Chapter 1
Status of Chinese Science Education Reforms: Policies and Development Framework

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K-12 basic education in China is largely a system of public education run by the Ministry of Education (MOE). All citizens in most provinces and districts of the country must attend school for at least 9 years, which is known as "nine-year compulsory education" including 6 years of primary education, starting at age 6, and 3 years of junior secondary education for ages 12–14. Education at the kindergarten level in China has not been fully developed, and the enrollment rate was only 56.6 % in 2010 according to the MOE (2014a). So the term "basic education" in China normally means Grades 1–12 rather than K-12. After compulsory education, students can go to either a senior secondary school for 3 years or a technical school for 2–3 years. The Ministry of Education reported an attendance rate of more than 99 % for primary schools and 80 % for primary and junior secondary schools combined. The gross enrollment ratio for higher education reached 34 % in 2013 (MOE 2014b).

In 2013, there were 213,500 primary schools with 93,605,500 pupils and 5,584,600 full-time teachers in China. The pupil-teacher ratio, including part-time teachers, was 16.76:1. At the secondary education level, there were 52,800 schools with 44,412,900 students and 3,481,000 full-time teachers. The student-teacher ratio was 13.59:1. The entrance examinations for higher education and senior secondary education as well are very competitive. The examination for higher education had been held by the Ministry of Education as a national uniform exam until 2000, when various provincial examination authorities took the place of the

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central government (Zhen and Yang 2003). At present, a more differentiated examination scheme has been applied in the city of Shanghai and Zhejiang Province as a pilot project of the central government aiming at further nationwide promotion in the near future (State Council of China 2014).

Current policies and practices in Chinese education reform can be directly traced back to the historic National Conference of Science and Technology held in 1978. Several months before the conference, Deng Xiaoping, the "chief designer" of the great national reform, had proclaimed that ideological arguments could not help the country realize modernization; knowledge and talents were needed, and an atmosphere of respecting the knowledge and talents in the Communist Party must be built up (Deng 1977). So for preparing the historic national conference, he hosted the National Symposium of Science and Education Development, and dozens of well-known scientists and scholars, some of whom were still treated as "class enemies" or even criminals at that time, were invited by him to attend the symposium. distinguished educator, Mogeng Liu, an alumnus of Tsinghua and determinant talk to the scientists and scholars on reconstructing the national systems of sciences, technology, and education in order to enhance the quality and academic atmosphere in educational and research institutions. He declared that science and technology modernization was the foundation for modernization of all other sectors in China. This instrumentalist policy had dominated almost all sectors of science education until the eve of the new century when the phrases like "quality education" and "children centered" emerged in policy documents. This chapter will review the process of the reform and development of science education in the past few decades in six areas, covering both practical and infrastructural domains: school science education, preservice and in-service science teacher training, the national evaluation system, research in science education, the administrative structure of the science curriculum and textbook compiling, and informal science education. In particular, the underlying policies, consequences, and challenges encountered will be discussed, and suggestions for further research will be provided.

1.1 School Science Education

The development of school science education together with the overall education enterprise in China can be divided into three stages from the end of the Cultural Revolution: the Recovery stage from 1977 to 1985, the Transformation stage from 1985 to 2001, and the Fast Development stage from 2001 to 2013, the eve of the Third Plenary Session of the Eighteenth Congress of the Communist Party of China, which constitutes a milestone for a new era in the country. The transition within these stages is manifest in three historic documents: the *Decision for Educational Infrastructure Reform* issued by the Central Committee of the Communist Party of China ([CCCPC] 1985), the *Outlines for Curriculum Reform in Elementary and Secondary Education* (*Trial Version*, hereafter referred to as *Outlines*) issued by the

MOE (2001a), and the *Decision on Several Major Issues for Deepening the Reform* (CCCPC 2013), which was approved by the Third Plenary Session.

The earliest academic articles that formally applied the concept "scientific literacy" in Chinese curriculum reforms were in the 1990s (e.g., Zhong 1997). "Scientific literacy" was very often interpreted as the combination of (a) the knowledge of science, (b) the investigative nature of science, (c) science as a way of knowing, and (d) the interaction of science, technology, and society (Chiappetta et al. 1991; Bybee 1997). Since then, the objectives prescribed in the national curriculum at all levels have included three dimensions: knowledge and skills, processes and methods, and emotions, attitudes, and values. However, this new concept of science, together with its accompanying educational theories and administrative infrastructure, has encountered many challenges in the Chinese education system during the past decades at all levels and sectors.

1.1.1 Science Education in Primary Schools

The science curriculum "Nature" in primary schools was resumed in 1981 (MOE 1981) soon after the 10-year turbulence of the Cultural Revolution, during which the course "Common Sense" was taught with contents directly related to industrial and agricultural activities (e.g., how to grow rice plants). The objectives of the new science curriculum that was formulated by the Committee of Education of China (1992), the precedent of MOE, moved away from learning sheer technological skills and factual knowledge to scientific literacy, including attitudes toward observations, communication skills for scientific exploration, and the understanding of the relationships among science, technology, and society (STS, Li 1989), which was the pervading theory in Western countries. Chinese scholars and teachers worked hard to assimilate and accommodate the modern curricular ideas and teaching methods into their teaching practice. One distinguished educator, Mogeng Liu, an alumnus of Tsinghua University, had achieved great success using an instructional design that helped develop pupils' competence in observation, discovery, and investigation (Liu 1998). However, most teachers found it difficult to apply or even understand these modern theories in regard to the loose connections among STS in contemporary China. Classroom teaching remained largely focused on factual knowledge and the rote learning style aimed for passing examinations.

This preliminary reform was significantly accelerated by the authoritative document *Decisions on Deepening the Reform and Promoting the Quality Education* (*Quality Education* hereafter) issued jointly by the CCCPC and the State Council in 1999. The phrase "quality education" as a signal of a new revolutionary change in educational aims meant to take an opposite direction from the traditional "examination-oriented education," the real portrayal of Chinese education practice in the past.

As the new century approached, the nation's target for building a knowledge-based economy became more urgent especially under the pressure of the upcoming

2001 entrance into the World Trade Organization. In particular, accompanied with the ambitious call by the central government for building world-class universities at higher education level, curriculum reforms at all levels of education were required to be reconstructed in order to cultivate student's creative ability. As a result, a national expert board then was assembled by the MOE in order to execute the task of curriculum revision at the primary and the secondary education levels. The board had worked for more than 2 years to complete the *Outlines* document which was issued in 2001. The document clearly set up six goals for a new national curriculum across all school subjects: (a) paying attention to children's attitude toward learning instead of factual knowledge transmission; (b) paying more attention to the integrative nature of knowledge, rather than the current segregated structure of curricula, and designing a coherent system throughout the 9 years of the compulsory education period (i.e., years 1–9); (c) strengthening the connection between teaching content and real lives of children; (d) paying attention to the inquiry process of learning in order to cultivate competence in obtaining and retrieving information and analyzing and solving problems and in order to develop communication and cooperation skills; (e) encouraging formative evaluation in order to facilitate children's learning and teachers' professional development instead of focusing on selecting or ranking students; and, finally, (f) changing the centralized curriculum administrative structure into a "national-local-school," three-part consortium model in order to tailor the curriculum to the needs and characteristics of districts and their schools.

Under this general education reform policy, the *National Science Curriculum Standards for the Full-Time Compulsory Education* (*Grades 3–6*) (*Trial Version*) was issued almost at the same time by the MOE (2001b). The importance of this new official document lies not only in changing the title of the curriculum from "Nature" to "Science" and sketching the national curriculum standard but also in raising the status of the subject with a heightened science educational aim: "Science courses in primary schools aim to improve the scientific literacy of children" (MOE 2001b, p. 1). Moreover, this broad aim was broken down into concrete domains of objectives: "scientific inquiry process, the attitude and value towards science, and scientific knowledge" (MOE 2001b, p. 3–4). Eventually, the first *National Science Curriculum Standards for the Full-Time Compulsory Education* (*Grades 3–6*) (*Trial Version*) (MOE 2001b) was established to replace the Nature curriculum, which had been implemented for the previous 10 years.

Accordingly, a nationwide experiment for the new Science curriculum was set up in 2001 in 38 districts of 27 provinces and autonomous regions of China, or about 80 % of all provinces and autonomous regions. Four years after the experiment was initiated, all primary schoolchildren in Year 3 and above in China have had the new curriculum afterward. In 2007, organized by MOE, a meeting called "Second Session of Science Curriculum Standards Revision" was convened, and it proposed further that the Science course should be embodied in school curriculum from the very beginning of primary education, i.e., Year 1. Nowadays this desire has been fulfilled in most urban schools in China.

Generally speaking, Chinese science education at the primary school level in the new century has gone beyond factual knowledge learning. Today, modern theories of science learning have not only been written in the official documents and the national standard of science curriculum but also witnessed in some classroom activities (Wang 2010) such as inquiry learning and cooperative learning as framed by J. Dewey in his monograph entitled *Democracy and Education*. However, the inquiry activities following the prescribed steps in textbooks are often too ossified to adapt to individual students' backgrounds. As a result, classroom atmosphere tends to be either undemocratic or out of control. "Teachers talked too much," as a guest trainer from the USA commented during an in-service teacher training program carried out in Suzhou in 2010 when the first author of this article presented.

1.1.2 Science Education in Secondary Schools

Science education at the secondary level in China has a longer history than at the primary level, but with the same tradition of focusing on knowledge transmission. This inevitably resulted in most students perceiving science as too hard, boring, and irrelevant to their life (Shao 1991). This situation reached its peak during the Cultural Revolution when, for example, the physics course in senior secondary schools in an eastern coastal province even included nuclear physics.

Significant changes took place simultaneously at the secondary school level along with those at primary education level as described above. In fact, the national curriculum standard and the accompanying policy documents for primary education had their counterparts at the secondary education level. In addition to the standard for integrated science curriculum for students in Grades 7–9 (MOE 2001c), there were also a series of curriculum standards for all individual science subjects, including physics, chemistry, biology, and geography, at both junior and senior secondary school levels, which were published in the same year based on the instructional policies prescribed in the *Outlines*.

Although the policies and documents for reform were produced quite efficiently, the majority of teachers' understanding of and ability to implement these reforms took a long time. One big challenge science education reform faced at the secondary level was the traditional subject-based curriculum model. Dating back to the early twentieth century after John Dewey visited China, a kind of integrated science course was offered in junior secondary schools. But it soon returned to the single subject-based model for almost an entire century until the policy document *Outlines* was issued in 2001, encouraging a "move away from the separated nature of single subject-based curriculum through reducing the number of courses and teaching hours while adding a new integrated course to form a balanced, comprehensive curriculum, leaving more space for student choice" (MOE 2001a: p. 1). The integrated science course was resumed subsequently when the *National Science Curriculum Standard for the Full-Time Compulsory Education* (*Grades 7–9*) (*Trial*

Version) was issued in 2001 (MOE 2001c). Meanwhile, the US *National Science Education Standards* (National Research Council [NRC] 1996) and the series "Project 2061" were translated into Chinese.

Just as in primary education, the experiment for the new integrated science curriculum in secondary schools was carried out around 2001, and it encountered more challenges. The experiment was primarily carried out in four provinces (Hangzhou city in Zhejiang, Shenzhen city in Guangdong, Hubei, and Hunan) and one municipality (Shanghai)[1] but only Zhejiang has survived until today. Shenzhen and Shanghai, which are among the most developed cities in China, dropped out only a few years after the experiment commenced. The reasons were mainly poor curriculum resources, lack of qualified teachers, and poor teaching equipment in schools (Cai 2007). Moreover, many schoolteachers in the experimental districts explicitly opposed the reform (Yu 2003; Wang et al. 2007).

The astounding phenomenon of the Shanghai PISA 2009 does demonstrate great progress in Chinese education reform, especially in eastern coastal regions. In terms of the three subscales of reading literacy that were the main target of the year, access and retrieval, integration and interpretation, reflection and evaluation, Shanghai scored higher on the first subscale than the other two. In particular, in the "reflection and evaluation" subscale, which corresponds closely with scientific literacy, Shanghai scored the lowest (Shanghai Group of PISA 2013), as did some other Asian countries and districts (HKPISA Centre 2011). These findings are congruent with an earlier observation from the 2006 PISA, which had science as its focus subject, where it was found that children's self-conception of and confidence in science scores in Confucian Asian countries were lower than most other regions of the world (Ho 2009). Findings showing greater incidences in Chinese students of rote learning and surface learning and a lower development level of critical thinking and psychological well-being are numerous (Sun et al. 2010; Zhang 2010).

The most remarkable development of secondary science education in recent decades lies in the involvement of the integrative content of STS (science, technology, and society) as a component of the curriculum at both the integrated and individual subject levels. In classrooms, more hands-on activities and group work are assigned for students, although these phenomena appear mainly in some of the cities located in developed regions. The challenge resulting from the lack of qualified teachers will be elaborated more in subsequent sections.

[1] The three cities, Shanghai, Shenzhen, and Hangzhou (the capital of Zhejiang province), are in the top 10 of 2014 GDP city ranking in China. Hunan and Hubei provinces are also in the top 10 of the GDP ranking at the provincial level.

1.2 Science Teacher Education

1.2.1 Preservice Teacher Education

Most of the science teachers in primary schools in China graduated from teacher training schools with 2- to 3-year programs at the tertiary level that largely did not have a science major. This situation was changed in 2010 when all of the teacher training schools with 2-year programs have been required to upgrade to normal colleges offering 3- or 4-year programs (Gong 2000). According to a national survey conducted by the authors of this article in 2003 involving 1,737 teacher participants[2] from 21 provinces and autonomous regions, only 29.2 % of primary schoolteachers were graduates with science or math degrees; 16.8 % had Bachelor's degree or above (Zhang and Yu 2004). For longitudinal comparison, a follow-up national survey was taken in 2013 with 2,005 participants, which found that although the degree level rose enormously, in that Bachelor's or above degree holders now made up 61.7 %, the percentage of teachers in science or math degrees decreased to 21.2 % (Zhang et al. 2013).

Most teachers at secondary schools were educated at traditional normal colleges[3] for preservice teaching education where science discipline courses only constituted a part of the 4-year undergraduate program for science majors (Yan 2009). The programs typically utilized factual knowledge-centered curricula and rote learning or implanting teaching methods. In addition, science teacher education in China had been exclusively carried out in the form of separate science disciplines (Hao 2014), such as physics, chemistry, biology, and geography, until 2001 when the undergraduate major "Science Education" was established by the *Outlines* in selected normal colleges and universities (MOE 2001a, b, c). The number of such institutions is currently at least 66 (Zhang and He 2012).

The quality of the new major, however, was not as good as expected according to an investigation which was conducted in 2010 through interviewing 27 college senior students and 25 past graduates from six normal universities offering the program. The reasons identified mainly related to the quality of the educators (Zhang and He 2012). A very recent qualitative study on the undergraduates' views of the nature of science with a sample of normal university students revealed that most of the preservice students in science majors did not understand the concept of experiment, the objective nature of science, and the purpose of cooperation among scientists unless these concepts were transformed to the context of human relationships, which, as interpreted by the authors, shows the impact of the traditional Chinese philosophy of *Zhong Yong* (中庸) on the students' learning

[2] There were a total of 150,983 science teachers in primary schools in 2003, increasing to 173,505 in 2011, according to the website of CERNET (Chinese Educational Research Network): http://www.edu.cn/jcjy_9453/.2014,8,8.

[3] Today there are a total of 108 normal colleges and universities with strong teacher education commissions. Six of these are run by the Ministry of Education.

(Wan 2014). In Chinese academia, *Zhong Yong* can be generally interpreted as a school of dialectics paying emphasis on interpersonal relationship. It was also termed as "naive dialectics" by some Western scholars (Peng and Nisbett 1999).

Currently, preservice teacher education in China, including science teacher education sector, is largely conducted in the traditional normal colleges and universities where student teachers are assigned to individual science departments, where the first 2 or 3 years are devoted to subject-based learning and the last 1 or 2 years to pedagogical learning, which is called the "2 + 2" or "3 + 1" model (Yan 2009). This "normal college-based" teacher education system has been changing gradually since 1999 when the authoritative document *Quality Education* was issued. That was the first time China encouraged "institutions of all kinds of higher learning, including non-normal ones, to participate in teacher training enterprises and to set up educational departments in some of these institutions" (CCCPC and State Council of China 1999, p. 8). This policy was repeated in the *Educational Revitalization Action Plan 2003–2007*, issued by the MOE (2004), which focused primarily on developing western rural areas and the national lifelong education system. A few years later, the Ministry of Science and Technology (MST) (2007) also appealed to more institutions of higher learning and research academies to support and participate in the process of curricular reform, textbook compilation, and science teacher training through taking advantage of their own strengths. However, the implementation process for these policies was not a success. For example, in spite of the number of colleges and universities offering the integrated undergraduate major Science Education reaching 66 (MOE 2011a), only one of them, Southeast University, was a research-intensive university; its program leader was an academician and former Deputy Minister of the MOE who has made tremendous contributions to primary science education reform in the past decade.

1.2.2 Professional Development for In-Service Teachers

With the conditions in the preservice teacher education system as shown above, it is understandable that the quality of school science teachers constitutes a bottleneck in Chinese science education reform. This problem is more serious in science education than in any other subjects because the history of modern science education at any level dates back only 100 years. A recent survey of junior secondary school science teachers' view of the nature of science was conducted in Zhejiang Province with 222 teacher participants from ten countries or cities where the integrated science course had been implemented for about 20 years. The results showed that the teachers had difficulty understanding nature of science (Wu 2011). Another study using qualitative methods in the same districts corroborated these findings and called for more investigation into teachers' professional development programs in order to enhance their effectiveness (Wang 2010).

With regard to the serious shortage of qualified teachers of integrated science and the uneven distribution of educational resources across the vast country, a consensus was reached that the nationwide reform of science education must have nationwide scale programs for teacher training in order to support the reform (see Huang and Miao 2015). Therefore, in the *Outlines* it was proclaimed that "normal colleges and universities as well as other institutions of higher learning that participate in teacher training should adjust their programs, curriculum, and teaching methods to fit the new educational aims and targets. In-service teacher training programs should conform with the new policy, for which local governments should make a feasible and sustainable executive plan to ensure that teachers in the experimental schools are supported by the training programs" (MOE 2001a, b, c).

Consequently, the central government organized many kinds of in-service training programs. For example, a national project in 2003 for promoting the integrated science course at the junior secondary level, initiated by the MOE, targeted teachers' inquiry teaching ability. This project trained more than 500 schoolteachers and local curriculum administrators in ten sessions of the program from 2004 to 2007 (Zhang 2007). Another influential outcome of the project was the special science education website called "Xinhua Science Education" on the MOE's *Research for Teaching and Learning* website, which provides curriculum resources and a communication platform for teachers' professional development on the national scale.

Furthermore, in 2006 the State Council also called for cultivating a large number of highly qualified trainers for science teachers by issuing *Outlines of the National Scheme for Scientific Literacy* (*2006–2010–2020*) (State Council of China 2006). This document was the first one by the State Council specifically concerned with science education. It listed several programs entitled "Fundamental Engineering" which were to be implemented where training the trainers was to be the priority. Following this general policy, the MOE and the Ministry of Finance jointly initiated a "National Teacher Training Program" in 2010 on an unprecedented scale and effort, with a 550 million RMB annual budget from 2010 to 2012.[4] An example of the program is the immediate creation of two pioneer teacher training bases for science education at Guangxi Normal University and Southeast University.[5] Again, the latter was the sole research-intensive university that participated in this teacher training program.

However, the effectiveness of the training programs was not as great as anticipated, given that most of the trainers themselves had the same knowledge structure as their trainees (Ding 2000). In 2012, a national survey of 9,026 trainees and 298 trainers on the quality of the teacher training programs found out that the content of the training courses did not fit the trainees' needs, the teaching mode was mainly lecture, and the trainers themselves had not been adequately trained (Xue and Chen 2012).

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[4] National Teacher Training Program. http://www.gpjh.cn/cms/gygp/index.htm. Retrieved June 24, 2012.

[5] National Teacher Training Program. http://www.gpjh.cn/cms/gygp/index.htm. Retrieved June 24, 2012.

Teacher training was largely conducted in the traditional form of "expert lecture" for a large audience rather than class discussion or individual presentation in small classes (Bo 2011). Many trainees expect and even prefer, however, to deal with their learning difficulties by themselves after the lectures. This special large audience mode has been viewed as a powerful tool for accelerating the efficiency of large-scale training programs in a country with a large population but limited resources, which definitely needs further systematic research (Zhang 2003a, b). Inquiry learning activities have appeared in a few training bases, especially after the document *Some Suggestions for Strengthening Teacher Training Programs* was issued by the MOE (2011b). In very recent years, the use of digital learning as an educational technology has been changing the situation significantly as many online teacher training programs have been emerging at all levels from the central government to local administrative departments and teacher training institutions (Wu 2012).

Generally speaking, the two "outlines" documents, *The Outlines for Curriculum Reform in Elementary and Secondary Education* and *Outlines of the National Scheme for Scientific Literacy* (*2006–2010–2020*), have played the key role in promoting science teacher training in China in the past decades. These training programs have to date made a considerable impact on filling the huge personnel shortage of teachers and trainers for school science education regardless of its quality. Another up-to-date document by the State Council of China, *Outline of China's National Plan for Medium and Long-Term Education Reform and Development* (*2010–2020*) (2010), further proclaimed "to build up an open and flexible teacher education system with normal universities and colleges as the main platform, with comprehensive universities and the whole society participating and contributing in various forms."

1.3 Evaluation System

The educational evaluation system for national quality control of basic education in general and science education in particular in China is just at its starting stage. At the beginning of this new century, the Chinese educational assessment system was largely a pen-and-paper-based test system (He and Chen 2007) which was operated at the midterm and the end of term. Evaluation activities for school quality improvement were controlled by the central government through their agents in the provincial governments with commitments at the local levels. The data source for the evaluation was confined to schools with no participation from the outside society. The results of the evaluation were kept in the hands of the government with little information open to the public. The general logic of evaluation was that high scores meant good students, good students meant good teachers, and good teachers suggested good schools, which finally led to the conclusion of a good national education system (He and Chen 2007). Furthermore, the implicit presumption before conducting the evaluation was that the system could not be wrong.

Triggered by many international assessment programs such as PISA and TIMMS, the Center for National Assessment of Education Quality[6] (CNAEQ) was established by the MOE in September 2007, at Beijing Normal University. Although the staff of the center is largely scholars from the university, it is completely financed and directed by the central government. CNAEQ functions mainly as a data warehouse to service the central government that is monitoring the reform process and making new policies. It also acts as a coordinator to mediate its branch agencies normally affiliated with universities with strong teacher education traditions or local government agencies. Each branch is responsible for designing the student assessment instrument of a particular subject for certain age groups that is used for the nationwide survey beyond its local area. The constructs of the assessment tools for student learning have been prescribed by the CNAEQ as moral and citizenship literacy, physical and health level, literature and art literacy, and practical and creative ability, all of which have been approved by the MOE. The reality, however, is that the instruments are largely focused on how much knowledge students have remembered from their textbooks. The CNAEQ itself is responsible for designing the questionnaire used to survey teachers and principals nationwide, which is mainly concerned with the issues of the qualification of teachers and the facilities and conditions of education in their schools and affiliated local districts.

The national survey, charged by the CNAEQ, was conducted by the branch institutions responsible for collecting the data of their assigned subjects and age groups by the CNAEQ. The target of the surveys was once limited to the eastern area of China, at the beginning, and now has extended gradually to the inner part of the country in recent years. In 2012, it was reported on the center's website that in the subjects of science and math, the survey sample covered 271 counties[7] with 210,000 pupils[8] from 5,290 primary and secondary schools. In addition, about 5,290 principals and 53,000 teachers[9] of these subjects participated in the survey.

The feedback mechanism of the evaluation system has not yet been well constructed. The findings from the surveys cannot be found in public media; they often appear in oral reports at official conferences normally held in the capital city of a province. In those conferences, the staff from branches of the CNAEQ would report their findings largely in the form of average scores of the districts. The attendees of the conference are mainly local officers, principals, and teacher representatives who would not be permitted to access any specific information in

[6] Center for National Assessment of Education Quality http://www.eachina.org.cn/eac/index.htm

[7] There are more than 2,800 counties in China.

[8] There were about 140,000,000 students in primary and secondary schools in 2012 according to the website of CERNET (Chinese Educational Research Network): http://www.edu.cn/jcjy_9453/. 2014,8,8.

[9] There were about 870,000 teachers who taught math and sciences in 2012 according to the website of CERNET (Chinese Educational Research Network): http://www.edu.cn/jcjy_9453/. 2014,8,8.

written form. Specific results of the survey are also not available on the website of the CNAEQ.

Consequently, this agenda of education quality control for K-12 is restated in the new official document *Outline of China's National Plan for Medium and Long-Term Education Reform and Development* (*2010–2020*) (State Council of China 2010). As one of the targets of the national education infrastructural reconstruction, a multi-criteria evaluation mode has been called for to tailor curricula to the various abilities and needs of children and to serve the developmental educational objectives rather than the traditional competitive ones for selective purposes. The multi-criteria evaluation mode also encourages all interested parties to participate in the process of evaluation, including parents, local communities, and social organizations. In terms of science education in particular, the new multi-criteria instrument has just finished its pilot stage and is going to be applied full scale in late 2014.

China has entered a new era of reform of the whole society, including the education system, which is signified by the issuing of the landmark document from the central party authority at the end of 2013: *CPC Central Committee Decision on Several Major Issues for Deepening the Reform* (CCPCC 2013). The task in the new era will be to focus on promoting the administration-execution-evaluation "three-pipe-run" mechanism and expanding provincial governments' responsibility and raising schools' overall autonomy.

1.4 Research in Science Education

The paradigm of science education research in China had been based on separate subjects, such as physics education, chemistry education, etc., before the 1980s, with little attention to the comprehensive view of science and the cross-disciplinary nature of science education among learning science, philosophy, sociology, and so on (Liu 1988). Entering the 1980s, many scholars turned to massive translation work for introducing modern theories they could access from the developed countries. For example, the monograph *Teaching Elementary Science*: *Through Investigation and Colloquium* by Brenda Lansdown, a Professor of Science Education at Harvard University, was translated into Chinese. Based on her teaching in person in Chinese classes, she demonstrated in this book that Chinese children, like their counterparts in the USA, could initiate their own observation without previous instruction by their teachers only if the materials and equipment provided in front of them were well structured (Lansdown et al. 1983). Later, some classroom-based observations of Chinese educational practices started to appear in domestic educational journals, although they were rather primitive by international standards (Cai and Chen 2011; Hu 2007).

The traditional mode of Chinese academic study was the same as that for writing an argumentation article full of personal opinions (Zhang 2011). Modern science, as well as many other disciplines in universities being imported into China in the late nineteenth century, is incongruent with Chinese society in many aspects, including the conceptions of what knowledge is, how to generate new knowledge, and how to assess the reliability and validity of the knowledge generation process (Zhang 2010). This has unavoidably caused it to be difficult for most researchers to adapt to the Western empiricist paradigm, so the quality of the limited number of empirical studies is generally poor. In fact, the majority of empirical studies of science education published in recent Chinese journals were conducted by Master's degree students, suggesting a bright future in China. The limitations of these empirical studies are mainly associated with poor representative sampling and little consideration of threats to validities in data interpretation (Zhang and He 2012). In addition to the cultural factor influencing the paradigm of the research, some Chinese scholars pointed to the background of the researchers themselves, who were largely graduates from the traditional colleges with little training in conducting research or inquiry learning (Ding 2000).

In 2001, *Outlines* required major normal universities to set up national research centers for elementary and secondary education practice so as to actively take part in the ongoing curriculum reform (MOE 2001a). Consequently, eight national curriculum research centers were set up across the country, as shown in Table 1.1. In addition, some provincial research centers were also set up in institutions of higher learning by local governments. These centers have played a pioneering role in guiding school practice, training hundreds of teachers and graduates and promoting research quality in science education.

A unique contribution to the development of science education research in China was the "Learning by Doing" project adopted from France, which was jointly

Table 1.1 Eight national research centers and their missions[a]

The centers	Missions and focuses
1. Curriculum Research Center at Beijing Normal University	Evaluations of teacher professional development and student learning and textbook compilation for some subjects
2. Curriculum Research Center at Central China Normal University	Standard development for both the national curriculum and the "integrated practice" curriculum at the junior secondary level
3. Curriculum Research Center at Eastern China Normal University	Evaluation of curriculum development and policies, comparative and international education, and student development and learning science
4. Curriculum Research Center at Southern China Normal University	In-service teacher training and assessment of student learning at the senior secondary level
5. Curriculum Research Center at Northwestern China Normal University	In-service teacher training and school-based curriculum practice and research
6. Curriculum Research Center at Guangxi Normal University	Teacher professional development support and research for *Science for Grades 7–9*
7. Curriculum Research Center at Southwestern China Normal University	In-service teacher training and local school experiments for the new curriculum standard
8. Curriculum Research Center at Fujian Normal University	Information technology application in teaching and learning in schools

[a]The data in this table are mainly from the websites of the institutes

initiated and sponsored in 2001 by the MOE, the Chinese Academy of Science, and the Chinese Association of Science and Technology. The project was led by academician Yu Wei, who was a Deputy Minister of the MOE during 1990s, and involved hundreds of principals and teachers who have now become leaders of science education research and practice in Beijing, Shanghai, and Jiangsu provinces (Ye 2011). The project now is expanding to more provinces such as Jilin in northeastern China. Another influential project worthwhile to mention is the experimental research on the Science and Technology for Children (STC) curriculum for application in Chinese classrooms, which was originally developed by the Center of Science Resources in the USA. The experiment was approved by the Department of Basic Education of the MOE in 2006 and was carried out for 6 years in 20 classes in ten primary schools nationwide from Year 1 to Year 6. The project has trained hundreds of high-quality trainers with the help of professional trainers sent by the center and has published a series of materials in case studies.

At the end of the twentieth century, the ideas of postmodernism spread over Chinese research journals in the social sciences including education, which was coincident with the strong domestic conservative movement of antiscientific methods while upholding Confucianism. Paradoxically, this conservative antiscientific ideology embraced John Dewey's children-centered theory by assuming that Dewey was the founder of constructivism while neglecting the fact that Dewey was a founder of pragmatism and saw "science is a name for knowledge in its most characteristic form" (Dewey 2001, p. 196). This radical constructivism in China recapitulated the progressive movement that took place in the USA in the early twentieth century (Zhang 2005). One of the consequences can be demonstrated by the survey results conducted by Liang et al. (2008) that Chinese teachers possessed higher scores in views of nature of science assessment in most of the advance dimensions than their American counterparts except the most traditional one: "observation and inference." This kind of paradoxical phenomenon in non-Western countries like China may indicate that science education should follow an evolutionary course, so different countries with different development stage of science and the corresponding society should have different science education in terms of both curriculum and teaching methods, although the territory of science itself has no boundary between countries. Considering the fact that modern science did not originate from Chinese culture, Chinese education should place emphasis on the classical elements of science, such as the importance of observation and the objectivity of data collection, before incorporating any postmodernist thoughts into the curriculum (Zhang 2003c). Some Chinese researchers, therefore, raised the issue of curriculum localization for science education and argued that the most urgent task for Chinese researchers is to create "a true, relevant, and affordable science curriculum for Chinese children" (Wei 2008; Zhang 2002).

In order to prepare high-quality researchers for the future, doctoral programs in Science Education were established 4 years ago in a few top normal universities such as South China Normal University and Southwest University, although this is obviously far from sufficient for this vast country.

Another significant event for Chinese science education research was the foundation of the Chinese National Association for Science Education in November 2009, which is affiliated to the Chinese Society of Education. The association not only serves to provide a platform for academic research but also to improve the communication between practicing teachers and researchers. Just a few months after the founding ceremony, 14 science education research projects were listed as the Special Projects in the 2010 Scheme of National Educational Research, which was the first time science education research topics were included in this scheme in this country.

Generally speaking, the most significant improvement of the research community in recent decades has taken place in the domain of organizational construction rather than research conduct itself. Thus, there have not been sufficient numbers of researchers and expertise in China for either national science curriculum standard formation or textbook compilation. In addition, most of the scientists and professors in outstanding universities are rarely interested in these jobs (Ding and Luo 2005). Therefore, there has not been a special academic journal in the science education field in China to date. Nevertheless, some specific institutions (see Table 1.1) designated by the central government to be in charge of both research conduct and teacher training, like those in Beijing Normal University, Guangxi Normal University, and Southwest University, have indeed recently played a key role in the development of science education research in China. This "Confucian model" that emphasizes the organizational function over individual or local special needs has shown some strength at present (Marginson 2011). But its limitations will emerge as soon as the organization has been established, because unlike commercial activities, academic endeavors have to be developed in a scientific and democratic environment.

1.5 Administrative Structure of Curriculum and Textbook Development

The efficiency of the well-known government control model of modernization in Confucian Asia (Marginson 2011) can be clearly demonstrated by the development process of science education in China since 1949 when the Soviet Union's education system model was adopted by the new government of the People's Republic of China. The model ran efficiently until the end of 1950s when the diplomatic relationship between the two countries was broken. The first Nature curriculum was issued in 1956 uniformly for the entire country (MOE 1956). However, the revolutionary province-based curricula issued in place of the uniform national curriculum during the Cultural Revolution from 1966 to 1976 proved to be ineffective or even disastrous. Thus the priority of the education reform which commenced in 1978 was to rebuild the common national education curriculum.

This government control model was also adopted in research and teacher training domains in addition to the curriculum domain. The themes of research projects and the funding mechanism are controlled by the government at all administrative levels. Even international cooperative projects are also largely monitored by the government because many foreign organizations nowadays have been known to take advantage of the Chinese infrastructure so as to ensure the effectiveness of their projects. In particular, the National Institute of Education Research (including its publishing house) is directly controlled by the MOE and has played a key role in the process of education reform. For example, with funding from UNESCO, the institute convened a national symposium in Jiangsu Province in 1985 on Chinese science teachers' quality, and the STS program was initiated at this conference.

This administrative model also penetrated into the textbook compilation system, since the publishing houses were responsible for training their customers. In fact, before 2001 many training programs were assigned to certain publishing houses affiliated with the MOE or local governments. Even today, after being transformed into private commercial companies, publishing houses still rely strongly on the government because the latter decides which publishing companies are qualified to participate in projects of new textbook compilation and associated teacher training programs.

The government control model began to change in 1985 when the issue was addressed in the historic document *Decision for Educational Infrastructure Reform*. From that time on, the power of the central government gradually moved to provincial governments. For example, a province-based curriculum development project was initiated and experimented with in Zhejiang Province first and then Shanghai 3 years later. In 1989, the textbook compilation scheme was further changed from the original single set of textbooks designated by the MOE to a national-local collaboration model in a half-market system with several private publishing companies competing with each other.

This national-local collaborative model was further extended to that of a national-local-school one referred to as the "three-party consortium model" after the publication of the document *Decisions on Deepening the Reform and Promoting the Quality Education* in 1999 (CCCPC and SCC 1999). Provincial governments were empowered to make decision about when and how to execute the national curriculum or even make their own local curriculum programs. Schools were also empowered to develop or adopt a curriculum to fit their own strength, traditions, and special local needs.

The government control administrative model of curriculum and textbook development changed further after entering the new century, from prescribing curriculum and textbook contents to quality control on the basis of the national standard publication. The former government-nominated board for supervising textbook writing has been replaced by the textbook examination committee. As stated in the document *Outlines*, "All textbooks, including those following the national curriculum standard as well as local products, which are intended to be distributed to other provinces should be reviewed by the national textbook examination committee. Local texts should be reviewed by the provincial committee. In addition, the writers of textbooks should not serve as members of the committee taking part in the process of review.... A competitive bidding mechanism should be in place for textbook publication."

It has been legislated that the national curriculum standard at the top level of the curriculum administration system should play the key role in ensuring the right of children to receive compulsory education and in linking the different stages of education. Local governments should pay attention to local needs while implementing the national standard. Therefore, the space for schools to creatively implement the national and local governments' requirements has been enlarged. This school-based model has special value for science education with regard to the rationale that inquiry learning for children is best presented within the local environment where they live.

Generally speaking, the Chinese centralized power structure of curriculum and textbook development has been in the process of devolution. Another significant milestone in this progress is manifested by the open and transparent process of creating the new policy for the mid- and long-term reform framework from 2010 to 2020 (State Council of China 2010). For instance, the draft of the document was put in the Internet for public consultation. Although there is little in this document directly concerning science education specifically, the general policy orientation and the scientific and democratic attempts implicated by the process definitely allude to a bright future for science education development in China.

Indeed, China has entered into a new era of reform in all sectors of its society, including education, which has been signified by the 2013 issue of landmark document from the party central committee: *CPC Central Committee Decision on Several Major Issues for Deepening the Reform* (CCPCC 2013). The tasks and purposes in the document are sharply clarified. One task is further constructing the separation mechanism for the administration, execution, and evaluation processes. For this purpose, provincial governments' rights and the schools' overall autonomy will be expanded, and the social organizations for educational evaluation will be developed. Furthermore, social resources are being encouraged in the conduct of education.

1.6 Informal Science Education

Chinese informal science education originated at the end of the 1980s when a national pilot survey of public scientific literacy, organized by the Chinese Association of Science and Technology, was conducted by use of the common inventory issued by the International Society of Science Education. The formal National Survey of Scientific Literacy of the Public has been conducted at least eight times since 1992. Based on the alarmingly negative results from the survey, many arguments for acceleration science education inside and outside schools pervaded the media. A few years later, the first National Law of Science and Technology

Popularization in China was approved by the Chinese People's Congress in 2002 (State Council of China 2002), which was also a response to the national strategy of raising the country's power and sustainability via science and technology advancement. This indicated that the top leaders of the country had recognized that it was imperative to promote public scientific literacy in order to not only benefit economic health but also social welfare. The law outlined a framework for the responsibility of the government, the duties of related social organizations, and the measures to ensure the effectiveness of public science education. It also specified the objectives, contents, and approaches of the popularization task.

In terms of the administrative duties, the law requires that governments at all levels must make a great effort to popularize science and technology by including it into their regional plans of economic and social development so as to ensure adequate support conditions and environment. By defining the popularization as a benefit for all of society, the law requires all kinds of social institutions to take part in the endeavor, including schools of all types at all levels, institutions of scientific research and development, academic associations of all disciplines including natural and social sciences, and organizations in the medical and healthcare sectors.

These authoritative arrangements have special importance for present-day China, since the attention of the country has been largely paid to the economic function of science and technology, especially focusing on prestigious organizations of scientific research and technological innovation. Chinese scientists normally look down upon and hesitate to participate in popularizing work since it is of no importance in academic and personnel promotion evaluation, especially in research-intensive universities. Furthermore, 19 of the 21 scientist interviewed did not agree to include the work of popularization into the evaluation criteria for their research projects (Wang and Li 2010). They argued that conducting research to generate new knowledge was the primary duty of scientists or professors, for which there had been already too many hard evaluative criteria; scientists' work would be interrupted negatively if a new criterion of popularization was added into the evaluation system. This reveals that several generations of scientists in this country lack both a basic awareness of the humanistic function of science and a profound view of the relationship between science and social development, a deficiency which is embedded in the long historical roots of instrumentalism in the nation (Wu 2002).

The weak point of the science education system in China, as stated earlier, is the gap between normal universities and research-intensive universities (Wan and Zhang 2011). Moreover, the segregation also exists among the MOE, the Ministry of Science and Technology, and the National Science Foundation of China, since the latter two have nothing to do with the former or even the informal education endeavor. On the other hand, the MOE and its local educational authority subbranches have paid little attention to informal science education. Science popularization in China is a job solely assigned to the Association of Science and Technology at both the national and local levels. So, unlike the National Science Foundation in the USA, for example, requiring its funding applicants to clarify their methods to popularize research findings, the Chinese counterpart, the National

Natural Science Foundation of China, addresses little of this issue. Also, unlike many famous universities in the Western world that maintain their own museums or laboratories of science and technology which are open to the public, there is none in this country so far.

The current challenge is how to encourage more participation from various organizations in the academic and social sectors through establishing an effective collaboration mechanism among them. In the recent document, *Outline of China's National Plan for Medium and Long-Term Education Reform and Development*, the task of comprehensive universities' participation has been specified as one of their institutional duties: "Science popularization should be embraced as one of the duties of social service of all institutions of higher learning in order to promote the scientific literacy of the public along with their humanistic literacy." Very recently many associations of science and technology at the university level have been newly founded at certain top Chinese universities' campuses with solemn inaugural events. However, they seem to be treated as the same kind of routine activities that would happen whenever dealing with the brainstorm commands from the central government, so the members of the associations are almost the same as those in the senate of the university. The issue of the working mechanisms of those associations has not been taken into the agenda.

As the law is configured, it is important that the tasks and approaches of popularization go beyond the form of factual transmission of knowledge and should emphasize scientific methods, reasoning, and aspiration. However, there have not been clear and consensual conceptions among the experts such as museum curators and schoolteachers about what scientific reasoning is and how it is different from pseudoscience. In fact, pseudoscience has been persistent in public media and publications, which has tragically coincided with the radical postmodernist ideology that pervaded Western countries in past decades, and could be harmful to Chinese science education practice due to the nonscientific tradition of Chinese culture (Zhang 2003c).

Although the Law of Science and Technology Popularization had definitely brought about new perspectives and a promising future for the enterprise in this country, the mechanism for monitoring practicable approaches was not developed. Therefore, the State Council of China issued the *Outlines of the National Scheme for Scientific Literacy* (*2006–2010–2020*) (2006) which prescribed the main targets, contents, and means in the following 5, 10, and 15 years, respectively. More specifically, a series of key programs were promulgated via the document: Scientific Literacy Activity for Youth, Scientific Literacy Activity for Farmers, Scientific Literacy Activity for Citizens, and Scientific Literacy Activity for Public Servants. Related administrative measures for these key programs were then also described. For example, the financial and personnel support projects for the programs in the next 5 years were made clear through establishing a series of "engineering projects" including Science Education and Training Engineering, Resources Development and Sharing for Science Popularization, Media Empowerment for Science and Technology, and Infrastructure Building for Science Popularization. Very recently, a new education program specially tailored for a career in informal education at the master's degree level has been created jointly by the Chinese Association of Science and Technology and a few top universities mainly located in Beijing and Shanghai. The students in these programs will work in science parks and museums after their graduation.

These policies issued by the State Council seem to have had some effectiveness. For example, the TV programs about nature, science history, and the modern development of science and technology appear more frequently nowadays especially on Chinese Central Television. Some big research projects from the Ministry of Science and Technology leave space for science popularization. Local schools, universities, and other social organizations, however, have not fully understood their duties, for it is hard to see any substantial progress in popularization activity apart from numerous associations having been funded in a rush at university campuses, as mentioned earlier. Therefore, it is imperative for China to find a more practical resolution to encourage and combine every resource in the academic and civil world to break through the segregated administrative mechanism of policy formation. Of course, it would not be an easy endeavor in China because these persistent problems are caused by the dilemma that the ultimate goal of popularization is to overcome the unscientific traditions and habits of society from which the reform leaders themselves have benefited.

1.7 Conclusion and Suggestions

Generally speaking, Chinese science education reform and development in the past decades can be divided into three stages, Recovery (1977–1985), Transformation (1985–2001), and Fast Development (2001–2012), and now it has entered a new era of reform with "internal adjustment" as its focus (Table 1.2), as designated in the report of the Third Plenary Session of the Eighteenth Central Committee of the Communist Party held in 2013. In terms of school science education, it has experienced the common sense model in the early 1980s, and the later factual knowledge-centered model, and the current model with learning theories being implemented into classroom activities through enacting the policy of national curriculum standards. The infrastructure of the endeavor has also been reformed. Many professional organizations have been established recently, including the Chinese Association of Science Education and the Center for National Assessment of Education Quality. More fundamental changes also took place in the past decades. The intensive centralized administrative system established in the 1950s has been gradually changed, especially after entering the new century. The MOE that once controlled everything including curriculum development, teacher training programs, and textbook compilation now has limited its responsibilities only to accreditation and evaluation undertakings. The research paradigm of science education has also shown apparent progress in the past decade though the dominant style remains controversial.

Table 1.2 The stages of science education development in China

	Restoration (1977–1985)	Transformation (1985–2001)	Fast development (2001–2013)	Internal adjustment (2013–future)
Curriculum	"Common Sense" course in primary schools; factual knowledge-centered learning with rote method	"Nature" replaced "Common Sense"; modern learning theories and STS ideas were imported from abroad	"Science" replaced "Nature"; integrated science course at secondary schools, the series of national curriculum standards	The national curriculum standards are in the process of revision
Teacher education	"Normal college-based" teacher education system in separated subject-based teaching mode	The old system was changing slowly with "lesson study" or "expert lecturing" dominating for in-service training	Many national programs and institutions were set up in normal colleges and universities; online training programs flourished	The system of normal university domination with participation of other universities has been established
Evaluation	"Pen-and-paper" examination of rote learning		The national central CNAEQ was set up	More social organizations will participate
Administration	The central government control model	Dilution of the central government power	National-local-school, the three-party consortium model	Administration, execution, and evaluation will be separated
Research	Introducing modern learning theories mainly through translation work	Argumentative and comparative papers on how to reform education in China	Eight research centers and the national data bases were set up; primitive empirical studies appeared	More focus will be paid on "Chinese Issue" in order to search for the "Chinese Model"
Informal education	Spontaneous activities in spare time relying on individual interest of some writers and scientists		The first law of science and technology popularization was approved and followed by some professional organizations being founded	The increasing social crisis caused by low scientific literacy will push the business into a substantial development stage

The main challenges that reform encountered in past decades were related to an autocratic administrative system that might be more effective than a democratic system for early stages of a restoration and transformation characterized by massive adoption from developed countries, but may be problematic as soon as the fast development stage is entered, because only a democratic system can guarantee the creative production of policies that will fit the variety of needs of a vast country. Thus, reform has been going into a new era of directly challenging the administrative mechanism so as to build up a more democratic system.

The fundamental challenge for school science education practice is the stereotyped and authoritative conception of knowledge by teachers and researchers that is embedded in traditional Chinese culture. Chinese epistemology perceives knowledge as the permanent and transcendent truth which is inseparable from the human mind. This belief obstructs researchers and teachers from understanding the nature of science as well as related educational theories. Rote learning and implantation teaching styles, the traditional teacher training model, and the dominant rhetoric research style are the consequences of this culture.

Thus, how to design teacher training programs to help teachers in both the preservice and in-service domains change their innate beliefs about knowledge will be a fundamental task in the future, especially for the science education sector. Science education reform in China as well as in other developing countries should follow the evolutionary law rather than the revolutionary one by putting more emphasis on classic science concepts and beliefs before introducing postmodernist ideas of science. This argument, of course, should be treated as a fundamental research topic for researchers in China and abroad.

Given this unique Chinese situation, a balance should be cautiously kept between the more fashionable postmodernist model of science teachers' professional development and that of classic conceptions of science as an objective and truth-searching endeavor (Wang 2004). In this regard, the government should act once again as a strong leader to push professional scientists and research-led universities to join this great fundamental work for their beloved science.

In conclusion, science education in the world could be divided into two models. One might be called "Education for Creative Learning" and the other "Education for Massive Learning." Chinese science education largely belongs to the latter. The unique Chinese collectivist way of running education enterprises, which has been developed over thousands of years and proven appropriate to the condition of limited resources with a large population, has also been proven very powerful in modern times. This might also imply that the government-centered model is effective for popularizing science knowledge in a developing country in its early stage. However, this model might not work so effectively when the reform gets deeper. Therefore, Chinese science education development in the future should not rely solely on transforming the teacher education system by embracing research universities' manpower, but also on the whole nation's elevation of scientific literacy of the people and the democratic system of the government, which have been addressed specifically in the emerging historic document, *Decision on Several Major Issues for Deepening the Reform* by CPC Central Committee. Of course, all these issues would constitute research topics in the near future.

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