

## Chapter 2

# Science Education Research in Mainland China

Lei Wang, Yujun Zhu, Yanxia Jiang, Rui Wei, Yao Zhou,  
Yuying Guo, Xin Wei, Wenyuan Yang and Enshan Liu

**Abstract** Since the eighth curriculum reform of basic education started in 2001 in Mainland China, many changes and innovations have occurred in science education practice and research. This chapter presented the status of science education research (SER) in Mainland China. In order to provide an overview of SER, four Chinese core journals that focused on physics education, chemistry education, biology education, and geography education, respectively, were selected to review and analysis the papers in 2011 and 2012; the results showed the affiliation of researchers and research topics. Moreover, this chapter introduces SER in Mainland China from research fields such as curriculum and textbook, science teaching, science learning, teachers' professional development, scientific inquiry, and learning progressions and students' domain-specific cognitive development. In the research fields, the representative studies in physics, chemistry, and biology education were reviewed, because the SER in Mainland China is closely integrated with separate science subjects.

## 2.1 Introduction

In 2001, the eighth curriculum reform of basic education commenced in Mainland China, and the Ministry of Education of the People's Republic of China issued an educational document entitled *Guideline of Curriculum Reform for Basic Education (trial)*. After that, a series of curriculum standards and policy documents which were published included integrated science curriculum standards for primary and middle schools, individual subject (physics, chemistry, biology, and geography) curriculum standards for middle and high schools, *Outline of the National Action Scheme of Scientific Literacy for All Chinese Citizens* (2006–2010–2020), *The National Mid-and Long-term Education Reform and Development Framework* (2010–2020), and

---

L. Wang (✉) · Y. Zhu · Y. Jiang · R. Wei · Y. Zhou · Y. Guo · X. Wei · W. Yang · E. Liu  
Research Center of Science Education, Beijing Normal University, Beijing,  
People's Republic of China  
e-mail: wangleibnu@126.com

so on. The main goals of the reform were to improve Chinese citizens’ scientific literacy, build up human resources, enhance the country’s capacity for independent innovation, and realize the great rejuvenation of the Chinese nation; the reform opened a new chapter of science education in Mainland China. Over the past 10 years, science education researchers in Mainland China have had fruitful achievements, paid much attention to the trend of the development of international science education, and actively participated in the conferences of international science education.

Science education of Mainland China has provided a large number of science and engineering talents for the development of China and the world. In 2011, the number of papers in the SCI database, written by researchers from Mainland China, has been ranked second in the world, next only to the USA (Research Group of China scientific and Technical Papers Statistics and Analysis 2013). In PISA 2009 and PISA 2012, students from Shanghai won the first place twice. As such, the world has been paying more attention to Chinese science education and many studies on science education by scholars from Mainland China (Wang et al. 2012d; Sun et al. 2014; Zheng et al. 2014) have been published in mainstream international journals of science education.

Currently, all of the core science education academic journals in Mainland China are single-subject journals. Consequently, the studies on science education are mainly published in journals aimed at physics education, chemistry education, biology education, or geography education, respectively. In order to provide an overview of SER in Mainland China, the study reported in this chapter selected four Chinese core journals, namely *Physics Teacher* (PT), *Chinese Journal of Chemical Education* (CJCE), *Bulletin of Biology* (BB), and *Teaching Reference of Middle School Geography* (TRMSG), based on *The Guide to Chinese Core Journals*, consulted the experts in physics, chemistry, biology, and geography education, and reviewed the papers in selected journals in 2011 and 2012 by statistical analyses and content analyses.

The data of the selected journal papers were from the *Chinese Journal Full-text Database*. It included the title, author, organization of the author, publication name, key words, abstract, and the year published. Non-research papers, such as conference notices, test questions of contest, journal bulletin, and news of science and technology, were excluded. Table 2.1 presents the number of papers published in the selected journals, indicating that about 40 physics education papers, 29 chemistry education papers, 23 biology education papers, and 26 geography education papers were published per month from 2011 to 2012.

**Table 2.1** Number of papers in the selected journals in 2011 and 2012

Journal	Amount of papers		
	2011	2012	Total
PT (monthly)	490	460	950
CJCE (monthly)	359	338	697
BB (monthly)	288	263	551
TRMSG (monthly)	311	318	629

**Table 2.2** Papers by different organizations in the selected journals in 2011 and 2012

Journal	Papers from different organizations			
	University/college <i>n</i> (%)	Secondary school <i>n</i> (%)	Teaching research office <i>n</i> (%)	University/college and secondary school <i>n</i> (%)
PT	128 (13.5)	689 (72.5)	47 (4.9)	44 (4.6)
CJCE	319 (45.8)	329 (47.2)	46 (6.6)	82 (11.8)
BB	262 (47.5)	241 (43.8)	33 (6.0)	65 (11.8)
TRMSG	130 (20.7)	436 (69.3)	63 (10.0)	40 (6.4)

The authors of the papers published in the selected journals in 2011 and 2012 were mainly from universities or colleges, secondary schools, and teaching research offices which are set in provincial and municipal Commissions of Education. Table 2.2 presents papers according to the authors’ organizations, showing the number and percentage of papers whose authors’ organizations were university/college, secondary school, teaching research office, or both university/college and secondary school. The table indicates that the number of papers from universities/colleges and secondary schools is almost equivalent in chemistry education and biology education; papers from secondary school far outnumber papers from universities/colleges in physics education and geography education; papers from teaching research offices are relatively few; cooperation between university/college and secondary school in SER should be strengthened.

The research topics are divided into eight categories based on content analyses of the 2011 and 2012 papers in the selected journals. The number and percentage of papers in each category is shown in Table 2.3: (1) *Instruction* includes instructional design, instructional theories, instructional mode, classroom instructional record, and instructional reflection; (2) *Subject Knowledge* includes subject frontier knowledge, special topic knowledge, subject knowledge in context; (3) *Test Questions* includes development, adaption, analysis, and question solutions of college entrance examinations, senior high school entrance examinations, and contest examinations and exercises; (4) *Experiment teaching* includes experiment improvement, experiment design, experiment teaching theories; (5) *Curriculum and*

**Table 2.3** Research topics of papers in the selected journals in 2011 and 2012

Research topics	Journals				Rank
	PT <i>n</i> (%)	CJCE <i>n</i> (%)	BB <i>n</i> (%)	TRMSG <i>n</i> (%)	
Instruction	366 (38.5)	223 (32.0)	187 (33.9)	256 (40.1)	1
Subject knowledge	71 (7.5)	85 (12.2)	179 (32.5)	158 (25.1)	2
Test questions	296 (31.2)	24 (3.4)	27 (4.9)	126 (20.0)	3
Experiment teaching	164 (17.3)	166 (23.8)	127 (23.0)	9 (1.4)	4
Curriculum and teaching materials	21 (2.2)	61 (8.8)	11, (2.0)	34 (5.4)	5
Teacher education	16 (1.7)	52 (7.5)	4 (0.73)	32 (5.1)	6
Learning	12 (1.3)	62 (8.9)	2 (0.36)	4 (0.6)	7
Accomplishment evaluation	3 (0.32)	19 (2.7)	4 (0.73)	6 (0.95)	8

*Teaching Materials* includes curricula at home and abroad, curriculum resources, curriculum standards or programs, school-based courses, textbooks, and teaching materials; (6) *Teacher Education* includes professional development, training, and pedagogical content knowledge of preservice and in-service teachers; (7) *Learning* includes learning process, learning psychology, misconceptions or alternative conceptions, and learning ability of students; and (8) *Accomplishment Evaluation* includes development and application of evaluation scale and evaluation methods, and evaluation of students' accomplishment. Table 2.3 presents the number and percentage of papers published in the selected journals of 2011 and 2012 concerned in terms of the eight research topics, indicating that SER in Mainland China paid most attention to *Instruction*, followed by *Subject Knowledge*, *Test Questions*, *Experiment Teaching*, *Curriculum And Teaching Materials*, *Teacher Education*, *Learning*, and *Accomplishment Evaluation*.

In the following sections, SER in Mainland China is introduced in detail in six aspects—*curriculum and textbook*, *teaching*, *learning*, *teachers' professional development*, *scientific inquiry*, and *learning progression and students' domain-specific cognitive development*—with representative studies in physics (chemistry or biology) education, based on the review of literatures which are not limited to the journals mentioned above.

## 2.2 Curriculum and Textbook

Because of the eighth curriculum reform in basic education, *curriculum and textbook* became one of the hottest study fields in science education in Mainland China. The research topics included curriculum standard, curriculum philosophies and beliefs, analysis and comparison of textbooks, use of textbooks, evaluation of textbooks, and so on.

There were mainly two types of research on curriculum standards of science education: analytical and comparative, in which the main method was text analysis. The analytical studies aimed to give annotations for the contents in the curriculum standards of Mainland China and to provide references from other countries and regions to the curriculum reform in Mainland China. For example, Wang (2012b) elaborated overall exposition and concrete analysis of the basic thoughts and practical basis on the newly revised *Chemistry Curriculum Standard of Compulsory Education* which was issued by the Ministry of Education of the People's Republic of China in 2011. Curriculum standards from the following countries and regions were also analyzed: the USA, Malaysia, France, Australia, Canada, Britain, New Zealand, Singapore, Japan, Russia, Hong Kong, Macao, Taiwan, and so on.

The comparative studies on curriculum standards included the contrast between the 2011 version and the 2001 version of *Curriculum Standards of Compulsory Education*. For example, the characteristics of the new curriculum standards and inspirations for chemistry teaching in high schools were drawn (Wang and Wang 2012). Some researchers carried out a comparative study of Mainland China's and

other countries'/regions' curriculum standards. This research selected nine high school chemistry curriculum standards from America, Canada, France, Finland, Japan, Britain, Korea, Australia, and Taiwan and compared them with Mainland China's high school chemistry curriculum standards. The following six key terms were extracted from the comparison: *curriculum structure*, *learning progressions of chemical key concepts*, *breadth and depth of chemistry knowledge*, *capacity requirements*, *performance standards*, and *curriculum evaluation*. And the research summarized the common and forward-looking characteristics of the international curriculum standards. Feasible suggestions to problems on issues such as the selectivity of the school chemistry curriculum, the organization of the curriculum content and the selection of specific content, and the set of learning levels in Chinese chemistry curriculum were given (Wang et al. 2013a).

Based on literature analysis, international science curriculum comparison, and the tradition of local K-12 biology education, the committee of biology curriculum teaching standards summarized the philosophies and beliefs for middle school biology curriculum: (1) biology for all students, (2) promoting biology literacy of students, and (3) to advocate inquiry-based and active learning in the classroom (Liu and Wang 2012). Apart from the three beliefs outlined above, there is an additional one for high school biology curriculum—learning biology in real-life context. All of these beliefs are the guiding principles for selecting curriculum content and developing biology learning activities.

In the studies on analysis and comparison of textbooks, researchers commonly focused on the construction of textbooks, the difficulty and coverage of textbooks, and some specific topics (e.g., experiments, theories of sciences, history of sciences, key concepts, exercises), and important ideas in science education, such as scientific literacy, STS (Science, Technology and Society), and scientific inquiry. For example, there was the overall analysis of the current high school chemistry textbooks, based on the viewpoint of cultivating students' scientific literacy (Hu and Wang 2009; Zhi and Wang 2009; Wang et al. 2010a). These studies described unique connotations and values of the textbooks in developing the students' scientific literacy and analyzed systematically the organization of the curriculum content, selection of the specific content, column setting, and teaching function. The analysis and comparison of textbooks from the following countries and regions were also conducted: the USA, Malaysia, France, Australia, Canada, Britain, New Zealand, Singapore, Japan, Russia, Hong Kong, Macao, Taiwan, and so on. For example, the analysis of the core concepts, topic contents, and charts in the textbook *Chemistry: Concepts and Applications* from the USA and its comparison with other textbooks from other countries/regions were studied. It was also compared with three versions of high school textbooks in Mainland China, which were published by People's Education Press, Shandong Science and Technology Press, and Jiangsu Education Press (Huang and Wang 2010; Yang and Wang 2010; Jiang and Li 2011). And there were also some studies on the textbook *Advanced Chemistry* from the perspectives of basic concepts, basic theories, organization of its contents, and layout characteristics (Xing et al. 2011).

On how teachers/students use textbooks, Bi and Wan (2013a) made the investigations of middle school and high school chemistry teachers with the *Questionnaire on How Teachers Use Textbooks* and the students with the *Questionnaire on How Students Use Textbooks*. The questions in both questionnaires were corresponding, so as to evaluate the consistency between the teachers and the students. At the same time, interviews and classroom observations were used to supplement the information collected about the use of the textbooks. In order to inquire about what kind of textbooks the schools need, the researchers used the methods based on the Grounded Theory to analyze the collected information. Then, a further study (Bi and Wan 2013b) found that teachers, textbooks, students, curriculum resources, and the teaching management system were the five core factors that influence how the chemistry teachers used textbooks.

There were some studies on the evaluation of textbooks. Yang and Hu (2011) used the model of the Quantitative Analysis on the Curriculum Difficulty Degree to analyze and evaluate the degree of difficulty of textbooks. Ji and Bi (2010) used fuzzy comprehensive evaluation method to evaluate the quality of chemistry textbooks. Yan and Li (2012) used evaluation systems based on nature of science (NOS) which include “explicit naive, implicit naive, mixed, implicit informed, and explicit informed levels” to analyze the presentation mode of NOS in the textbooks published by Shandong Scientific and Technology Press, and found that textbooks mainly reached the explicit level of the integration between the scientific content and NOS. The difficulty of some physics content knowledge in textbooks was analyzed, such as relativity theory (Yin et al. 2010) and quantum theory (Zhong and Guo 2010). Niu and Li (2013) evaluated the consistency of the coverage, difficulty, and distribution of content knowledge in different curriculum standards and textbooks of physics. Lu and Liu (2012a) explored the consistency between the standards-based high school biology textbooks and high school biology curriculum standards with Porter’s alignment model. Yu and Zheng (2013) analyzed the structure of high school biology textbooks published by People’s Education Press with interpretive structural model (ISM) and introduced a practical method for analyzing the logical structure of a textbook.

## 2.3 Teaching

Research on science teaching in Mainland China mainly included topics such as basic science ideas, NOS, history and philosophy of science, inquiry-based teaching, classroom teaching behavior, evaluation of teaching, experiment teaching, and various teaching strategies/models.

Bi and Lu (2011) thought that the basic chemical ideas (BCI) refer to the students’ whole view of chemistry based on the deep understanding of the characteristics of chemistry, the BCI mainly include the ideas of chemical elements, particles, chemical change, chemistry experiment, classification and the values of chemistry, and so on, and BCI teaching can transform students’ learning style, promote the level of

understanding and application of chemical knowledge, and improve students' scientific literacy ultimately. Liang (2011a) thought that matter and its transformation are the basic questions of chemistry; therefore, the views on elements, energy, and NOS are the core chemical ideas. The effective teaching strategies of BCI included the following: teaching specific knowledge under the leadership of BCI; highlighting the thinking style of chemistry; mining the connotations of chemical knowledge; designing thought-provoking questions; and guiding students to explore, experience, and rethink (Bi and Cui 2011). Wang et al. (2008) constructed an instructional design model based on BCI and expounded how to conduct the instructional design based on BCI by using the case of "ionization balance."

The NOS-related studies included theoretical analysis and empirical investigation. For example, Zhou and Zheng (2010) discussed the basic situation of NOS education in Mainland China. Meng and Li (2011) explored the relationship between NOS and history of science (HOS) by taking the theory of ionization as an example and summarized the elements and principles of teaching with the use of chemistry history. The empirical investigations proved that the history and philosophy of science (HPS)-based teaching mode had an obvious influence in promoting the high school students' understanding of NOS (Yang et al. 2012). Yan (2009) used open-ended questionnaires, semi-structured interviews and group interviews, and structured text analysis to analyze the understanding levels and characteristics of high school students' views of NOS, and found both grade and gender had significant main effect on understanding NOS.

Inquiry-based teaching is advocated by the eighth curriculum reform in basic education in Mainland China, to change the traditional teacher-centered and lecture-based teaching approaches. As inquiry-based teaching/learning was new and challenging for most science teachers, it aroused researchers to study both theory and practice. For example, only in biology education, there were over 25,000 papers published between 2010 and 2013 when searching the key words "biology" and "inquiry" on the China National Knowledge Infrastructure (CNKI) Web site—the most influential Chinese academic database in Mainland China. All of these papers showed the research findings and practical reflections on inquiry-based teaching/learning of biology. Deng and Liu (2011) set up a school-based course *Refusing Alcohol* in a middle school in Beijing. This course was adopted from American BSCS supplementary courses and modified according to local situations. The whole course emphasized inquiry and was designed in accordance with the 5E instruction model. This empirical study indicated that the 5E model is an effective way to implement inquiry-based teaching/learning and showed a good example of applying the model. Fu and Liu (2013) developed a school-based course with resources from the network platform *Web-based Inquiry Science Environment* (WISE) established by the American organization *Technology Enhanced Learning in Science* (TELS). The entire course was also designed based on the 5E model and implemented in two middle schools in Beijing. After comparing the pretest and posttest scores of the experimental class, Fu and Liu found that students' understanding of biology concepts and ability to solve problems had improved significantly. Yang and Liu (2014) proposed a procedure of instructional design, *Starting*



*Your Lesson Planning from Key Concepts Focused Questions*, based on previous studies of inquiry-based learning, teaching for understanding, and “less but better.” This procedure is a guide for teachers to design student-centered teaching activities based on key concepts, so as to give students the opportunities of independent thinking and help them to deeply understand concepts. Besides, argument-driven inquiry (ADI) recently becomes an emerging topic in SER in Mainland China (He and Liu 2012).

On classroom teaching behavior, since 2003, a research team led by Changlong Zheng in Northeast Normal University has begun to study the classroom structure in secondary chemistry lessons. Using classroom observation and textual analysis in more than 900 chemistry lessons, they argued that “teaching behavior” and “learning behavior” happened simultaneously in real lessons rather than being isolated from each other, and they always came out as an Instruction Behavior Pairs (IBP). Based on this standpoint, they proposed two key concepts: Instruction Behavior Pairs (IBP) and Instruction Behavior Chain (IBC) (Lou and Zheng 2010b). From a huge number of classroom observations and statistical analyses, they found there were mainly five common models of the smallest IBCs in chemistry lessons. According to the degree of students’ classroom participation, the five models were defined as “Model of Teachers’ Direct Lecture” (MTDL), “Model of Teachers’ Self-Questioning (MTSQ),” “Model of Students’ Direct Response (MSDR),” “Model of Students’ Discussions and Exchange (MSDE),” and “Model of Students’ Self-Directed Learning (MSSDL)” (Zheng 2013). Another notable classroom teaching behavior on which research was based was about the characteristics which can promote students’ chemical domain-specific cognitive and reasoning mode development (Wang and Ren 2013). The research took into account the nature, characteristics, and requirements of the teaching which promotes students’ cognitive and reasoning mode development and the current studies on the classroom behavior observations in national and international studies. It also proposed that classroom teaching behaviors were divided into seven categories: asking questions by teachers, making use of students’ answers, explaining by teachers, modeling, making students’ thinking explicit, answering by students, and students’ activities and built a chemistry classroom teaching behavior model of promoting the development of students’ epistemic mode. In the study, two typical categories of lesson cases were selected based, respectively, on “analyzing knowledge” and “promoting students’ chemical domain-specific cognitive and reasoning mode development.” Then, the researchers coded the videos of the selected lessons in terms of the model of the teaching which promotes students’ cognitive and reasoning mode development and conducted quantitative analysis of the time and frequency of different teaching behaviors. The research showed that the most important teaching behaviors in the lessons in light of promoting students’ epistemic mode development were modeling and making students’ thinking explicit.

With respect to evaluation of teaching, there were two types of research. The first type was the construction of evaluation frameworks. Jiang (2013) developed an evaluation framework for the validity of inquiry-based teaching, reviewed existing study results, proposed the initial framework, then invited experts on physics



education from faculties, teaching personnel from schools, senior in-service physics teachers as consultants, and revised the initial framework to be a content validity-based evaluation framework. At last, a survey was conducted on students and teachers, and the internal reliability and content validity were tested and analyzed. In the second type of research, researchers proposed performance evaluation, progression evaluation, formative evaluation, motivated evaluation, and multiple approaches to conduct these evaluations. The implementation approaches included guided worksheets, open-ended writing, progression files, concept maps, and so on. Li (2012) explored the usage of performance evaluation through analyzing physics teachers' responses to a questionnaire, designed the procedures of performance evaluation used in laboratory teaching, and took "how to measure velocity" section as an example to demonstrate how the procedures were used in specific knowledge teaching.

The studies on experiment teaching are an important part of SER in Mainland China. The focus mainly included the following: the status of experiment teaching in schools, experimental projects and contents, and the use of new experimental technologies. For example, according to the articles published in *CJCE* from 2011 to 2012, the researchers investigated the present status of chemistry experiment teaching in secondary schools (CETSS) in some particular provinces (e.g., Hubei, Tianjin) and special areas (e.g., the Western rural areas, the earthquake areas) of Mainland China with questionnaire survey and text analysis. Numerous studies showed that the present situation of CETSS does not look good, and there are a lot of problems. It is common that teachers "just explain experiments orally," "just draw experiments on the blackboard," "just show experiments on the screen," and "just ask students to recite experiments," without doing real experiment demonstrations or letting students do experiments by themselves. Studies on the experimental projects and contents are the largest part of experiment teaching study. Many experiments set in textbooks were improved or redesigned by teachers to match the needs of specific contents teaching, such as catalytic oxidation of ammonia, verify the properties of the carbon dioxide, the reaction of sodium and water, ethanol dehydration to ethylene, hydrogen combustion in chlorine gas, and so on. This type of studies reflected the teaching creativity of teachers in CETSS. On new experimental technologies used in experiments, some researchers applied handheld technology to explore conductivity changes in aluminum hydroxide preparation experiment (Li and Qian 2012), and some explored the acetic acid ionization balance with handheld technology (Cui et al. 2011). Moreover, digital information system combined with various sensors was used to present the results of experiments with brief graphs, allow visualization of the process of chemical change, and help students to understand related concepts and contents.

Various teaching models, methods, and strategies were developed because of the eighth curriculum reform in basic education in Mainland China. For example, using "physics and teaching model/method/strategy" as key words, academic publications were searched in CSSCI, graduate students' dissertation data base and *Physics Teacher Journal*. The analysis on these publications showed that the number of publications was continually increasing from 2001 to 2013. Dozens of publications

on teaching models, methods, and strategies were found, such as the 5E model, modeling instruction, interactive teaching, peers' collaboration teaching, POE (Prediction, Observation, Explanation) teaching strategy, cognitive conflict-based teaching model, and scaffolding teaching model. These models/methods/strategies were developed based on the following four foundations: specific content knowledge, the orientations (e.g., problem solving, concept understanding, and experimental training) of different lessons, epistemological ideas of teaching, and different cognitive levels of students. Li and Wang (2013) used the 5E teaching model to develop teaching activities for "lever" concept in Grade 9, and the teaching procedure included five stages: inspiring students' interests, exploring, explaining, transferring, and evaluation. Constructivism and inquiry-based teaching ideas were employed mostly to develop teaching strategies/models.

## 2.4 Learning

This section focuses on science learning research in Mainland China, such as alternative conceptions, conceptual change, and academic achievements.

Qian and Li (2011) found that high school students had alternative conceptions in learning electrolyte solution which were attributed to: (1) students' limitations of thinking about quality; (2) interferences from related concepts; (3) influence of the factors, such as students' cognition, emotion, and motivation; and (4) the presentation of teachers' teaching and teaching materials. With the implications of the study above, two strategies for conceptual change teaching were put forward: One was to reinforce the practice and to increase students' perceptual knowledge and another was to encourage students to construct complete cognitive structure by independent inquiry. Zhang and Wang (2012) conducted a study to investigate middle school students' conceptions of acids/bases in different grades in Beijing and compared the results with those in Taiwan, so as to explore how curricula and instruction affected the conceptual development of students. Eleven secondary schools were selected in the study. The results indicated that students' conceptions of acids/bases in Beijing were different from those in Taiwan, and there were also differences in different schools in Beijing under the influence of core concept learning and the curricula. The conceptions and conceptual evolution were explained in light of students' epistemic development. Deng et al. (2011) found middle school students' different degrees of conceptual change when teachers used POE (Prediction, Observation, and Explanation) strategy and PDEODE (Prediction, Discussion, Explanation, Observation, Discussion, and Explanation) strategy in teaching "solution," compared the effects of the two strategies, and provided suggestions for teaching of conceptual changes.

Teaching beliefs, instructional materials, and teaching approaches have changed greatly in the K-12 education reform in Mainland China, which triggers corresponding reforms in the assessment of student learning achievements. So, many questions about student assessment were raised and followed up by corresponding studies, such as “whether the standardized test is aligned with national curriculum standards,” “what the status of students’ conceptual understanding is,” and “how to develop and implement diversified ways of assessment.” Lu and Liu (2012b) conducted quantitative analysis of the alignments between the national high school biology curriculum standards and the standards-based high school exit examination (HSEE) of 2009 in four provinces with Porter’s alignment model. As a result, it was found that none of the four HSEEs of 2009 were significantly aligned with the national biology standards. The low alignment indexes are mainly because the four HSEEs generally require lower levels of cognitive skills than that of the standards. These results deserve universal attention of both policymakers and test developers in Mainland China. Liu and Liu (2012) investigated Grades 10–11 students’ understanding of photosynthesis by designing and using a two-tier test fitting for the Rasch Model. This study showed that it was easier for students to understand factual knowledge than the conceptual knowledge. Ren and Li (2011) analyzed the consistency of item difficulty with multidimensional analysis system (MAS) and cognitive task analysis (CTA). The absolute difficulties of 30 typical test questions of ion reaction were calculated with MAS and CTA, respectively. The relationships between these two results were analyzed in detail in three aspects: the transformation dimensions, coding numbers, and MAS absolute difficulties. This study suggested that the results of the two methods were of high coherence. Chi and Wang (2010) studied the composition and characteristics of chemistry examination papers of the college entrance examinations in Mainland China, discussed the problems in compiling examination paper, and provided suggestions for reforming chemistry examinations and chemistry teaching.

Students’ competence in disciplines (e.g., chemistry, physics, and biology) as a core component of academic achievements has got attention of the researchers in Mainland China. For example, Yang and Wang (2012) conducted a study on CDC, which is defined as a kind of special ability “the competence that students acquired in the learning activities of chemistry curriculum.” They thought the core components of CDC as “competence in representation of symbols,” “competence in experiments,” “competence of model-based thinking,” and “competence of quantitative thinking.” This study analyzed the learning progressions of the CDC components and defined the performance and content knowledge of different levels of CDC. In light of the Rasch Model, this study designed a set of assessment instruments which could be applied in testing students’ CDC on a large scale. And the results showed that there were significant differences between grades, genders, and schools in CDC.

## 2.5 Teachers' Professional Development

As the basic education reform is sweeping across Mainland China, teachers are facing challenges of having to constantly enhance their professional literacy to do a good job. Under these circumstances, the teachers' professional development comes into researchers' sight.

Liang (2011b) analyzed the value of pedagogical content knowledge (PCK) based on international studies. He thought that PCK has ideational and practical characteristics, affects teachers' teaching ideas and behaviors, and serves as a bridge between the two. Then, he studied the structure and construction of chemistry teachers' PCK and pointed out that chemistry teachers' PCK included chemistry knowledge based on teachers' understanding of chemistry, knowledge about students' understanding of chemistry, knowledge about the chemistry course, teaching strategies, and representation of specific chemistry themes. Zhang and Wang (2013) analyzed the conception and structure of PCK based on previous international studies of science teachers' PCK. Furthermore, they discussed two factors—teaching experiences and teacher training—that impacted on the development of teachers' PCK and provided references for effective science teacher training.

Wang et al. (2012c) investigated chemistry teacher's PCK based on specific themes of chemistry knowledge with questionnaire and found that chemistry teachers in high schools did not do well in understanding the new content of the “chemical reaction principle,” whereas some older teachers did even worse and that teachers with higher education background had better PCK. They suggested that the teacher training agencies should pay more attention to explain the new knowledge in the new chemistry curriculum to help teachers acquire it as soon as possible.

Hu and Wang (2010) conducted some intervention studies on chemistry teachers' PCK. They carried out remote training with training video and online discussion for teachers based on problems of teaching elements and compounds in compulsory courses (ECCC). They also investigated teachers' understanding of content systems, teaching characteristics, teaching methods, and ideas on ECCC by a questionnaire. They found that after training, teachers' understanding of ECCC became better; however, their teaching practice on ECCC needs to be strengthened.

Some researchers investigated the differences between expert and novice chemistry teachers from several aspects, such as teaching strategies (Lou and Wang 2010a), selection and use of teaching methods (Zhang and Yang 2011), and experiment teaching behaviors (Gai et al. 2012). The methods of classroom observation, video analysis, case analysis, and interviews with teachers were adopted. These studies found a lot of differences between expert and novice chemistry teachers which were useful for novice teachers' reflection on their teaching and training of preservice teachers.

In recent years, investigations on the situation of teachers' professional development have become abundant and covered both general and specific aspects such as curriculum beliefs (Xu and Li 2011; Yang and Yang 2011). Besides, with the

rapid development of the Internet, online learning has already become a new approach for teachers' professional development in Mainland China (Liu et al. 2008).

## 2.6 Scientific Inquiry

Scientific inquiry is emphasized in science curriculum standards in Mainland China, not only as a learning objective and content, but also as a learning style. So, scientific inquiry is a very hot topic in SER.

Studies on scientific inquiry-based teaching focused on four categories. The first category is research on the model and strategy of scientific inquiry-based teaching. The subject is experience from teaching practice summarized by school teachers in scientific inquiry-based teaching, such as four-step teaching method, collaboration and exploring learning model, and student-centered scientific inquiry teaching strategies. And some graduate students also proposed some scientific inquiry-based teaching models and strategies and conducted empirical investigations, such as a scientific inquiry-based teaching model to facilitate students' cognitive change, a worksheet-based scientific inquiry teaching strategy, and a network-based physics scientific inquiry teaching model in middle and high schools (Wang et al. 2013b). The second category is about studies on designing scientific inquiry-based teaching plans. The subject is teaching samples developed for specific curriculum content by school teachers. The third category is about studies on the function of scientific inquiry-based teaching, such as Wang's (2012a) "scientific inquiry, retrospection, and implication" teaching model to improve students' understanding of NOS. This study selected Grade 11 students in Nanjing as samples, and the results illustrated that students taught via scientific inquiry-based method understood better on "the relativity of scientific theory," but the understanding of their whole knowledge of NOS was not improved significantly. The fourth category is studies on the status quo of scientific inquiry-based teaching, which were conducted by university/college faculties and graduate students via questionnaire-based investigations and interviews, focusing on teachers' beliefs on inquiry-based teaching, teachers' teaching practice, and teaching effect and influence factors.

Studies on students' inquiry ability and evaluation are mainly conducted by university/college faculties and graduate students. Researchers investigated students' performance on different subskills used in scientific inquiry process, such as asking physics questions, analyzing data, and argumentation. As for asking physics questions, the results illustrated that there were seven factors correlated with this skill, which are as follows: students' interests in physics, contexts created by teachers, students' knowledge foundation, new knowledge, students' sense of self-respect, the atmosphere of asking questions, and the influence of authority (Bao 2006). As for the validity study of worksheets used as an evaluation tool for

students' inquiry performance, the results illustrated that the raters' reliability of observation-based scale was relatively high and acceptable, while the reliabilities of the open-ended worksheets, structured worksheets, and guiding worksheets were lower than observation. As the openness degree of the worksheets decreased, the raters' reliability went up, because the requirements on worksheet were more and more explicit and consistent with students' performance, and it was easier for raters to rate (Luo 2007).

Studies on teachers' beliefs and performance on scientific inquiry are mainly conducted with questionnaire-based investigations. For example, researchers compared teaching in the USA and Mainland China by using Likert items, open-ended items, and teaching videos. The findings illustrated that teachers working in Mainland China considered scientific inquiry as using unchanged procedures to understand content knowledge, whereas American teachers paid more attention to how to create context to facilitate students' engagement in learning activities and also focused more on the process of the development of students' cognition. Meanwhile, the expected performance evaluation criteria on "how to do inquiry" in Mainland China is lower than that in the USA, whereas some expectations—such as operating with laboratory equipment, using scientific terms, and information and communications technology (ICT)—were higher than those in the USA. Teachers in Mainland China considered how to guide students to do inquiry in class and also thought that teachers should guide students to collect and analyze data, interpret phenomena, and do communications. In comparison, the US teachers focused on the development of students' asking questions, collaboration and communication, argumentation, and critical thinking, and they also paid more attention to students' problem-solving ability in exploratory processes and guiding them to give explanations. Lastly, teachers in Mainland China focused more on the safety issues of inquiry activities than did US teachers (Wang and Guo 2011). Another researcher employed qualitative and quantitative methods in a study analyzing the text of 67 teaching plans in order to gain knowledge on teachers' understandings of: (1) what inquiry-based teaching is; (2) why inquiry-based teaching is needed; and (3) how to practice inquiry-based teaching in language expression and teaching practice. The results illustrated that teachers took inquiry-based teaching as an ideal teaching model, but teachers' understanding of the overall scientific inquiry and elements involved in it was very superficial (Lu 2013). In addition, this study also found that there were nine factors mainly accounting for the development of teachers' beliefs in inquiry-based teaching, which are as follows: cases of inquiry teaching, the environment of teachers' work and living (such as job training opportunities provided for in-service teachers), teachers' study on pedagogical theory, experience of individual progression, the practice of inquiry-based teaching, the practice of inquiry, the consideration on inquiry and inquiry teaching, the consideration on students' thinking for problem-analyzing processes, and the understanding of NOS.

## 2.7 Learning Progressions and Students' Domain-Specific Cognitive Development

Learning progressions (LPs), as a hot topic in international SER, also attract the interest of researchers in Mainland China.

Some researchers selected key biology concepts and constructed the concept progression map for elementary, middle school, and high school students (Zhang and Liu 2010; Li and Liu 2010). The results and conclusions of these studies were adopted by Grade 7–9 National Biology Curriculum Standards (2011 edition) with clear statements of students' understanding of each key concepts in different biology topics (Liu et al. 2012).

Tan (2010) developed an inventory, which was named “energy and life,” to describe students' understanding of progressions on energy from Grades 8–12, and anchor items were designed and set in assessments for students of different grades.

Li and Liu (2012) studied LPs of scientific inquiry in K-12 science curriculum. Based on Lawson's theory of scientific reasoning patterns, researchers measured students' development of scientific reasoning ability via the instrument Classroom Test of Scientific Reasoning (CTSR) developed by Lawson for elementary school students to undergraduate students (Guo et al. 2011). The results implicated that students' progressions for scientific reasoning could be significantly observed across Grades 5–10 and were consistent with Piaget's developmental theory (Wei et al. 2011). However, for undergraduates, the progressions of scientific reasoning were not significant across the years. The underlying reason now is still vague although the researchers have discussed the potential influencing factors based on the current teaching method and content, whereas the mechanism in cognition development is also not reached, and the ceiling effect of the test was eliminated for the low mean scores of overall students' responses (Guo et al. 2011).

In 2004, Lei Wang at Beijing Normal University and her team members proposed a new notion named “chemical cognitive and reasoning mode (style) (CCRM)” for the first time. They thought that there was an interior factor which influences specific concept learning and student's cognition on specific topic and content domain. The factor is a kind of thinking mode or perspective of cognition which is used in conceptual understanding, reasoning, and problem solving. What is the cognitive and reasoning mode of a specific domain? They defined it as “the mode of cognition and reasoning which is used by students when analyzing phenomena, solving problems, and understanding ideas in a specific domain.”

At present, the theoretical and practical research on CCRM has achieved certain results. They recognized that there were three components of the cognitive and reasoning mode; in other words, cognitive and reasoning mode can be illustrated by the following three cognitive variables: (1) *perspective of cognition*, that is, the special lens or viewpoints which are used by students to understand ideas, analyze phenomena, and solve problems. The perspectives of cognition are differently based on different cognitive objects and domains or different students; (2) *path of reasoning*, that is, the path and process of reasoning which are usually supported and



influenced by the combination of the perspectives of cognition; (3) *patterns of cognition and reasoning* which are generally classified into macroscopic/microscopic, qualitative/quantitative, isolated/systematic, and static/dynamic categories (Wang and Xiao 2004; Wang and Yang 2006).

Wang and her research group's studies indicated that CCRM did exist in chemistry learning and had many kinds of categories and levels. It is stable, educable, and invisible (Wang and Xiao 2004). The cognitive and reasoning mode relied on a specific domain named as the cognitive domain. The cognitive domain reflects the knowledge content attribute of the cognitive and reasoning mode, for example, water solution, inorganic substance, organic substance, and chemical reaction. The level of a student's cognitive and reasoning mode is related with what kind of cognitive and reasoning tasks the student is capable of doing and what level his/her performance is. There are several categories of the cognitive and reasoning tasks and performances, such as describing, illustrating, explaining, predicting, designing, and controlling. Understanding the concept of "cognitive and reasoning mode of the specific domain" can help us to characterize the differences between students and the development in their learning. The differences among students are reflected by the amount and the level of *perspective of cognition* and *pattern of cognition and reasoning*, as well as what kind of cognitive tasks they can deal with (Wang and Yang 2006).

Lei Wang and her research group have been pushing forward the development of the theoretical framework of cognitive and reasoning mode. They thought that the learning progressions of the specific domain or topic could be described by the development of domain-specific cognitive and reasoning mode of students. And the latter could be described from the changes that took place from five aspects: (1) the perspectives of cognition, (2) the relations and combinations of different perspectives of cognition, (3) the path of reasoning, (4) the category of patterns of cognition and reasoning, and (5) the level of cognitive and reasoning performances. The development of domain-specific cognitive and reasoning mode of students was related to grade, curriculum, and content knowledge, but it is not absolute. It was decided mostly by the transformation from knowledge to cognitive and reasoning mode (Wang and Zhi 2011).

Later on, researchers conducted a series of studies of instructional design and teaching strategies which can promote students' epistemic development as well as students' cognitive and reasoning mode of core chemical knowledge. By January 2014, more than 200 lessons based on promoting students' chemical domain-specified cognitive and reasoning mode development had been conducted in 37 secondary schools under the project of "Design Based Lesson Study by University-School-Collaboration (DBLSUSC)." The case content covered most of the contents of elementary school and middle school (Wang et al. 2010b; Zhi et al. 2012; Wang et al. 2012a; Jiang et al. 2012). All of the studies achieved good teaching results.

The basic procedure of the above studies involved: (1) forming a research group, including chemistry education experts, graduate students, and high school teachers; (2) diagnosing the problems of original teaching design and classroom teaching by

classroom observation, video analysis, and interviews with teachers and students; (3) discussing the problems found, reaching a consensus and redesigning teaching based on promoting students' epistemic development and designing pretest and posttest to detect the teaching effect; (4) putting the new teaching design into classroom teaching, carrying out pretest and posttest to test the teaching effect by classroom observation, video analysis, teachers' interviews, and interviews with students; (5) summarizing the effective teaching strategies and discussing the problems needed to solve in the future; and (6) studying the problems in the studies. This is an all-win process of the action research, and it solved the problem that SER is hard to be applied to teaching practice. In above process, the science education theories can be tested and developed in practice; an effective path of putting the science education theories into practice is found and will promote the secondary school teachers' understanding of the theories and improve their teaching research ability, reflection ability, and classroom control ability; and finally, these theories promote the secondary school teachers' professional development.

## 2.8 Concluding Remarks

Encouraged by the K-12 science education reform in Mainland China, SER has generated a large number of publications over the past 10 years, which is considered to be a golden age for the researchers. Because SER in Mainland China is closely integrated with separate science subjects, the reviews above were presented by studies in physics, chemistry, or biology education due to the length limitation of this chapter. In fact, physics, chemistry, and biology education all have had fruitful achievements in all the six aspects above. But, the internationalization of SER in Mainland China is not enough, especially in publishing studies in international journals. How to bring the native studies to overseas and how to get recognition of international peers are important tasks for the researchers in Mainland China.

## References

- Bao, S. (2006). 初中学生提出物理问题的过程及相关因素研究 (Factor analysis for students' ability on raising physical questions). Unpublished master's thesis, Beijing Normal University, Beijing, China.
- Bi, H. L., & Cui, S. F. (2011). 促进“观念建构”的化学教学策略 (Chemistry teaching strategies for promoting construction of big ideas). 中学化学教学参考 (Teaching and Learning Reference for Middle School Chemistry), (7), 3–6.
- Bi, H. L., & Lu, W. (2011). 化学基本观念的内涵及其教学价值 (The connotation of basic chemical concepts and its teaching value). 中学化学教学参考 (Teaching and Learning Reference for Middle School Chemistry), (6), 3–6.
- Bi, H. L., & Wan, Y. L. (2013a). 学校需要什么样的教科书——基于教师和学生使用化学教科书的调查研究 (Research of what kind of textbooks do schools need: a study based on the

- investigation of teachers' and students' use of chemistry textbooks). 教育学报 (Journal of Educational Studies), (4), 70–75.
- Bi, H. L., & Wan, Y. L. (2013b). 化学教学中教师使用教科书的影响因素分析——基于扎根理论的研究方法 (The influence factors of teachers' using textbooks in chemistry education-based on grounded theory research methods). 化学教育 (Chinese Journal of Chemical Education), 34(7), 47–51.
- Chi, S. H., & Wang, Z. H. (2010). 高考化学试题的特点分析及问题探讨 (Characteristic analysis and problem discussion of chemistry test questions in China's College Entrance Examination). 基础教育课程 (Chinese Basic Education Curriculum), (9), 57–60.
- Cui, X. F., Ma, H. J., & Feng, X. Q. (2011). 运用手持技术探究醋酸电离平衡移动 (Exploration of acetic acid ionization equilibrium with hand-held technology). 化学教学 (Education in Chemistry), (8), 18–21.
- Deng, Q. P., & Liu, E. S. (2011). 美国BSCS“认识酒精:生物学与行为学研究”课程的构建思路与特点 (Analyze the intention and feature of American BSCS supplementary course “Understanding Alcohol: Investigations into Biology and Behavior” for grades 7–8). 生物学通报 (Bulletin of Biology), 46 (10), 18–21.
- Deng, Y., Wang, H. X., & Xie, J. (2011). 基于POE和望PDEODE策略的化学概念转变教学实验研究 (Experimental teaching research of chemistry concept transformation based on the strategy of POE and PDEODE). 中学化学教学参考 (Teaching and Learning Reference for Middle School Chemistry), (10), 3–7.
- Fu, X., & Liu, E. S. (2013). “抗生素:会有效吗?”单元的教学设计与实践——基于WISE的网络教学策略 (An empirical study on the design and implementation of school-based courses by using WISE resources). 生物学通报 (Bulletin of Biology), 48(2), 26–30.
- Gai, L. C., Zheng, C. L., & Qin, W. (2012). 专家-新手教师化学课堂“实验教学行为组合”结构特征的比较 (Teaching behavior structure comparison of Experts-novice teachers' “experimental teaching behavior” in chemistry lessons). 化学教育 (Chinese Journal of Chemical Education), 33(11), 83–86.
- Guo, Y., Wei, X., Zhong, K., & Wang, W. (2011). 高师物理专业本科生科学推理能力研究 (An investigation on the development of students' scientific reasoning ability in physics department of teaching colleges). 物理教师 (Physics Teacher), (1), 1–6.
- He, J. Y., & Liu, E. S. (2012). 论证式教学策略的发展及其在理科教学中的作用 (The argument-driven inquiry model and its application in science education). 生物学通报 (Bulletin of Biology), 47(10), 27–31.
- Hu, J. H., & Wang, L. (2009). 基于促进学生科学素养发展的高中化学新课程教材研究——“鲁科版”高中化学必修模块教材分析 (Teaching material research of new high school chemistry curriculum based on promoting students' scientific literacy—analysis of compulsory high school chemistry textbooks published by Shandong Science and Technology Press). 中学化学教学参考 (Teaching and Learning Reference for Middle School Chemistry), (9), 3–7.
- Hu, J. H., & Wang, L. (2010). 教师对高中化学必修模块元素化合物内容及教学认识的调查研究 (Investigation on Teachers' understanding of the contents and teaching of elements and compounds in high school compulsory modules). 化学教育 (Chinese Journal of Chemical Education), 31(2), 27–29.
- Huang, F. Q., & Wang, H. X. (2010). 美国高中化学教材《化学:概念与应用》的评析 (Analysis of American high school chemistry textbook *Chemistry: Concepts and Applications*). 中学化学教学参考 (Teaching and Learning Reference for Middle School Chemistry), (9), 61–63.
- Ji, G. M., & Bi, H. L. (2010). 基于模糊综合评判的中学化学教材质量评价模型研究 (Quality evaluation of middle school chemistry textbooks based on fuzzy comprehensive evaluation model). 化学教育 (Chinese Journal of Chemical Education), 31(5), 37–38.
- Jiang, T. (2013). 物理探究课有效教学评价指标体系构建研究 (On the construction of the evaluation indicator system for effective inquiry teaching of physics lesson). Unpublished doctoral dissertation, Southwest University, Chongqing, China.
- Jiang, H. J., & Li, G. Z. (2011). 中学化学教材中的类比策略 (Analogy strategy in middle school chemistry textbooks). 化学教育 (Chinese Journal of Chemical Education), 32(6), 6–10.

- Jiang, Y. X., Wang, L., & Zhi, Y. (2012). 元素化合物知识的教学价值分析及教学策略研究 (Teaching value analysis of element compound knowledge and teaching strategy research). 课程教材教法 (Curriculum, Teaching Material and Method), (9), 106–112.
- Li, J. (2011). 中美物理教科书评价指标体系比较研究 (Comparative study on the indicator system of evaluation of Chinese and American physics textbooks). 课程教材教法 (Curriculum, Teaching Material and Method), (9), 99–103.
- Li, C. (2012). 表现性评价在中学物理教学中的应用 (The application of performance evaluation in high school physics curriculum). Unpublished master's thesis, Shanxi Normal University, Xi'an, Shanxi province, China.
- Li, H. J., & Liu, E. S. (2010). 中小学生物学课程中生态学重要概念的筛选及其表述 (Study on screening the key concepts about ecology for primary and secondary schools). 生物学通报 (Bulletin of Biology), 45(10), 31–34.
- Li, H. J., & Liu, E. S. (2012). 基础教育理科课程中科学探究概念的研究 (Study on the progression of inquiry concepts in K-12 science curriculum). 生物学通报 (Bulletin of Biology), 47(1), 32–35.
- Li, Y. Y., & Qian, Y. Y. (2012). 利用手持技术探究氢氧化铝制备实验电导率变化 (Exploration of the electrical conductivity change with hand-held technology in the experiment of aluminum hydroxide preparation). 化学教育 (Chinese Journal of Chemical Education), 33(9), 103–108.
- Li, H. J., & Wang, L. H. (2013). “力臂”概念教学对“5E”模式的借鉴——论教学模式的借鉴机制 (Designing a 5E teaching model based instructional plan for “Arm” concept). 物理教师 (Physics Teacher), 34(2), 2–3, 6.
- Liang, Y. P. (2011a). PCK: 教师教学观念与教学行为发展的桥梁性知识 (PCK: The bridge between the development of teachers' conceptions of teaching and the development of their teaching behavior). 教育科学 (Education Science), 27(5), 54–59.
- Liang, Y. P. (2011b). 化学科学理解的基本视角及其核心观念 (The basic perspective and core concepts of understanding of chemistry). 化学教育 (Chinese Journal of Chemical Education), 32(6), 4–7.
- Liu, C., & Liu, E. S. (2012, March). *Design and use two-tier test fitting for Rasch Models to investigate grades 10–11 students' understanding of photosynthesis*. Paper presented at the National Science Teachers Association 2012 Conference, Indianapolis, USA.
- Liu, Z., She, J. Y., & Liu, E. S. (2008). 新课程背景下生物学教师网络学习的内容与方法 (Study on the content and approach of biology teachers' online learning in the context of K-12 education reform). 生物学教学 (Biology Teaching), 33(1), 26–28.
- Liu, X., Liang, L. L., & Liu, E. S. (2012). Science education research in China: challenges and promises. *International Journal of Science Education*, 34(13), 1961–1970.
- Lou, S., & Wang, Z. H. (2010a). 专家与新手型科学教师课堂教学策略的比较研究 (Comparative study of expert-novice science teachers' teaching strategies). Unpublished master's thesis, East China Normal University, Shanghai, China.
- Lou, Y. G., & Zheng, C. L. (2010b). 化学课堂结构的教學行为解读 (Interpretation of the structure of chemistry classroom teaching behavior). 化学教育 (Chinese Journal of Chemical Education), 31(6), 44–46.
- Lu, M. Z. (2013). 中学物理教师探究教学观现状及其影响因素研究 (Research of grade 8–12 in-service physics teachers' belief in inquiry-based teaching and the influencing factors). Unpublished doctoral dissertation, Beijing Normal University, Beijing, China.
- Lu, Q., & Liu, E. S. (2012a). 高中生物学教科书与课程标准的一致性研究——以人民教育出版社和浙江科技出版社教科书为例 (Research on the consistency of biology textbooks for senior high schools with the curriculum standards). 课程教材教法 (Curriculum, Teaching Material and Method), 32(5), 75–82.
- Lu, Q., & Liu, E. S. (2012b). Alignment between high school biology curriculum standard and the standardized tests of four provinces in China. *Journal of Biological Education*, 46(3), 149–164.
- Luo, G. Z. (2007). 科学探究能力的评价方法 (The assessment methods of scientific investigation abilities). 教育科学 (Education Science), 23(3), 7–10.

- Meng, X. H., & Li, G. Z. (2011). 基于化学史教学的理论与实践研究 (Theory and practice research of chemistry teaching based on history). Unpublished doctoral dissertation, Nanjing Normal University, Nanjing, Jiangsu province, China.
- Ministry of Education. (2001). 基础教育课程改革纲要(试行) (Guideline of curriculum reform for basic education (trial)). Retrieved from [http://www.moe.gov.cn/publicfiles/business/htmlfiles/moe/moe\\_309/200412/4672.html](http://www.moe.gov.cn/publicfiles/business/htmlfiles/moe/moe_309/200412/4672.html)
- Niu, C. H., & Li, X. X. (2013). 高中物理教材习题与课程标准的一致性研究 (Consistency between exercises in high school physics textbook and high school physics curriculum standard). 物理教师 (Physics Teacher), (4), 2–4.
- Qian, H., & Li, L. Z. (2011). 电解质溶液学习中中学生“相异构想”的调研 (Research of secondary school students' alternative framework of electrolyte solution). 化学教学 (Education in Chemistry), (11), 9–12.
- Ren, J. W. (2013). 高中化学课堂教学行为研究——基于促进学生认识发展的视角 (Study on the characteristics of teaching behavior of promoting the development of students' chemical epistemic mode). Unpublished master's thesis, Beijing Normal University, Beijing, China.
- Ren, H. Y., Li X., & Li, G. Z. (2011). MAS 法和CTA法标定离子反应试题绝对难度的研究 (Study on calibrating absolute difficulty of reaction problems with the methods of MAS and CTA). 中国考试 (China Examinations), (12), 17–21.
- Research group of China scientific and technical papers statistics and analysis. (2013). 2011年中国科技论文统计与分析简报 (Statistics and analysis report of China scientific and technical papers 2011). 中国科技期刊研究 (Chinese Journal of Science and Technology Periodicals Research), 24(1), 57–64.
- Sun, D. E., Wang, Z. H., Xie, W. T., & Boon, C. C. (2014). Status of integrated science instruction in junior secondary schools of China: an exploratory study. *International Journal of Science Education*, 36(5), 808–838.
- Tan, X. (2010). 中学生对物理学科中能量概念认识状况的调查研究——以北京市两所中学为样本 (Investigation on middle school students' understanding about the concept of energy in physics—taking two middle schools in Beijing as samples). Unpublished master's thesis, Beijing Normal University, Beijing, China.
- Wang, F. (2012a). 科学探究教学对高中生科学本质观影响的实证研究 (An empirical study on the influence of inquiry based teaching of the development of students' understanding on the nature of science). Unpublished master's thesis, Nanjing Normal University, Nanjing, Jiangsu province, China.
- Wang, Z. H. (2012b). 化学课程标准修订:依据和视角 (The revision of chemistry curriculum standard: basis and perspective). 基础教育课程 (Chinese Basic Education Curriculum), (Z1), 76–81.
- Wang, J., & Guo, Y. Y. (2011). 中美高中物理教师对探究教学认识的比较研究——基于四节探究教学录像的量化分析 (Comparative research on Chinese and American teachers' understanding on inquiry teaching: based on the quantitative analysis of videos of four inquiring teaching lessons). 教育学报 (Journal of Educational Studies), (1), 54–59, 67.
- Wang, S. C., & Wang, H. X. (2012). 《义务教育化学课程标准(2011年版)》解析 (The chemistry curriculum standards of compulsory education (2011 edition)). 中小学管理 (Elementary and Middle School Administration), (4), 23–28.
- Wang, L., Zhang, Y. Q., & Qiao, M. (2008). 观念建构为本的化学教学设计研究 (Investigation on the chemistry teaching design based on the construction of conception). 化学教育 (Chinese Journal of Chemical Education), 29(6), 7–12.
- Wang, L., Song, W. J., & Pan, C. (2010a). 基于促进学生科学素养发展的高中化学新课程教材研究——北师大“新世纪”(鲁科版)《化学与生活》模块教材分析 (Teaching material research of new high school chemistry curriculum based on promoting students' scientific literacy—analysis of the textbook of Chemistry and Life published by Shandong Science and Technology Press). 中学化学教学参考 (Teaching and Learning Reference for Middle School Chemistry), (1), 6–9.

- Wang, L., Zhi, Y., & Xu, M. (2010b). 基于促进学生认识发展的“物质的量浓度”教学设计研究 (Research of teaching design based on promoting students' understand of the "amount of substance concentration"). *化学教育* (Chinese Journal of Chemical Education), 31(1), 3–8.
- Wang, L., Jiang, Y. X., Zhi, Y., Huang, Y. N., Cao, H., & Liu, H. L. (2012a). 促进学生认识发展的“化学反应原理”绪言课教学研究——基于化学反应认识模型建构 (Teaching research of the exordium of chemical reaction principle for promoting the development of students' understanding based on chemical reaction model construction). *化学教育* (Chinese Journal of Chemical Education), 33(11), 12–20.
- Wang, S. C., Wang, H. X., & Zhou, Z. (2012b). 新时期义务教育化学学科教育的新目标 (The new objective of compulsory education in the new period of chemical subject education). *中学化学教学参考* (Teaching and Learning Reference for Middle School Chemistry), (7), 46–47.
- Wang, X. H., Liu, J. Z., & Li, Y. M. (2012c). 高中化学教师“化学反应原理”知识的调查分析 (Investigation on senior high school chemistry teachers' knowledge of chemical reaction principle). *化学教育* (Chinese Journal of Chemical Education), 33(11), 69–71.
- Wang, Z. H., Wei, S. L., Ding, W., Chen, X., Wang, X., & Hu, K. (2012d). Students' cognitive reasoning of graphs: characteristics and progression. *International Journal of Science Education*, 34(13), 2015–2041.
- Wang, L., Huang, M. C., Wang, W. Z., Jiang, Y. X., Zhang, L. N., & Zhang, R. H. (2013a). 从国际比较的视角来看高中化学课程标准的稳定性和趋势性 (Prospective Research of High School Chemistry Curriculum Standards: Based on the comparison with International Curriculum Standards). *全球教育展望* (Global Education), (11), 98–109.
- Wang, W. Q., Guo, Y. Y., & Jia, Y. (2013b). 促进科学认知发展的高中物理探究教学模型 (Developing an inquiry based instructional model for advancing students' progression on scientific cognition). *课程教材教法* (Curriculum, Teaching Material and Method), (10), 75–79.
- Wei, X., Guo, Y., & Xu, Y. (2011). 中小学生科学推理能力发展现状研究——以北京市中小学生为样本 (Development of scientific reasoning of Grade 2–12 students: taking students in Beijing as an example). *北京师范大学学报:自然科学版* (Journal of Beijing Normal University: Natural Science), 47(5), 461–464.
- Xiao, H. (2004). 高中生化学核心概念学习中的认识方式研究 (Study on high school students' understanding style of chemistry conceptions). Unpublished master's thesis, Beijing Normal University, Beijing, China.
- Xing, L. J., Zhou, Q., & Chen, W. (2011). 英国《高级化学》教材中基本概念与基础理论的设计特点分析 (The design characteristics of basic concepts and theory in the textbook of Senior Chemistry). *教育实践与研究* (Educational Practice & Research), (1), 54–56.
- Xu, Q. Y., & Li, Y. R. (2011). 贫困地区农村中学化学教师专业发展的现状调查 (The status quo of the rural middle school chemistry teachers' professional development). *化学教育* (Chinese Journal of Chemical Education), 32(5), 38–41.
- Yan, W. F. (2009). 高中生科学本质观及其影响因素的研究 (High school students' scientific view of NOS and its influence factors). Unpublished doctoral dissertation, Southwest University, Chongqing, China.
- Yan, W. F., & Li, Y. H. (2012). 基于科学本质的鲁科版高中化学教材研究 (Research of high school chemistry textbooks published by Shandong Science and Technology Press based on NOS). *化学教学* (Education in Chemistry), (12), 8–11.
- Yang, Y. (2006). 促进学生认识方式发展的化学概念教学研究——基于对化学反应原理核心概念的教与学 (Study on the chemical conception teaching to promote the development of students' understanding style—based on the learning and teaching of key conceptions of the chemical reaction principle). Unpublished master's thesis, Beijing Normal University, Beijing, China.
- Yang, C. Y., & Hu, H. Q. (2011). “氧化还原反应”课程难度比较研究 (A comparative study of difficulty of the “redox reaction” lessons). *中学化学教学参考* (Teaching and Learning Reference for Middle School Chemistry), (7), 35–38.

- Yang, W. Y., & Liu, E. S. (2014). 为了理解的教学设计:从指向核心概念的问题开始 (Teaching for understanding: starting from questions directing to key concepts). *生物学通报* (Bulletin of Biology), 49(1), 28–33.
- Yang, Y. Q., & Wang, Z. H. (2010). 中美高中化学教材中科学本质内容水平的比较及启示 (A comparative study of levels of NOS in high school chemistry textbooks of Mainland China and the United States). *化学教育* (Chinese Journal of Chemical Education), 31(12), 11–15.
- Yang, Y. Q., & Wang, Z. H. (2012). 化学学科能力及其测评研究 (Research on measurement and assessment of the competence of subject ability of chemistry). Unpublished doctoral dissertation, East China Normal University, Shanghai, China.
- Yang, C. Y., & Yang, X. X. (2011). 高中化学教师的课程信念及其行为对策 (High school chemistry teachers' curriculum beliefs and behavior). *化学教育* (Chinese Journal of Chemical Education), 32(3), 39–41.
- Yang, X. C., Liu, Y., Zhao, Y., Lei, J. P., & Zhou, Q. (2012, April). *HPS* 教学模式对高中学生科学本质观的影响 (The influence of HPS teaching mode on high school students' view of NOS). Paper presented at the 28th conference of Chinese Chemical Society, Chengdu, Sichuan province, China.
- Yin, L., Zheng, W., & Wang, J. Y. (2010). 基于定量模型的高中物理教科书课程难度比较——以“相对论”教学内容为例 (A quantitative model based comparison of the difficulty of high school physics textbook with a quantitative model: Taking relativity theory as an example). *教学月刊* (Teaching Monthly), (9), 3–6.
- Yu, J. P., & Zheng, X. H. (2013). ISM法在中学生物学教材分析中的应用及案例分析 (A case study on text analysis of middle school biology instructional materials with ISM model). *生物学通报* (Bulletin of Biology), 48(5), 22–24.
- Zhang, Y. Z., & Liu, E. S. (2010). 核心概念在理科教学中的地位 and 作用——从记忆事实向理解概念的转变 (The significance of key concepts in science teaching: the transforming from memorizing facts to understanding concepts). *教育学报* (Journal of Educational Studies), 6(1), 57–61.
- Zhang, R. H., & Wang, L. (2012, April). 中学生酸碱个人概念探查及概念发展研究——基于北京、台湾两地的比较 (Survey of students' conceptions and conceptual development of acids/bases—based on the comparison between Beijing and Taiwan). Paper presented at the 28th conference of Chinese Chemical Society, Chengdu, Sichuan province, China.
- Zhang, X. J., & Wang, Z. H. (2013). 科学教师学科教学知识的研究 (The science teachers' pedagogical content knowledge). *全球教育展望* (Global Education), 42(8), 68–79.
- Zhang, Z., & Yang, C. Y. (2011). 新手与专家型化学教师教学方法运用策略比较研究 (Comparative study of novice-expert chemistry teachers' teaching strategies). Unpublished master's thesis, Shanxi Normal University, Xi'an, Shanxi province, China.
- Zheng, C. L. (2013). 课堂教学行为研究新视野 (A new vision of classroom teaching behavior research). Changchun: Northeast Normal University Press, 82–101.
- Zheng, C. L., Fu, L. H., & He, P. (2014). Development of an instrument for assessing the effectiveness of chemistry classroom teaching. *Journal of Science Education and Technology*, 23(2), 267–279.
- Zhi, Y. (2011). 高中生化学认识方式及其发展研究 (Study on the epistemic style of senior high school students in learning chemistry). Unpublished doctoral dissertation, Beijing Normal University, Beijing, China.
- Zhi, Y., & Wang, L. (2009). 基于促进学生科学素养发展的高中化学新课程教材研究——北师大“新世纪”(鲁科版)《化学反应原理》模块教材分析 (Teaching material research of new high school chemistry curriculum based on promoting students' scientific literacy—analysis of the textbook of Chemical Reaction Principle published by Shandong Science and Technology Press). *中学化学教学参考* (Teaching and Learning Reference for Middle School Chemistry), (10), 3–8.
- Zhi, Y., Wang, L., Zhang, R. H., & Zhao, X. M. (2012). “物质的分类”促进高中生无机物性质学习的功能价值分析及其教学实现 (The value analysis of “matter classification” to high school students' learning of properties of in organics and teaching practice). *化学教育* (Chinese Journal of Chemical Education), 33(4), 28–35.



- Zhong, C. Z., & Guo, Y. Y. (2010). 高中物理课程标准教科书内容难度定量分析——以“量子理论”为例 (A quantitative analysis on difficulty degree of senior high school physics textbooks under new curriculum standards: Taking quantum theory as an example). 课程教材教法 (Curriculum, Teaching Material and Method), (4), 67–71.
- Zhou, S. D., & Zheng, C. L. (2010). 论实现科学本质教育的前提条件 (The basic conditions of NOS education). 中国教育学刊 (Journal of the Chinese Society of Education), (10), 39–41.

Science Education Research and Practice in Asia  
Challenges and Opportunities

Chiu, M.-H. (Ed.)

2016, VIII, 578 p. 44 illus., Hardcover

ISBN: 978-981-10-0845-0