers, shop-assistants, rag pickers and porters. The children of UCEP continue to work and earn while they attend school. UCEP schools operate three shifts a day, each of three hours duration. A child can choose a shift of his/her convenience. UCEP has a shortened school year and runs two
academic sessions in a calendar year, each of six months. So a child can complete
two grades in a given year and they complete up to grade 8 in four years. They take
six months of pre-technical schooling after completing grade 8. The UCEP schools
basically follow the NCTB curriculum both at primary and lower secondary level
in abridged form. Girls above the age of 10 and boys above 11 with diverse
abilities and backgrounds have access to UCEP schools but priority is given to
girls. General school graduates of UCEP schools are provided Technical Education
in 16 trades through its Technical Schools corresponds to the demand of the
employment market in the area where the school is located.

The Centre for Mass Education in Science (CMES), an NGO, is providing
training to marginalized rural youth (male and female) on science and technology
trades. These youths can earn their livelihood while they are learning. This
program is very popular among the youth because it provides meaningful education
for a vast member of young people, disadvantaged in various ways (Ibrahim,
2007). CMES provides an alternative and a flexible education program for the
young people from disadvantaged families of rural areas. This programme offers
diverse options through an integrated education, skill-training and profitable work
practice which helps skilled employment and self-employment. It also gives
exposure to new opportunities and new technology leading to immediate income
generation. The skill training of CMES ranged from simple soap making, candle
making and carpentry to small scale scientific poultry farms and solar electrification
and computer use. All the traditional artisan and technical trades were brought
within the reach and practices of the people at the grassroots. This NGO has trained
many village girls who were married as young as 12 or 13 and helped them to
escape poverty by getting some education and becoming a family asset by earning
some money (Ibrahim, 2007).

SOCIO-CULTURAL AND POLITICO-ECONOMIC ISSUES

There is a large gap between the enrolment of science students at the urban and
rural secondary schools and colleges. The enrolment of science students in the
secondary level of Bangladesh is about 26% but this enrolment is only about 15% at
the rural secondary schools. These percentages at the higher secondary level are
between 20% and less than 10%, because most of the rural colleges do not offer
science due to lack of facilities such as laboratories, equipment, and qualified
teachers. In comparison to urban areas, there is a large gap in standards of science
teaching at the secondary and higher secondary levels in the rural areas due to low
enrolment, lack of facilities, and lack of qualified teachers. These gaps have to be
minimized. Efforts have been made through the development projects to bridge
this gap. About 3,800 secondary schools and 200 madrasas in the rural areas
were supplied with equipment, furniture, chemicals, books, and aids for science
teaching along with building of a science room in some schools where it was
absent. Nine Secondary Education and Science Development Centres (SESDC)
were established within the campuses of the nine Teachers’ Training Colleges for
impacting in-service training to secondary teachers. About 10,000 teachers every
year were given in-service training of two to three weeks duration in physical and biological sciences, mathematics, social science, and Bengali. Instructional materials in physical science, biological science and mathematics have also been prepared. These equipments were not effectively used by the teachers as they were not familiar with these equipment and they were not oriented with the use of these equipment.

There is a gender gap in the enrolment in the science-group both in urban and rural areas. These gaps are related to socio-cultural and economic problems and issues. The enrolment of girls in science-groups both at secondary and higher secondary levels are less than that of boys. The percentage of enrolment of girls in science group are 37.97% and 32.83% at the secondary and higher secondary level respectively. Special projects in terms of free tuition and the female student stipend project have been launched to increase female enrolment but no such project has been taken to enrol more girls in science. Therefore the development of the country is hindered much. We know that manpower with knowledge and skill of S&T is very essential for national development. Projects should be taken to increase girls’ participation in S&T education. Separate educational institutions of S&T education for girls may be established and more financial assistance should be given to female students in science. For the development of the country and to bridge the gap of digital divide with developed countries not only the females but also more males should be educated in S&T.

Science education is expensive in comparison to humanities and business education. Students have to pay more fees in terms of tuition, laboratory fees, and fees for private tuition or coaching. People think that science education is for rich people, not for poor. Therefore, poor parents feel discouraged in sending their children even if they are brilliant and meritorious to learn science. It is also found, with few exceptions, from the results of science students that students from rich families obtain better results. The former can spend more money on private coaching and notes, which the poor cannot do. In order to bridge this divide, special facilities in terms of stipends, scholarships, free tuition should be provided to poor meritorious students.

**Bridging Divides and Development Projects**

The digital divide is the difference or gap in electronic access to information with respect to difference of economics, race, ethnicity or social groups and geographical location. The digital divide is a great problem in Bangladesh. It not only exists between Bangladesh and other developed countries but digital divides exist within the country between rural and urban area, among the schools and colleges. Computer education is provided for students in top government and private schools and colleges with internet facilities. But many schools and colleges in the urban areas do not provide students computer education and internet facilities, and, of course, these are very rare in rural areas. A few schools and colleges in rural areas teaches computer as a subject with very limited facilities. There are no internet facilities in the rural schools and colleges. The Bangladesh
government has supplied computers to some secondary schools but that is not properly used for teaching due to lack of trained teachers in computer. It is used only for word processing and printing of some official letters and documents. Some intensive project should be launched for supplying computers to every school, training requisite number of teachers, and giving internet facilities where it is possible. Some people of remote areas are using internet services through mobile phones. It can be used for educational purpose. The teachers and students should be motivated to use this facility for bridging the digital divide.

The Bangladesh Atomic Energy Center in Dhaka for the first time installed a mainframe computer in 1964 for their research purpose. Bangladesh started to use Internet in 1993 and IP connectivity was established in 1996. Now the scenario of Internet usage in the country is changing rapidly and the national ICT policy has already been approved. Intel Corporation and MOE have agreed to work together to start information technology based education programs in the country. Intel and Grameen Solutions also agreed to set up telecentres to offer services to the public. Grameen CyberNet is trying to bring the Internet to rural villages. Grameen Communications has the intention to establish an e-education system that will reach rural villages in Bangladesh.

Problems associated with ICT applications in Bangladesh are inadequate ICT infrastructure support; lack of internet facilities; inadequate budget provision for ICT facilities; lack of reliable power supply, and so forth. To narrow the digital divide, the ICT policy should be implemented properly. The government should take steps to build the basic infrastructures and create ICT awareness in rural areas so that people at the grass root level can have access to education and knowledge through ICT. In brief, this is the situation of science education in Bangladesh. The Bangladeshi government and concerned authorities are taking different steps in terms of projects to improve science education and to make it more effective and meaningful.

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INTRODUCTION

As acknowledged by Treagust (2000) in his presidential address to members of the National Association for Research in Science Teaching (NARST), science education has become a growing international research domain. Recently, through a series of content analyses of the articles published in the three selected journals in science education—Science Education (SE), the Journal of Research in Science Teaching (JRST), and the International Journal of Science Education (IJSE)—Tsai and Wen (2005) explored the research trends in science education from 1998 to 2002. According to the results of their study, it was revealed that this area of research has progressively become an internationalized academic pursuit, providing some empirical evidence for Treagust’s (2000) message.

Abell and Lederman (2007) in their handbook on science education for the advancement of research in science education have advocated that the ultimate purpose of science education is the improvement of science teaching and learning throughout the world. From their perspective, a global understanding of science education research may be crucial. In the past, researchers from four English-speaking countries—the USA, UK, Australia, and Canada—have published a major proportion of the articles in SE, JRST, and IJSE, and their work has enriched our understanding of science education in English-speaking countries (Lee, Wu & Tsai, 2009; Tsai & Wen, 2005). A further understanding of science education research in other countries may therefore show us a way to what has been suggested by Abell and Lederman (2007).

According to Tsai and Wen (2005), authors from Taiwan have made impressive contributions to the global science education community during the years 1998 to 2002. For example, in these five years, Taiwan was one of the top ten countries contributing to all the three selected international journals of science education (i.e., SE, JRST, and IJSE). Besides, in 2002, excluding those from the USA, the UK, and Australia, authors from Taiwan contributed the greatest number of articles in these three journals. Therefore, the exploration of science education research conducted in Taiwan in recent years may broaden our understanding of science education research and provide us with some ideas of research trends in science education.

To provide deeper insights into recent science education research in Taiwan, this chapter reviews the publications of authors from Taiwan in selected international as well as local science education journals from 1998 to 2007. The research trends as observed from the content analysis were also compared to those of projects funded by the Taiwanese government (i.e., the National Science Council, Taiwan) during the same period. Finally, some major large-scale research projects conducted in recent years are also reviewed and discussed.
METHODOLOGY

Through content analyses, this study explores science education research in Taiwan from 1998 to 2007. There are two major components of data: Analyses of journal papers published by authors from Taiwan from 1998 to 2007 and analyses of funded projects by the Taiwanese government during the same period. In addition, two major large-scale research projects conducted in recent years were also reviewed and discussed. In this study, the research types, research topics, research methods, and the participants of the publications were categorized. Also, the citation statistics by Taiwanese authors were analyzed. Similarly, the research topics as well as the participants in the projects funded by the Taiwanese government were categorized. The research sample and the coding methods regarding the content analyses mentioned above are described as follows.

Research Papers and Funded Projects for Analyses

Among science researchers, Science Education (SE), the Journal of Research in Science Teaching (JRST), and the International Journal of Science Education (IJSE) have been recognized as three of the important international journals in the area of science education research. In this study, all of the papers published by authors from Taiwan in these three journals from 1998 to 2007 (ten years) were used as the research sample for the analyses of publications in international journals. A total of 73 papers were selected as the sample for this part of the analysis.

According to the analyses conducted by Chang, Chiou, and Lin (2002), two local journals in Taiwan, the Chinese Journal of Science Education (CJSE) and the Journal of National Taiwan Normal University: Mathematics & Science Education (JTNUE), have been recognized as significant local journals of science education. Thus, a total of 192 studies published in these two journals between 1998 and 2007 were selected and used as the research sample for the analyses of publications by authors from Taiwan in local journals.

In addition, this study reviewed the projects funded by the Taiwanese government during the period 1998 to 2007. According to the titles of funded projects listed on the website of the National Science Council of Taiwan, a total of 1,381 projects supported by the Council were chosen as the sample for this component of the analysis. Of these, two large-scale research projects conducted in recent years were selected for further discussion.

Coding Method for Analysis of Research Topics

The research topic of each published paper was allocated to one of the following nine categories: (1) Teacher Education; (2) Teaching; (3) Learning-conceptions; (4) Learning-context; (5) Goals and policy; (6) Culture, social, and gender issues; (7) History, philosophy, epistemology, and Nature of Science; (8) Educational technology, and, (9) Informal learning. These categories were mainly adapted
from the National Association for the Research in Science Teaching conference strand categories in the years 2000-2003, and are exactly the same as those used by Tsai and Wen (2005). Detailed descriptions of the nine categories are presented below:

- **Teacher education**: Preservice and continuing professional development of teachers; teacher education programs and policy; field experience; issues related to teacher education reform.
- **Teaching**: Teacher cognition; pedagogical knowledge and pedagogical content knowledge; forms of knowledge representation; exemplary teachers; teacher thinking; teaching behavior and strategies.
- **Learning-Students’ conceptions and conceptual change (Learning-conceptions)**: Methods for investigating student understanding; students’ alternative conceptions; instructional approaches for conceptual change; conceptual change in learners; conceptual development.
- **Learning-Classroom contexts and learner characteristics (Learning-context)**: Student motivation; learning environment; individual differences; reasoning; learning approaches; exceptionality; teacher-student interactions; peer interactions; laboratory environments; affective dimensions of science learning; cooperative learning; language, writing and discourse in learning; social, political, and economic factors.
- **Goals and policy, curriculum, evaluation, and assessment**: Curriculum development, change, implementation, dissemination and evaluation; social analysis of curriculum; alternative forms of assessment; teacher evaluation; educational measurement; identifying effective schools; curriculum policy and reform.
- **Cultural, social and gender issues**: Multicultural and bilingual issues; ethnic issues; gender issues; comparative studies; issues of diversity related to science teaching and learning.
- **History, philosophy, epistemology and Nature of Science**: Historical issues; philosophical issues; epistemological issues; ethical and moral issues; nature of science.
- **Educational technology**: Computers; interactive multimedia; video; integration of technology into teaching; learning and assessment involving the use of technology.
- **Informal Learning**: Science learning in informal contexts (e.g., museums, outdoor settings, etc.); public awareness of science.

**Coding Method for Analysis of Research Type**

The coding method for research type used by Tsai and Wen (2005) was also adopted in this study. In Tsai and Wen (2005), each published article was grouped into one of the following five categories: (1) empirical research article, such as quantitative or qualitative research; (2) position paper, that is, one holding a specific position on a certain issue; (3) theoretical paper, that is, proposing a new theory or framework; (4) review, that is, a paper summarizing the research
literature without proposing a strong position; and (5) others (e.g., a description of the science curricula of a specific country). The frequencies of each category were calculated for analysis.

**Coding Method for Analysis of Research Method**

According to its research method, each selected journal article in this study was allocated to one of the following three categories:

- **Quantitative research**: Only quantitative research methods were used in the study.
- **Qualitative research**: Only qualitative research methods were used for data collection and analyses in the study.
- **Mixed-methods research**: Both qualitative and quantitative research methods were used when conducting the research.

**Coding Method for the Participants**

According to the academic levels of the context in which each study was conducted, the research participants in each chosen journal paper were grouped into the following categories: (1) kindergarten; (2) elementary school (grades 1-6); (3) high school (grades 7-12); (4) university or college; (5) others, such as the participants of research regarding informal learning; (6) cross-sectional, that is, the context of research conducted was more than one of the aforementioned academic levels.

**Analyzing Citations of Papers Conducted by Authors from Taiwan in Selected International Journals**

In this study, citations of papers conducted by authors from Taiwan in SE, JRST, and IJSE during the period from 1998 to 2007 were examined. In the Social Sciences Citation Index (SSCI) database, some indicators of the quality of the articles published in a specific journal over a period of years, such as total papers published, total times cited, and average citations per paper, are available. Therefore, through using the SSCI database, the indicators of the quality of the journal papers published in SE, JRST, and IJSE from 1998 to 2007 (i.e., total papers published, total times cited, and average citations per paper) were calculated. Similarly, the total times cited and the average citations per paper of the 73 papers conducted by authors from Taiwan in these three journals from 1998 to 2007 were also calculated, and further compared with the indicators for all articles published in SE, JRST, and IJSE during 1998-2007.

**RESULTS AND DISCUSSION**

**Publications by Authors from Taiwan in Selected International Science Education Journals from 1998 to 2007**

In this study, all of the papers published by authors from Taiwan in SE, JRST, and IJSE from 1998 to 2007 were used as the research sample for the analyses. Table 1
presents the details of these publications. We see that during the five year period from 1998 to 2002, a total of 24 journal articles by authors from Taiwan were published in SE, JRST, and IJSE, while a total of 49 research papers were published during the years 2003 to 2007. This indicates that Taiwan has made impressive progress in science education research and has made an increasing contribution to the field of science education during the last decade. In Tsai and Wen (2005) it was found that, compared with SE and JRST, IJSE published relatively more papers written by authors from diverse non-English-speaking countries. Similar to the findings in Tsai and Wen (2005), Table 1 also reveals that, of the three journals, IJSE published the most articles written by authors from Taiwan (64%) during 1998 to 2007.

Table 1. Publications by authors from Taiwan in the three selected international journals (SE, JRST, and IJSE) from 1998-2007 (n=73).

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<td>Science Education (SE)</td>
<td>7 (29%)</td>
<td>10 (20%)</td>
<td>17 (24%)</td>
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<tr>
<td>Journal of Research in Science Teaching (JRST)</td>
<td>3 (13%)</td>
<td>6 (12%)</td>
<td>9 (12%)</td>
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<tr>
<td>International Journal of Science Education (IJSE)</td>
<td>14 (58%)</td>
<td>33 (67%)</td>
<td>47 (64%)</td>
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<tr>
<td>Total</td>
<td>24</td>
<td>49</td>
<td>73</td>
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Research Topics of Publications by Authors from Taiwan in Selected International Science Education Journals from 1998 to 2007

According to their research type, all the papers by authors from Taiwan in the three journals from 1998 to 2007 were categorized into nine categories: (1) Teacher education; (2) Teaching; (3) Learning-conceptions; (4) Learning-context; (5) Goals and policy; (6) Culture, social, and gender issues; (7) History, philosophy, epistemology, and Nature of Science; (8) Educational technology; and (9) Informal learning.

It was revealed in Table 2 that, during the first five year period from 1998 to 2002, most of the papers were concerned with “Learning-context” (33%), followed by “Learning-conceptions” (25%), “Teaching” (17%), and “Philosophy, history, Nature of Science” (17%). Similarly, during the following five years, most of the studies were regarding “Learning-context” (39%), followed by “Learning-conceptions” (35%), and “Philosophy, history, Nature of Science” (10%). During the full ten year period from 1998 to 2007, the top three research topics were “Learning-context” (37%), “Learning-conceptions” (31%), and “Philosophy, history, Nature of Science” (12%). This implies that researchers in Taiwan have been relatively recognized by the community of science educators for their research in these three areas of science education research.
Table 2. Research topics of publications by authors from Taiwan in the three selected international journals (SE, JRST, and IJSE) from 1998-2007.

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<tr>
<td>Teacher education</td>
<td>1 (4%)</td>
<td>1 (2%)</td>
<td>2 (3%)</td>
</tr>
<tr>
<td>Teaching</td>
<td>4 (17%)</td>
<td>2 (4%)</td>
<td>6 (8%)</td>
</tr>
<tr>
<td>Learning-conceptions</td>
<td>6 (25%)</td>
<td>17 (35%)</td>
<td>23 (31%)</td>
</tr>
<tr>
<td>Learning-context</td>
<td>8 (33%)</td>
<td>19 (39%)</td>
<td>27 (37%)</td>
</tr>
<tr>
<td>Goals, policy, curriculum</td>
<td>0 (0%)</td>
<td>2 (4%)</td>
<td>2 (3%)</td>
</tr>
<tr>
<td>Culture, social and gender</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Philosophy, history, Nature of Science</td>
<td>4 (17%)</td>
<td>5 (10%)</td>
<td>9 (12%)</td>
</tr>
<tr>
<td>Educational technology</td>
<td>1 (4%)</td>
<td>3 (6%)</td>
<td>4 (6%)</td>
</tr>
<tr>
<td>Informal learning</td>
<td>0 (0%)</td>
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Research Types of Publications by Authors from Taiwan in Selected International Science Education Journals from 1998 to 2007

According to their research type, all the papers by authors from Taiwan in the three selected international journals between 1998 and 2007 were categorized into the following five categories: Empirical research article; position paper; theoretical paper; review, and, others. The results in Table 3 show that empirical studies were the major type of publication (92%) by authors from Taiwan during the last decade. Moreover, it should be noted that all the articles by authors from Taiwan in the three journals during the first five years were empirical studies, while some other types of journal papers (i.e., reviews and others) were published during the second five years, indicating a diversification in research during 1998 to 2007.

Table 3. Research types of publications by authors from Taiwan in the three selected international journals (SE, JRST, and IJSE) from 1998-2007.

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<thead>
<tr>
<th>Type</th>
<th>1998-2002 (n=24)</th>
<th>2003-2007 (n=49)</th>
<th>1998-2007 (n=73)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Empirical</td>
<td>24 (100%)</td>
<td>43 (88%)</td>
<td>67 (92%)</td>
</tr>
<tr>
<td>Position</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Theory</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Review</td>
<td>0 (0%)</td>
<td>4 (8%)</td>
<td>4 (5%)</td>
</tr>
<tr>
<td>Others</td>
<td>0 (0%)</td>
<td>2 (4%)</td>
<td>2 (3%)</td>
</tr>
</tbody>
</table>

Research Methods of Publications by Authors from Taiwan in Selected International Science Education Journals from 1998 to 2007

Table 4 reveals that, from 1998 to 2007, more than half of the publications (56%) by Taiwan authors in the three selected international journals were conducted both
SCIENCE EDUCATION RESEARCH IN TAIWAN

qualitatively and quantitatively (56%). Moreover, 25% of them were quantitative only studies, while 19% of them were qualitative only. It seems that various research methods have been used by science education researchers in Taiwan during this period.

Table 4. Research methods of publications by authors from Taiwan in the three selected international journals (SE, JRST, and IJSE) from 1998-2007.

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Quantitative research</td>
<td>5 (21%)</td>
<td>13 (27%)</td>
<td>18 (25%)</td>
</tr>
<tr>
<td>Qualitative research</td>
<td>4 (17%)</td>
<td>10 (20%)</td>
<td>14 (19%)</td>
</tr>
<tr>
<td>Mixed-methods research</td>
<td>15 (62%)</td>
<td>26 (53%)</td>
<td>41 (56%)</td>
</tr>
</tbody>
</table>

Participants of Publications by Authors from Taiwan in Selected International Science Education Journals from 1998 to 2007

As revealed in Table 5, during 1998 to 2007, most papers published in SE, JRST, and IJSE by authors from Taiwan involved research participants at high school levels (70%) followed by university or college levels (15%), and then cross-sectional studies (8%). However, it should be acknowledged that no cross-sectional study was published between 1998 and 2002. Table 5 also reveals that relatively more papers regarding elementary school science were published in 2003-2007 (8%) than in 1998-2002 (4%). The findings above seem to reveal that research educators may have shifted their focus from issues at high school level to other academic levels, such as university and elementary school. Moreover, more cross-sectional studies have been gradually conducted in the latter five years. This may be helpful in providing more integrated insights into science teaching and learning in Taiwan.

Table 5. Participants of publications by authors from Taiwan in the three selected international journals (SE, JRST, and IJSE) from 1998-2007.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Kindergarten</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Elementary school (grades 1-6)</td>
<td>1 (4%)</td>
<td>4 (8%)</td>
<td>5 (7%)</td>
</tr>
<tr>
<td>High school (grades 7-12)</td>
<td>20 (83%)</td>
<td>30 (63%)</td>
<td>50 (70%)</td>
</tr>
<tr>
<td>University or college</td>
<td>3 (13%)</td>
<td>8 (17%)</td>
<td>11 (15%)</td>
</tr>
<tr>
<td>Others</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Cross-sectional</td>
<td>0 (0%)</td>
<td>6 (12%)</td>
<td>6 (8%)</td>
</tr>
</tbody>
</table>

* The missing one is the review conducted by Tsai and Wen (2005).
Citations of Publications by Authors from Taiwan in Selected International Science Education Journals from 1998-2007

As mentioned above, citations of the papers by authors from Taiwan published in the three selected international journals between 1998 to 2007 were also examined in this study. By using the SSCI database, the total number of papers published, the total times cited, and average citations per paper were obtained (Table 6). Then, the total times cited and the average citations per paper of the 73 papers written by authors from Taiwan were calculated.

As shown in Table 6, the papers published by authors from Taiwan were cited 354 times up until August, 15, 2008. In addition, the average number of citations per paper of these published articles was 4.85. Compared with those of all papers in these journals, the average citations per paper of articles by authors from Taiwan was only lower than papers in JRST, and was in fact higher than the average for all papers in the other two journals (i.e., SE & IJSE), showing that the research being carried out by Taiwanese science educators is of high quality and impact.

Table 6. Comparisons of citations of publications by authors from Taiwan and three selected international journals (SE, JRST, and IJSE) from 1998-2007 (on August, 15, 2008).

<table>
<thead>
<tr>
<th></th>
<th>Total papers published</th>
<th>Total times cited</th>
<th>Average citations per paper</th>
</tr>
</thead>
<tbody>
<tr>
<td>SE</td>
<td>564</td>
<td>2664</td>
<td>4.72</td>
</tr>
<tr>
<td>JRST</td>
<td>588</td>
<td>4113</td>
<td>6.99</td>
</tr>
<tr>
<td>IJSE</td>
<td>834</td>
<td>3298</td>
<td>3.95</td>
</tr>
<tr>
<td>Publications by authors from Taiwan</td>
<td>73</td>
<td>354</td>
<td>4.85</td>
</tr>
</tbody>
</table>

Research Topics of Publications in Selected Local Science Education Journals from 1998 to 2007

In this study, 192 papers published between 1998 to 2007 in the two selected local science education research journals in Taiwan, the Chinese Journal of Science Education (CJSE) and the Journal of National Taiwan Normal University: Mathematics & Science Education (JTNUE), were analyzed, and the results are summarized in Table 7. We see that science education researchers in Taiwan have published journal papers covering diverse research topics in these two journals. Moreover, the top three research topics of the articles published during the five year period from 1998 to 2002 were “Learning-context” (33%), “Learning-conceptions” (19%), and “Teaching” (14%), while those published during the following five years were “Learning-conceptions” (34%), “Learning-context” (25%), and “Teacher education” (10%), showing that science education researchers in Taiwan have shifted their focus slightly during these ten years. In particular, they have shifted their research interest from studies regarding classroom contexts, learner characteristics, and teaching, to those concerned with student conceptions,
conceptual change, and teacher education. Moreover, the top three research topics of papers published in the two local journals in Taiwan during the full ten years were “Learning-contexts” (29%), “Learning-conceptions” (27%), and “Teaching” (10%).

Table 7. Research topics of publications in selected local science education journals from 1998 to 2007.

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Teacher education</td>
<td>9 (10%)</td>
<td>10 (10%)</td>
<td>19 (10%)</td>
</tr>
<tr>
<td>Teaching</td>
<td>13 (14%)</td>
<td>7 (7%)</td>
<td>20 (10%)</td>
</tr>
<tr>
<td>Learning-conception</td>
<td>17 (19%)</td>
<td>34 (34%)</td>
<td>51 (27%)</td>
</tr>
<tr>
<td>Learning-contexts</td>
<td>30 (33%)</td>
<td>25 (25%)</td>
<td>55 (29%)</td>
</tr>
<tr>
<td>Goals, policy, curriculum</td>
<td>6 (7%)</td>
<td>8 (8%)</td>
<td>14 (7%)</td>
</tr>
<tr>
<td>Culture, social and gender</td>
<td>3 (3%)</td>
<td>0 (0%)</td>
<td>3 (1%)</td>
</tr>
<tr>
<td>Philosophy, history, Nature of Science</td>
<td>4 (4%)</td>
<td>6 (6%)</td>
<td>10 (5%)</td>
</tr>
<tr>
<td>Educational technology</td>
<td>6 (7%)</td>
<td>7 (7%)</td>
<td>13 (7%)</td>
</tr>
<tr>
<td>Informal learning</td>
<td>3 (3%)</td>
<td>4 (3%)</td>
<td>7 (4%)</td>
</tr>
</tbody>
</table>

However, as mentioned earlier, the results in Table 2 reveal that the top three research topics of papers published by authors from Taiwan in SE, JRST, and IJSE during 1998 to 2007 were “Learning-context” (37%), “Learning-conceptions” (31%), and “Philosophy, history, Nature of Science” (12%). It seems that researchers interested in studies regarding “Philosophy, history, Nature of Science” in Taiwan may be more likely to submit their papers to international journals to share their research results with the wider community. Therefore, a relatively higher percentage of papers regarding in this category was published in the international journals than in the local journals.

Research Topics of Publications in Selected Local Science Education Journals from 1998 to 2007

The results in Table 8 show that most of the articles published in the two local journals in the ten years from 1998 to 2007 were empirical studies. The finding above is similar to the findings derived from Table 3 that empirical studies were the major research type of publications by authors from Taiwan in SE, JRST, and IJSE.


<table>
<thead>
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<tbody>
<tr>
<td>Empirical</td>
<td>84 (92%)</td>
<td>96 (96%)</td>
<td>180 (94%)</td>
</tr>
<tr>
<td>Position</td>
<td>5 (5%)</td>
<td>1 (1%)</td>
<td>6 (4%)</td>
</tr>
<tr>
<td>Theory</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Review</td>
<td>2 (3%)</td>
<td>1 (1%)</td>
<td>3 (2%)</td>
</tr>
<tr>
<td>Other</td>
<td>0 (0%)</td>
<td>3 (2%)</td>
<td>3 (2%)</td>
</tr>
</tbody>
</table>
Besides, it should be also noted that no theoretical research was published in Taiwan during this period. It seems that the next important step for science education research in Taiwan is to establish local theories regarding science teaching and learning.

Research Methods of Publications in Selected Local Science Education Journals from 1998 to 2007

According to Table 9, most of the articles published in the two selected local journals during 1998-2007 were conducted qualitatively (44%), followed by “mixed-methods research” (31%) and “quantitative research” (25%). However, the results above are very different from those in Table 4, revealing that, during this period, “mixed-methods research” was the dominant research method of the publications by author in Taiwan in the international journals, followed by “quantitative research” and “qualitative research”. This may be due to the fact that, to have qualitative research findings published in international journals, fluency in English writing is crucial. Coming from a non-English-speaking country, it is relatively difficult for authors in Taiwan to report their research findings in English. To share their research findings with the science education community, writing research articles in fluent English is a challenge that authors in Taiwan, like authors from other non-English-speaking countries, have no choice but to face.


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<tbody>
<tr>
<td>Quantitative research</td>
<td>20 (22%)</td>
<td>28 (27%)</td>
<td>48 (25%)</td>
</tr>
<tr>
<td>Qualitative research</td>
<td>43 (47%)</td>
<td>42 (42%)</td>
<td>85 (44%)</td>
</tr>
<tr>
<td>Mixed-methods research</td>
<td>28 (31%)</td>
<td>31 (31%)</td>
<td>59 (31%)</td>
</tr>
</tbody>
</table>

Participants of Publications in Selected Local Science Education Journals from 1998 to 2007

Table 10 reveals that “high school” (43%), “elementary school” (33%), and “university or college” (11%) were the top three categories of research participants in publications in the local journals from 1998 to 2007. Compared with the articles published in the three selected international journals, relatively more papers regarding science teaching and learning at elementary school level were published in the two selected local journals. Besides, researchers in Taiwan published fewer articles regarding science education at “university or college” level in local journals than they did in international journals during this ten year period.

Moreover, during 1998 to 2002, authors from Taiwan published most papers regarding science teaching and learning at “high school” levels (44%) in the selected local journals, followed by “elementary school” levels (29%), and “university and college” levels (13%), while during the period 2003-2007, the top three groups of participants were “high school” (38%), “elementary school” (35%), and “others” (12%). Some studies regarding early childhood science education...
(3%) were also published during these ten years. This implies that science educators in Taiwan have broadened the focus of their research to all academic levels as well as to informal learning settings during these ten years. This may be helpful for them to develop a more integrated and deeper understanding of science learning and teaching. Through the insights derived from science education research at all academic levels and in informal learning, integrated theories and models regarding science teaching and learning may be established in the future in Taiwan.


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<tr>
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</thead>
<tbody>
<tr>
<td>Elementary school (grade 1-6)</td>
<td>26 (29%)</td>
<td>35 (35%)</td>
<td>61 (33%)</td>
</tr>
<tr>
<td>High school (grade 7-12)</td>
<td>40 (44%)</td>
<td>38 (38%)</td>
<td>78 (43%)</td>
</tr>
<tr>
<td>University or college</td>
<td>12 (13%)</td>
<td>8 (8%)</td>
<td>20 (11%)</td>
</tr>
<tr>
<td>Other</td>
<td>3 (3%)</td>
<td>12 (12%)</td>
<td>15 (8%)</td>
</tr>
<tr>
<td>Cross-sectional</td>
<td>4 (4%)</td>
<td>2 (1%)</td>
<td>6 (3%)</td>
</tr>
</tbody>
</table>

Research Topics of Projects Funded by the Taiwanese government from 1998 to 2007

In this study, a series of content analyses of projects funded by the Taiwanese government (i.e., the National Science Council, Taiwan) during the years 1998 to 2007 was also conducted. A total of 1,381 projects supported by the National Science Council of Taiwan were analyzed. According to Table 11, the top three research topics of these projects from 1998 to 2002 were “Learning-conceptions” (25%), “Teaching” (18%), and “Learning-context” (17%), while most of the projects from 2003 to 2007 were concerned with “Learning-context” (21%), followed by “Learning-conceptions” (17%) and “Teacher education” (16%). Similar to the findings shown in Tables 2 and 7, Table 11 reveals that science researchers in Taiwan have shifted their research interest during the last decade.

Table 11. Research topics of projects funded by the Taiwanese government from 1998 to 2007.

<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Teaching</td>
<td>121 (18%)</td>
<td>61 (9%)</td>
<td>182 (13%)</td>
</tr>
<tr>
<td>Learning-conceptions</td>
<td>168 (25%)</td>
<td>122 (17%)</td>
<td>290 (21%)</td>
</tr>
<tr>
<td>Learning-context</td>
<td>113 (17%)</td>
<td>147 (21%)</td>
<td>260 (19%)</td>
</tr>
<tr>
<td>Goals, policy, curriculum</td>
<td>83 (12%)</td>
<td>100 (14%)</td>
<td>183 (13%)</td>
</tr>
<tr>
<td>Culture, social and gender</td>
<td>27 (5%)</td>
<td>41 (6%)</td>
<td>68 (5%)</td>
</tr>
<tr>
<td>Philosophy, history, Nature of Science</td>
<td>25 (3%)</td>
<td>28 (4%)</td>
<td>53 (4%)</td>
</tr>
<tr>
<td>Educational technology</td>
<td>25 (3%)</td>
<td>66 (9%)</td>
<td>91 (7%)</td>
</tr>
<tr>
<td>Informal learning</td>
<td>4 (1%)</td>
<td>27 (4%)</td>
<td>31 (2%)</td>
</tr>
</tbody>
</table>
Moreover, on the whole, most of the projects funded by the Taiwanese government during this ten year period investigated “Learning-conceptions” (21%), followed by “Learning-context” (19%) and “Teacher education” (16%). Similar to the results in Tables 2 and 7, “Learning-conceptions” and “Learning-context” were the top two research topics of the funded projects as well as of the publications in both the selected international and the selected local journals, indicating that science education research in Taiwan has focused on exploring student conceptions, conceptual change, classroom contexts, and learner characteristics, and has obtained fruitful outcomes in the last decade.

Participants of the Projects Funded by the Taiwanese government from 1998 to 2007

According to the titles of the funded projects listed on the website of the National Science Council of Taiwan, the participants of these projects were also examined. However, the participants of some funding projects could not be recognized merely from the titles listed. As shown in Table 12, of those that could be recognized, most were concerned with science education at high school levels (37%), followed by elementary school levels (33%) and “cross-sectional” (12%). This was similar to the findings derived from Tables 5 and 10, which showed that most articles published by authors from Taiwan in both the selected international and the selected local journals focused on science teaching and learning in high schools. Moreover, it was also found in Table 12 that some science educators in Taiwan have shifted their focus from issues of science education at high school levels to those at other academic levels, such as kindergarten, during the latter five years of the decade. As stated above, this will be helpful in providing more integrated insights into science teaching and learning in Taiwan.

<table>
<thead>
<tr>
<th>Table 12. Participants of projects funded by the Taiwanese government from 1998 to 2007.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elementary school (grade 1-6)</td>
</tr>
<tr>
<td>High school (grade 7-12)</td>
</tr>
<tr>
<td>University &amp; college</td>
</tr>
<tr>
<td>Others</td>
</tr>
<tr>
<td>Cross-sectional</td>
</tr>
<tr>
<td>Unrecognized</td>
</tr>
</tbody>
</table>

Major Large-scale Research Projects Conducted in Taiwan from 1998 to 2007

As previously mentioned, science education research in Taiwan has focused on exploring two major categories of research during the period from 1998 to 2007, namely “Learning-conceptions” concerned with student conceptions and conceptual
change, and “Learning-context” such as classroom contexts, and learner characteristics. Some large-scale research projects regarding these two topics were conducted and have obtained fruitful outcomes in Taiwan during this period.

During the years 1996 to 1998 and the years 2001 to 2003, a cross-national research project in Taiwan and Australia was conducted. This project aimed to explore the similarities and differences between science learners in Taiwan and Australia in terms of some important issues regarding “Learning-context” such as learning environments, teacher communication behavior in science classrooms, student perceptions, and student cooperation. The project obtained fruitful outcomes. For example, several instruments for assessing classroom contexts were developed (e.g., She & Fisher, 2000; Tuan, Chang, Wang, & Treagust, 2000). Also, some important findings have been published in the international journals of science education (e.g., Aldridge, Fraser, Taylor, & Chen, 2000; Wallace & Chou, 2001). It seems that science education researchers in Taiwan have recognized the importance of cooperation with researchers from other countries and are willing to share their research findings with the global community of science educators.

Moreover, a national project for assessing students’ conceptual understanding in science was conducted in Taiwan between 2000 and 2003. This major project was designed to assess elementary, middle, and secondary students’ conceptual understandings in science. About 30 senior researchers and 80 research assistants were involved in this project (for a detailed description, please refer to Chiu, Guo, & Treagust, 2007). In general, the results of Taiwanese students’ conceptions in science are similar to those of students from western countries, but some aspects of our students’ performance are unique with respect to their Taiwanese culture and language. This cross-sectional research may provide a strong basis for constructing local theories or models for representing student conceptual understanding in Taiwan and are also be helpful for science teacher education and professional development in Taiwan.

SUMMARY AND CONCLUSIONS

This study aims to provide deeper insights into science education research in Taiwan during the period from 1998 to 2007. To this end, this study reviewed the publications conducted by authors from Taiwan in selected international and local science education journals as well as projects funded by the Taiwanese government during that period. Besides, two major large-scale research projects conducted in Taiwan in recent years were also reviewed.

The findings derived from the content analyses of the publications and the funded projects revealed some trends in science education research in Taiwan. It was revealed that the topics favored by researchers in Taiwan have gradually shifted from “Learning-conceptions” and “Learning-context” to others such as “Teacher education” during the last decade. Science educators in Taiwan have also
become more willing to publish different types of research, such as reviews, in the last decade. Although Taiwanese researchers have continuing concerns with high school science education, some of them have also shifted their focus to other academic levels. Through analyses of citations of articles by authors from Taiwan in SE, JRST, and IJSE, it was found that their papers were of high quality and impact. The findings above provide us with some evidence not only of the abundant outcomes of science education research in Taiwan, but also of the vitality of this research. Undoubtedly, the National Science Council of Taiwan has played an important role in promoting the internationalization of research in science education in Taiwan over the last two decades. Since 2003, the National Science Council of Taiwan has also sponsored an international journal in science education, the *International Journal of Science and Mathematics Education* (IJSME). The journal has published many quality papers by the authors around the world (Lee, 2008; Lin, Yore & Yore, 2007).

In addition, researchers may also be interested in the future of science education research in Taiwan. The research proposals solicited from the website of the National Science Council of Taiwan in recent years offer some clues about future directions. Recently, the National Science Council of Taiwan has solicited research proposals in informal science learning and public understanding of science and technology. It implies that, based on abundant research outcomes regarding science learning in formal contexts (i.e., school science), improving citizens’ scientific literacy in Taiwan is now a new focal area. As a result, more and more research regarding informal science learning will be funded. That is, researchers in Taiwan will be encouraged to extend their research scope on science education from formal contexts to informal contexts and it is likely that more research articles regarding informal science learning in Taiwan may be published in international journals in the next five years. In addition, with the rapid development of neuroscience, how to apply the findings of neuroscientific work to science education has also been highlighted by the National Science Council of Taiwan. Relevant proposals have been also solicited in the recent years, and some researchers in Taiwan have tried to re-examine student science learning from these perspectives. For example, they have tried to investigate learners’ reasoning and conceptual change using eye tracking, a common instrument used in neuroscience research. Functional magnetic resonance imaging (fMRI) has also been used in some pioneering science education research in Taiwan. Indeed, a large gap still exists between the research findings in neuroscience and their applications to science teaching and learning. However, we still believe that, with ongoing endeavor, a breakthrough may be found in this line of research by researchers in Taiwan in the future.

Moreover, a large special interest group regarding technology enhanced science learning has been formed recently. With this special interest group, many researchers with science education or educational technology backgrounds have met and held regular discussions to integrate their research and find some issues for cooperation. Undoubtedly, research in technology enhanced science learning in Taiwan will likely flourish and be fruitful in the next five years.
Abell and Lederman (2007), in their handbook on science education for the advancement of research in science education, have advocated that the ultimate purpose of science education is the improvement of science teaching and learning throughout the world. The findings of this study not only provide us with the research trends in science education, but also with some possible ways to achieve what these authors have advocated. As researchers, science educators should try to broaden their research topics, research types, and research methods, and more cross-sectional studies should be conducted. Thus, they can construct local theories or models regarding science teaching and learning so that the learning outcomes of science learners, and science teacher education and professional development may be improved. Then, they should try to share their local research findings with the global science education community and try to cooperate with researchers from other countries or different cultures. In other words, science educators should try to publish local research findings in international journals and conduct cross-national or cross-cultural research. Science education research in Taiwan may be a good example for the development of such research in other non-English-speaking countries.

REFERENCES


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