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OPPORTUNITIES AND CHALLENGES OF CHINA'S INQUIRY-BASED EDUCATION REFORM IN MIDDLE AND HIGH SCHOOLS: PERSPECTIVES OF SCIENCE TEACHERS AND TEACHER EDUCATORS

ABSTRACT. Consistent with international trends, an emergent interest in inquiry-based science teaching and learning in K-12 schools is also occurring in China. This study investigates the possibilities for and the barriers to enactment of inquiry-based science education in Chinese schools. Altogether 220 Chinese science teachers, science teacher educators and researchers (primarily from the field of chemistry education) participated in this study in August 2001. Participants represented 13 cities and provinces in China. We administered two questionnaires, one preceding and one following a 3-hour presentation by a US science educator and researcher about inquiry-based teaching and learning theories and practices. In each of three sites in which the study was conducted (Shanghai, Guangzhou and Beijing), questionnaires were administered, and four representative participants were interviewed. Our coding and analysis of quantifiable questionnaire responses (using a Likert scale), of open-ended responses, and of interview transcripts revealed enthusiastic interest in incorporating inquiry-based teaching and learning approaches in Chinese schools. However, Chinese educators face several challenges: (a) the national college entrance exam needs to align with the goals of inquiry-based teaching; (b) systemic reform needs to happen in order for inquiry-based science to be beneficial to students, including a change in the curriculum, curriculum materials, relevant resources, and teacher professional development; (c) class size needs to be reduced; and (d) an equitable distribution of resources in urban and rural schools needs to occur.

KEY WORDS: Chinese science teacher, education reform, inquiry-based science, teacher beliefs, the nature of science

A popular view of the nature of science is that science is a process of inquiry in which scientists construct explanations concerning natural objects and events (American Association for the Advancement of Science (AAAS), 1990; Trowbridge & Bybee, 1990). Inquiry-based science teaching and learning, consistent with this constructivist view of science, has been recognized as an important theme of science education reform around the world (see AAAS, 1993; Driver, Newton & Osborne, 2000; National Research Council (NRC), 1996; Pfundt & Duit, 1994; Scardamalia & Bereiter, 1993/1994). A growing interest in inquiry-based science teaching

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and learning practices in K-12 schools is occurring in China (The State Council of China (SCC), 2001; Xu, 2001; Zhang, 2000).

Many factors shape inquiry teaching and learning reform including principals' conceptions of the importance of inquiry-based learning, professional development for using innovative approaches, limitations of teaching environments and resources, and students' learning habits (Blumenfeld, Fishman, Krajcik, Marx & Soloway, 2000; Yang, 2002). Changing teachers' practices from traditional to inquiry-based cannot be done quickly (Marx, Freeman, Krajcik & Blumenfeld, 1998). Teacher beliefs about the nature of science and science teaching have been identified as the sustainable and critical factor that affects practices (Abd-El-Khalick & Lederman, 2000; Gallagher, 1991; Jiang, 2002; Krajcik, Czerniak & Berger, 1999; Lederman, 1992). Their beliefs seem to be the basis on which teachers adopt or reject inquiry-based teaching and learning theories and practices.

Earlier studies have shown that there may be consistency between teachers' beliefs about the nature of science and their teaching practices (Brickhouse, 1990). For example, teachers holding constructivist beliefs are more likely to detect alternative conceptions and to use effective teaching strategies, congruent with constructivist beliefs, to improve students' conceptual change (Hashweh, 1996). However, research also shows that the relationship between beliefs and practices is complex (Duschl & Wright, 1989; Lederman, 1992, 1999) and demands continued study (Tsai, 2002).

Given limited research on this topic in the Chinese literature, this study was an attempt to explore Chinese teachers' knowledge and beliefs about the nature of science (NOS) and science teaching, as well as the possibilities for and barriers to inquiry-based practices that might enable or impede the enactment of constructivist pedagogy in Chinese schools. Four questions guided the research:

- What are Chinese science teachers' beliefs about the nature of science?
- What are Chinese science teachers' beliefs about science teaching and learning?
- How do Chinese science teachers respond to constructivist science teaching and learning theory and practices?
- What are the opportunities and barriers for Chinese science teachers in adopting inquiry-based teaching practices?

The perspectives of practising teachers and teacher educators can inform policy makers, administrators, curriculum developers, technology designers, educational researchers, teachers and teacher educators about the current status of reform in Chinese science education.

LITERATURE REVIEW

According to Chinese Academic Journals (CAJ), the first national digital-journal database of education and social science manuscripts in China, the number of articles on inquiry-based science teaching has increased dramatically in the past decade.[1] Although several Chinese terms describe inquiry-based science teaching and learning, two have gained prominence in the field. *Tanjiu* translates: "inquiry" or "inquiry-based learning." *Yanjiu Xing Xuexi* translates: "study learning" (Zhang, 2000), "research-learning" (Liu, 2001), or "research-oriented learning" (Xu, 2001). Although fewer manuscripts use the term *Tanjiu* than use *Yanjiu Xing Xuexi*, the increase in the use of both terms after 2000 is striking. A keyword search found 21 relevant manuscripts using *Yanjiu Xing Xuexi* from 1994–2000, and 1141 manuscripts from 2001–2003. A search for *Tanjiu* found an increase from 17 manuscripts in 1994–2000 to 202 in 2001–2003.

Although Chinese researchers and educators use different *terms*, the *meanings* of the terms are similar. In a Chinese manuscript – a precursor to using *Yanjiu Xing Xuexi* – students' physics learning activities were described as proposing questions, observing, designing experiments, collecting data, analyzing data, and making conclusions (Lin, 1987; Xu, 2001). Other references describe *Yanjiu Xing Xuexi* as first-hand experience that is student-centered, interactive and collaborative, and open-ended (Li, 1997; SCC, 2001; Zhang, 2000). We conclude that inquiry-based learning (Krajcik, Blumenfeld, Marx, Bass, Fredericks & Soloway, 1998) and *Yanjiu Xing Xuexi* are, in essence, the same pedagogy, based on a constructivist paradigm of science education (Pomeroy, 1993; Tsai, 1998).

The "nature of science" is also defined in multiple ways, but most commonly refers to values and assumptions inherent in the development of scientific knowledge (Lederman, 1992). In a study of students' epistemological beliefs about their learning orientation and the nature of science, Tsai (1998) described beliefs as either traditional or constructivist. The empiricist or traditional view,[2] according to Pomeroy (1993) and cited by Tsai (1998), supposes that: (a) scientific knowledge is unproblematic and it provides *right* answers; (b) scientific knowledge is *discovered* by *objective* data gathered from observing and experimenting or from a universal scientific method, and (c) scientific knowledge is additive and bottom-up, and evidence accumulated carefully will result in infallible knowledge. In contrast with this "right answer" orientation, knowledge can be viewed as *constructed* or invented by scientists (Pomeroy, 1993). Accordingly, scientific knowledge is constantly changing as its development experiences a series of revolutions or paradigm shifts. The implication is that science learning should help students understand how knowledge is constructed (Krajcik et al., 1998; NRC, 1996).

The study of the nature of science has been recognized as important for science learning (Driver, Leach, Millar & Scott, 1996) and for developing students' scientific literacy (NRC, 1996); therefore, it is important for teachers to be prepared to teach about the nature of science (Lederman, 1992; Nott & Wellington, 1998; Pomeroy, 1993). Ernest (1989) concluded that teachers' beliefs are useful in understanding and predicting how teachers make decisions about teaching. He and others argue that "understanding teachers' belief structure is essential to improving their professional preparation and teaching practices" (Ernest, 1989, p. 307; see also Smylie, 1988). Teachers holding constructivist beliefs were more likely to detect students' alternative conceptions; to have a richer repertoire of teaching strategies, and to value and use more effective strategies for inducing student conceptual change than did teachers holding empiricist beliefs (Hashweh, 1996). In a case study by Richardson, Anders, Tidwell & Lloyd (1991), changes in teacher beliefs were seen to precede changes in practice. Teachers must acquire new beliefs and practices in order to adopt inquiry-based approaches. Yet many teachers have not experienced inquiry-based and constructivist classrooms (Richardson & Placier, 2001).

In China, although some researchers have recognized the importance of teachers' beliefs for the success of educational reform (Jiang, 2002, Yang, 2002), few studies have explored beliefs about the nature of science. Ding's (2000) review of literature, which traced the topic of teacher beliefs and the use of the term "nature of science" in the western world, is the only piece in the CAJ database that addresses this topic. Given the impact of beliefs on teaching practices, we sought to collect information from educators (via self-report) about their beliefs about the nature of science, about science education, and about the feasibility of implementing inquiry-based approaches in Chinese schools. Herein, we illuminate opportunities and barriers from the perspective of these educators.

Research Design

One frequently used method for capturing beliefs is surveying. Post-survey interviews allow for elaboration of responses, and can reveal difficulties with a survey instrument when participants are asked to clarify responses (Lederman, 1992). Gallagher (1991) suggested that classroom observation is a better method for capturing practices and the rationale behind teachers' actions. Classroom observation was not an option for this study; therefore, we used both a survey instrument and participant interviews.

Context, Participants, and Timeline

This study was part of a two-week academic exchange trip to China in August 2001. A senior US science education researcher and faculty member from a major Midwest university was invited by Chinese universities in Beijing, Shanghai, and Guangzhou. The US professor gave talks on inquiry-based science, which is one way to instantiate constructivist teaching and learning theory and practices (Blumenfeld et al., 2000; Krajcik et al., 1998). The first author is a former Chinese chemistry teacher educator who served as the interpreter. He was a PhD student at the time of this study.

The three host universities recruited participants through a mailing to announce the conferences. Most participants were from schools interested in inquiry-based teaching and learning theories and practices, and they received support from their school or district in order to attend the conferences. Participants included science teachers, teacher educators, and science education researchers from 13 cities and provinces.[3]

Instrument Design

Because culture and background influence the way in which individuals respond to questionnaires and interviews, we took both into account when designing instruments (Eisenhart, 1998). We found several instruments used to measure teachers' or students' conceptions of the nature of science (in English). The Test on Understanding Science (TOUS), the Wisconsin Inventory of Science Processes (WISP), and the Nature of Science Scale (NOSS) have all been used on a large scale (Lederman, 1992). Although none had been used with science teachers from Mainland China, a questionnaire in (Pomeroy, 1993) – translated into traditional Chinese – had shown good validity (Tsai, 1998).

We adapted the Pomeroy questionnaire for exploring teachers' conceptions of the nature of science and science teaching. The first author translated the original so that the language would be familiar to those born and raised in Mainland China.[4] One challenge was to express English meanings so that they were precise and understandable in Chinese. Although Chinese textbooks contain western mainstream science and technology content, the language differences are numerous.

We hoped to administer the questionnaire immediately before and after the presentation so that it would be convenient, and we could ensure the greatest level of participation. To reduce its length, we divided the survey into two questionnaires, each with a different focus and each designed to take no more than 20 minutes. (See Appendix for representative questions.) Epistemological beliefs were addressed first: Questionnaire I investigated participants' perceptions of the nature of science. It also gathered demographic information. Questions that connected new teaching and learning theory and practices to teachers' own experiences were on Questionnaire II. Both surveys aimed to identify barriers and opportunities for inquiry-based teaching in Chinese schools.

Questionnaire Design: Questionnaire I (Q I)
We modified or excluded some items from Pomeroy's (1993) questionnaire; for example, references that might not be understood (e.g., #17 referenced the US judicial system), or items that did not lend themselves to distinguishing among the categories we wished to distinguish in this study (#4, 46, 49). We changed references to American teachers to refer to Chinese teachers (#47). In total, 45 questions were administered.

The questionnaires were designed using a Likert scale that ranged from strongly disagree (1) to strongly agree (5). The ratings aligned with empiricist to constructivist views about science (Tsai, 1998). In a pilot study (described later in this paper) some items caused confusion for reasons we were unable to discern; therefore, we added *not sure* or *uncertain* (0) as an option (see also Tsai, 1998).

Questionnaire Design: Questionnaire II with Open-Ended Questions
Questionnaire II (Q II) used the same Likert scale range and options. The 18 questions focused on a cluster of constructivist views of the nature of science and science teaching (Pomeroy, 1993) that tie to the inquiry-based science teaching and learning ideas presented to the participants in the US professor's talk (Blumenfeld et al., 2000; Krajcik et al., 1998). Another reason to have this cluster of questions was because Pomeroy's analysis (1993) of this cluster did not yield satisfactory results. Pomeroy (1993) reported that "clustering the responses to questions that would reflect a nontraditional approach to science education did not produce any indication of internal consistency" (Pomeroy, 1993, p. 265).

The questions focused on the following topics for the teachers:

1. Teachers' understanding of the theory base of inquiry-based science;
2. The possibilities of implementing constructivist approaches in their classes;
3. The barriers to implementing a constructivist approach in their classes.

Items in Q II corresponded to the pre-questionnaire but used scenarios that could happen in classrooms based on the first author's knowledge about Chinese science teaching and the research literature. In order to capture participants' rationale for their choices, we asked, "please explain your idea" after each question. This information enabled us to understand teachers' responses as tied to features of their practice. We hypothesized that both the culture and the environment would impact on teaching and learning practices. For example, whether resources would be available for students to conduct investigations in authentic settings might be a problem for a class comprised of 50 students. Q II enabled us to gather information about such opportunities and barriers.

Pilot Study for the Validity of the Questionnaire

A group of sixteen Chinese K-12 principals from Tianjin, China visited the University of Michigan prior to this study and piloted the instruments. Two criteria for administrative positions in Chinese schools include that principals are both experienced and are considered good teachers as recognized by students, parents, and colleagues. Participants in the exchange program were selected from all 18 school districts in Tianjin according to the reputation of their schools, their past research and achievement in teaching and administration, their English proficiency, and their representativeness (i.e. from elementary to senior high school; from literacy majors to science majors).

The pilot surveys took principals about 1.5 hours to complete, including time to provide feedback about clarity of the questions. Our goal was to have each part of the survey take no more than 20 minutes; therefore, the number of items needed to be reduced. We revised or deleted questions according to the feedback. The principals had little difficulty understanding the questions. However, one principal stated that the more he thought about them, the less certain he was about his answers. We found similar reports in other studies (e.g., Tsai, 1998); therefore, we added "uncertain" or "not sure" as an option (0 on the scale). Because the principals had a broad range of expertise, not likely to be true in science and science teaching, their answers to Q I were not further analyzed. The pilot study did show that the length and content of Q I was appropriate for our goals.

Interviews

In order to collect more information about survey responses, we interviewed 12 participants, 4 from each of the 3 cities (see Appendix for protocol). The researchers asked organizers at each institution to recommend participants from each category[5] based on information in their conference registration. The first author confirmed their selections and asked participants to voluntarily participate in an interview.

The interview focused on the possibility of implementing constructivist theory and practices in participants' classes or schools. Questions focused on the same topics as Q II, but enabled researchers to triangulate and further understand the survey answers:

1. Teachers' understanding and their own beliefs of the theory base and practices of inquiry-based science;
2. Teachers' consideration of the possibilities for implementing constructivist approaches in his/her classes;
3. Teachers' consideration of the barriers to implementing constructivist approaches in his/her classes;
4. Teachers' ideas about ways to overcome the barriers to implementing constructivist science teaching and learning approach in his/her classes and in Chinese schools at large;
5. Teacher educators' ideas about whether Chinese science teacher education has prepared teachers to use inquiry-based science approaches.

Data Collection

Questionnaires I and II were administered immediately before and after the researcher's presentation at each site. The first author conducted interviews following the presentations. Across the three sites, we obtained 230 responses to Q I and 170 responses to Q II. For the twelve interviews, we obtained six hours' of audio recordings.

Data Analysis

For the survey data analysis, we included questionnaires with a small number of missing cases (e.g., 90% of questions answered). Several questionnaires from participants who had recently graduated from teachers' colleges were excluded because they did not yet have teaching experience. Fewer participants returned Q II than returned Q I, mainly for logistical reasons. Because of time constraints, Q II was not administered (as planned) right after the US professor's talk but was delayed. Teachers either completed the survey during lunch break or at the beginning of an afternoon session. Some participants did not bring the questionnaires back; some were not present after the sessions.

Numerical data from the questionnaires were imported into SPSS from MS Excel for further statistical analysis. In order to analyze data, we divided participants into two groups according to type of institution. We called those who worked in K-12 schools, "school teachers." In China, schools recognized by provinces or local education governments are called

TABLE I

Characteristics of survey participants

	School teachers (SD)	Teacher educators (SD)	Total
N	166	54	220
Gender (male, %;	40.4%;	53.7%;	43.6%;
female, %)	59.6%	46.3%	56.4%
Age	28–45	32–51	N/A
Key schools	45.8%	N/A	N/A
Years of teaching	5.5–22	5–20.5	N/A
Average class size	49(± 6)	46(± 18)	N/A
Number of publications	2.3(± 8.6)	5.7(± 8.5)	N/A
Chemistry major	140 (84.3%)	26 (48.1%)	166 (75.5%)

Note. 1. SD = standard deviation. 2. “Key schools” are those schools that are recognized by the state or local government as “better” schools than their peer schools. 3. Since our focus is K-12 school, “class size” of colleges, “key schools” of teacher educators’ institutions are marked as “N/A.” 4. Because the majority of the participants are chemistry teachers or chemistry teacher educators, we report their number and percentage here. Other teachers and teacher educators are from the subject areas of biology, 18 (8%), physics, 20 (8.9%), and math 9 (4%). There were few teachers who have taught more than one subjects but one of the major subjects was usually chemistry.

“key schools.” They may be provincial key schools, big city key schools, or local school district key schools. Key schools have privileges in obtaining more government funding and recruitment for both students and teachers. Therefore, they were the best-equipped schools with the best students and teachers (Wang & Zhou, 2002). The majority of the K-12 schools, however, are simply called “regular schools” and are not offered the same privileges. Most teachers reported that they had taught at more than one grade level in their professional career. Class sizes reported were the average number of students in the classes they had taught.

Participants from ‘normal’ (meaning teacher education) universities, teachers’ colleges, and research institutes we called the “teacher educators” group. Although the conference was advertised for teachers and teacher educators from all fields of science, the colleagues who organized the conferences in China were chemistry teacher educators. Since it was more convenient to contact colleagues who were familiar, most of the participants were also from chemistry education. Participants’ demographic information is provided in Table I.

Chi-square tests and T-tests were used to compare the teacher group and the teacher educator group in terms of both their demographic information and their responses on the questionnaires. Cronbach's value was used to group the questionnaire questions into four sub-groups in terms of the participants' answers to the Likert scale questions to measure validity or internal consistency of questions in a cluster. The characterization of the questions according to their answers was based on the classification presented in Pomeroy (1993) and Tsai (1998).

Based on the research literature and the Chinese authors' understanding of Chinese education, we identified likely opportunities and barriers to inquiry-based teaching in China, and initially used those categories to code interview transcripts and open-ended responses on Questionnaire II. In this preliminary analysis of the data corpus, we found those codes to be adequate for our purposes, as well. For the qualitative analysis of both oral and written responses, we coded the following:

(a) Teacher preparation and practices: how did teachers talk about their own difficulties? How did teacher educators talk about pre- and in-service teacher education?
(b) Administration and curricula: how did interviewees talk about an inquiry-based approach with support or barrier from administration and curriculum perspectives?
(c) Evaluation: how did teachers and teacher educators talk about the impact of student evaluation on the implementation of inquiry-based science?
(d) Students: how did teachers, teacher educators, and researchers talk about or predict students' responses to inquiry-based science?
(e) Teaching environment and resources: how did teachers and teacher educators talk about whether the teaching environment and resources were sufficient for inquiry-based science?

FINDINGS

Although the confusion some participants expressed in our pilot study prompted us to add the option of "0" ("not understanding or uncertain") to our questionnaire, very few participants in the actual administration chose that option. Therefore, this choice was not included in the data analysis we present. Because the nature of their work is different, we compared teachers and teacher educators as different groups and anticipated that there would be differences between the groups. Teacher educators are expected to have higher education levels, are expected to know more about education theories, and educational research is part of their job responsibilities. The two groups did not show any statistical differences in terms of the participants' gender (Chi-square test, $p > 0.05$) and years of teaching (T-test, $p > 0.05$). However, the two groups of participants did differ in terms of their age (teacher group: mean = 36.5, SD = 8.4; teacher educator group: mean = 41.8, SD = 9.1) and average number of publications (teacher group: mean = 2.3, SD = 8.9; teacher educator group: mean = 5.7, SD = 8.5). There may be no gender difference because China once had a uniform national science education standard (called the national syllabi by subject area, such as national physics syllabi) (Li, 1997) so that everybody concerned would follow the same syllabi, which had never addressed gender issues. Also because of the uniform national syllabi for all subject areas, we did not differentiate teachers and teacher educators in chemistry from other subject areas. Although there was a significant difference between the two groups of participants in terms of the number of papers published, it seemed unusual that the teacher group had an average number of publications of 2.3 with a standard deviation of 8.9 because these teachers were relatively young (mean = 36.5, SD = 8.4). One reason may be that those teachers were usually the best teachers from the best schools and were more likely to be funded.

Although conceptually we considered science teachers and science teacher educators as two different groups (Paine & Ma, 1993), we did not find differences in their responses on the questionnaires (T-test, $p > 0.05$). Therefore, assuming that the two groups were somewhat homogenous, the following analyses considered the two groups of participants as the same ("teachers" or "educators"). The population size for Q I was 220 and for Q II was 166. There were missing cases for some questions; we report the N value if our statistical analyst judged that the missing cases might contribute to a biasing of the results. We analyzed participants' responses according to "traditional" and "constructivist" views for each of the four research questions that guided this study.

Question 1: What Are Chinese Science Teachers' Beliefs about the Nature of Science?

Traditional View of Science

As shown in Table II, the internal consistency or reliability for these statements was moderate (Cronbach's $\alpha = 0.517$). This value is lower than the alpha value in Pomeroy (1993) ($\alpha = 0.651$). One possible explanation is that in Pomeroy's study, the scientist group contributed consistently and

TABLE II

Results of multiple choices questions in Questionnaire I

	Question number	Cronbach's coefficient (α)	Average score (SD) [N]
Traditional view of science (Cluster 1)	q1, q7, q8, q10, q13, q15, q16, q20, q26	0.517	3.7 (± 0.4) [220]
Constructivist view of science (Cluster 3)	q3, q5, q6, q11, q12, q17, q19, q21, q22, q24, q25, q28	0.610	3.7 (± 0.4) [220]

Note: SD = standard deviation; N is the sample size.

stably to the traditional view of science. The distribution was approximately normal, and there seemed to be a relative agreement with these statements (Cluster 1; mean = 3.7, SD = 0.4).

Constructivist View of Science

In Table II, the internal consistency for these statements was moderate (Cronbach's $\alpha = 0.610$). The distribution was approximately normal, and there seemed to be relative agreement with these statements (Cluster 3; mean = 3.7, SD = 0.4).

Interestingly, the same population of science teachers and teacher educators agreed with both traditional and non-traditional views of science, apparently holding the two conflicting views simultaneously. One possible interpretation is that one paradigm did not disappear as a new paradigm emerged, but that the conflicting paradigms co-exist (see Shulman, 1986). Also, Chinese science educators are experiencing a transition in nationwide educational reform so that conceptual change might happen prior to change in practice (Richardson et al., 1991). There seems to be a growing awareness of non-traditional science practices as the Chinese government promotes non-traditional science teaching approaches from official documents, educational journals, and workshops. Most of the teachers interviewed mentioned open and demonstration classes they had done, or that they had watched influential classes. However, an *awareness* of non-traditional views does not mean that the ideas are well understood or are necessarily supported or enacted by those who learn the new ideas. These realities likely contribute to the finding that conflicting views co-existed for many participants. Also, barriers impede the sustainable efforts of implementing inquiry-based teaching practices, which likely shapes the view of participants (discussed in question four).

TABLE III

Results for multiple choices questions in Questionnaires I and II

	Question number	Cronbach's coefficient (α)	Average score (SD) [N]
Traditional view of science education (Cluster 2)	q2, q14, q23, q29, q31, q32, q34, q35, q36, q37, q41, q43, q44, q45	0.717	3.1 ($\pm$ 0.5) [220]
Constructivist view of science education (Cluster 4)	b1, b2, b3, b4, b5, b10	0.575	4.1 ($\pm$ 0.4) [150]

Note: SD = standard deviation; N is the sample size.

Question 2: What Are Chinese Science Teachers' Beliefs about Science Teaching and Learning?

Traditional View of Science Education

In Table III, the internal consistency (Cronbach's $\alpha = 0.717$) is relatively strong for those statements. The responses were mixed but generally neutral, or balanced (mean = 3.1, SD = 0.5). This result seems to confirm the explanation given for Question 1 about why participants held conflicting views of science. Teachers were in a stage of transition from traditional to non-traditional views of science and science education.

Constructivist View of Science Education

Questions in this cluster were administered in Q II for reasons previously noted. The questions reflected one type of constructivist approach to science education (Krajcik et al., 1998) according to what the US professor presented to participants. The internal consistency for test statements was moderately strong (Cronbach's $\alpha = 0.575$). The distribution was approximately normal. The responses tended toward a strong agreement with those statements in the cluster (mean = 4.1; SD = 0.4).

Correlation between Clusters

There were significant correlations, not unexpected, between traditional views of science and science education ($R = 0.397$; $p < 0.01$) and non-traditional views of science and science education ($R = 0.255$, $p < 0.01$). It is also not unexpected that there was an insignificant correlation between traditional views and nontraditional views of science education ($R = 0.055$; $p < 0.01$). However, the correlation between traditional views of science and nontraditional views of science education is a surprising finding ($R = 0.348$, $p < 0.01$). It is likely that participants' views of constructivist approaches to science education were influenced by the US professor's talk because Q II was completed immediately following. Closer analysis of participants' responses to the open-ended questions and their responses in interview transcripts provided more information about our Chinese colleagues' views. These will be addressed in the following two sections.

Question 3: What are Chinese Science Teachers' Responses to Constructivist Science Teaching and Learning Theory and Practices?

Statistical analysis of responses on Q II and the open-ended items provided data related to this question, and qualitative analysis of interview transcripts was used to confirm or refute our assertions.

Participants' Conception of Constructivist Teaching Theories and Practices

Their responses on Q II revealed that Chinese science teachers and teacher educators had relatively strong agreement with constructivist views of science education. However, their conflicting responses about traditional views and constructivist views of science complicated the situation. A neutral response (mean = 3.1; SD = 0.5) to traditional views of science education also did not confirm strong agreement with constructivist views of science education. In addition to the transition-between-paradigms explanation, the relative lack of education about the nature of science might also mean that there was no clear conception about what counts as nontraditional or traditional views. This is discussed in the following sections.

Participants' Teaching Practices in Reality

There was no clear indication from our data that the current inquiry-based teaching oriented education reform was a systemic reform that would be sustained. This was in conflict with a strong agreement with the constructivist view of science education.

First, there was no consensus about what "inquiry-based" science teaching looks like. There is a lack of good examples such as schools with open and demonstration classes in which a teacher tries innovative ways of teaching. Interview participants Ms. Yu, Ms. Dai, Ms. Yao, and Ms. Situ all mentioned that demonstration classes of inquiry-based teaching must have some kind of computer technology use, such as power point, or teachers developed software to teach students important content. It seemed that technology use became fashionable – a symbol of modern teaching. However, the students did not have any opportunities to use the software that their teachers developed because the software could not support students' inquiry as well as collaboration in science learning. So while the use of technology is viewed as an important aspect of science education, the use of technology to support inquiry-based learning is not a classroom reality in China.

Second, the effort to support inquiry-based teaching and learning cannot be sustained under the current education system. Ms. Yao indicated that an excellent physics teacher, who had won a national young teacher innovative teaching award for using inquiry-based teaching in an exemplary demonstration class from her school, "transformed a twelve-character conception in the physics textbook into a period of inquiry-based class." However, the teacher admitted that he could not use that approach in his daily teaching because it took too much time to prepare, and he could not satisfy his current class schedule in order to meet the current method of assessing students' achievement. Ms. Hu also made this point, although there had been a longer period time (one chapter of the textbook for one month) that she used inquiry-based teaching approaches for a research project, she prepared her organic chemistry unit classes with the help of other researchers (Hu, 2001). The same level of support would not be available at the end of the project when the researchers withdrew from her class.

The Teaching of the Nature of Science in Teacher Professional Development Programs

Since we had identified teachers' conception of the nature of science as an influential factor in their science teaching practices, we asked, "Have you taken course(s) about 'the nature of science' either in your own training experience or your work as a teacher educator?" More than 90% of the participants did not have such an experience. China once had a nationwide, uniform national curriculum standard and one set of textbooks, and a senior chemistry textbook developer as well as researcher, Mr. Li, indicated that they did not have such content in their teacher training programs. However, we did find that some in-service teachers' colleges in Beijing covered the nature of science in their workshops on science education and reform once every year for the past four years. Some key schools also had such content in their workshops for teachers. One university-affiliated school in Beijing had a seminar for science students as an extracurricular activity. Therefore, we are confident that the reported lack of such content was not due to translation but to the fact that the nature of science had not become part of most pre-service curricula. A typical response reveals the situation of how a teacher's beliefs about the nature of science developed. Ms. Hu from a regular school in Beijing recalled:

When I was in high school, I felt that there was only one correct answer to any question in science. When I started learning theories in chemistry in college, I found that it was hard to believe in any theory such as the movement of electrons because there were always alternative explanations to a science phenomenon. Then when I was in graduate school and took some courses about philosophy of science, I finally realized what was 'the nature of science' conceptually.

In China, most of the science teachers were not like Ms. Hu; they did not get access to knowledge about "the nature of science" because very few of them could have the opportunity to go to graduate schools. Therefore, there is a need to introduce courses about "the nature of science" for both in-service and pre-service teachers.

Question 4: What Are the Opportunities and Barriers for Chinese Science Teachers in Adopting Inquiry-Based Teaching Practices?

Findings for this research question came mainly from the open-ended answers and the interview transcripts. We identified both opportunities and challenges for each of the five aspects of the education system we analyzed: administration and curricula; teacher preparation and practices; students; evaluation, and teaching environment and resources. Our findings are presented according to each of these categories.

Administration and Curricula

Opportunities exist for adopting an inquiry-based approach to science education in China, especially since the Chinese government realized the drawbacks to traditional science education, and the State Council and Department of Education began to promote inquiry-based science teaching approaches (SCC, 2001). However, the development of different areas in China is very unbalanced. According to Dr. Wang, a member of the new national chemistry curriculum standard group, China had not included inquiry-based science in its formal science curricula.

Right now we just had some allocation of time blocks that did not take any of the original time of any science subject matter, but had a few special time blocks as well as after class activities that were used for inquiry-based science projects. The reason was that this kind of curriculum was still under-developed. Another reason was that the inquiry-based project, such as exploration of water ecology, was interdisciplinary so that very few teachers could teach in more than one science subject area due to the current teacher education system.

Dr. Wang also identified important barriers to inquiry-based approaches in China, the most significant of which is the need for a system that supports innovative science teaching and learning. Even within such a system, large class sizes were not likely to change because of the amount of financial support needed to have smaller classes. Making this kind of change was even more difficult than changing the college entrance exam or the evaluation system. Teachers were resistant to change because changes took extra time and energy, and sometimes the change was risky. Teachers were not well prepared to change from traditional methods of teaching science to inquiry-based teaching. Dr. Wang was very disappointed with the way science teachers were taught in normal universities. The teaching approach in normal universities was still very traditional; therefore, pre-service teachers' training lagged behind the needs of inquiry-based teaching.

None of the interview participants mentioned the importance of others' research to guide their decision-making and implementation of non-traditional science teaching practices. Several interviewees mentioned their own research and provided samples of their research; however, there was no rigorous research design for their studies, and very few of them produced data. This suggests a need for the support of empirical research from the administration of the educational system in China.

Teacher Preparation and Practices

From their strong agreement with constructivist ideas about teaching, we can see that teachers had realized the drawbacks to traditional ways of science teaching. As we found from both interviews and questionnaires, many teachers had been actively involved in some kind of innovative teaching. Usually the new way of teaching was shown in their open and demonstration classes to colleagues in the same school, the school district or even at a national level. However, this kind of initiative could not be sustained for lack of systemic support. As shown in our analysis, participants in this study (as a group) held conflicting views about the nature of science, and science teaching and learning. Given that the participants in this study were interested in inquiry-based science (and who represented schools in which there was an interest in inquiry-based science) the results suggest that teachers were not well prepared for adopting inquiry-based teaching approaches. This means that inquiry-based approaches to achieving a "science for all students" goal and improving science literacy is not yet possible.

Students

We do not have data from students in this study, but we were able to obtain some information about students' responses to inquiry-based teaching from anecdotal accounts of the participants. Ms. Hu, from a regular school in Beijing, had been using inquiry-based teaching for one month. According to the research with her class (Hu, 2001), many students welcomed the new way of science teaching and learning, and Ms. Hu described rapid and positive changes for some students who had not liked chemistry. However, some good students under the current system resisted new approaches. They were successful using traditional approaches and were afraid of losing their advantage if science instruction became inquiry-based. Their motivation for hard work in science was for good scores in order to go to college. These responses are understandable from those who are successful in traditional classrooms, yet they represent barriers to reform efforts as teachers must deal with students' resistance to change.

Evaluation

Almost every survey and interview participant mentioned the influence of college entrance examinations on teaching practices. Ms. Zhang indicated that if a school did not maintain or increase its student acceptance rate into colleges, the principal and the district head of education could be removed from their positions. According to many participants, the Chinese college entrance exam continues to favor traditional methods of teaching. Currently, the exam functions as one of the barriers to implementing inquiry-based science because it is difficult for the exam to evaluate students' learning in process. It is impossible for educators to discount the national college entrance exam because it is widely considered to be a fair exam and is seen by some people as a guarantee that students from any family background have equitable access to college. The good news, according to several interviewees, was that the college entrance exam is changing to include more test items that could reflect the results of inquiry-based teaching and learning.

Teaching Environment and Resources

In the narrowest sense, the teaching environment is just the classroom in which formal teaching takes place. From our survey, we found that Chinese schools, on average, had large class sizes (49 ± 6). The typical arrangement of the classroom is with the teacher at the front of the room, and the students and teacher facing each other. It is difficult for students to move around when tables are arranged together tightly. In order to have a small group discussion, some students have to turn around in their seats. Although this does not prevent group work from being implemented, the physical environment constrains inquiry-based teaching approaches. However, teachers were optimistic about solving this problem. On the relevant item on Q II, participants were asked, "Is it still possible for large class (more than 45 students) to implement 'inquiry-based' science approach?" Results showed moderate agreement with the statement (mean = 3.4; SD = 1.0). Teachers who were optimistic or had tried inquiry-based science said that dividing students into small groups was or would be a feasible arrangement for inquiry-based science learning.

In a more broad sense, the teaching environment includes the entire educational system, including the larger cultural environment with influences such as the media, parents and influential others, and the whole society as a community of learners. Resources are limited. For example, there are few good textbooks for inquiry-based science. There were no science databases that could be used by students for "authentic" inquiry practices. Those participants interviewed said that the educational software available to them was primarily for test preparation under the traditional approach. The larger society, overall, has not recognized the importance of innovative science teaching. Ms. Yao, for example, was concerned with safety when students planned a project requiring chemicals that teachers and parents had not been widely aware of.

Limitations of the Study

This study has a number of limitations. First, the survey instrument's reliability may be affected by issues in translation. We used our pilot study to address this issue. Second, the US researcher's presentation, which occurred between completion of the first and second questionnaire, might affect the reliability of the results, as inquiry-based approaches were fresh in the minds of participants. Third, biased sampling is a primary consideration (Pomeroy, 1993). The group of teachers and teacher educators selected as interviewees had chemistry backgrounds, although 25% of those in the science teachers or teacher educators groups were from other science fields (e.g., physics, biology). Participants either self-selected or were selected by their schools. They were likely individuals and schools interested in inquiry-based science, and probably obliged to participate according to the national reform curriculum plan. Participating teachers came primarily from schools in well-developed large cities or in areas with better economic situations. However, if we can identify barriers for these teachers who are from the best schools in China, we can reasonably infer that the change to inquiry-based teaching approaches is going to be even more difficult in regular schools and in less developed areas in China. Teachers from less developed areas are likely to lack materials and supplies, and to have limited access to professional development that would provide ongoing support for teachers new to inquiry-based approaches.

Conclusions and Discussion

Four themes resonated across participants' responses on questionnaires and in interviews that merit further attention.

Chinese Science Teachers Had a Mixed View of Science and Science Education

Although both Chinese teachers and teacher educators tended to agree with constructivist views of science and science education, the means were relatively low except for the constructivist view of science education ($M = 4.1$). Furthermore, there was a significant ($p < 0.01$) correlation between traditional view of science and nontraditional view of science education. These results demonstrate that Chinese teachers are in a transition between accepting nontraditional views of science education while still holding a traditional view of science that might have a large impact on their teaching practices as a long time tradition. Although they may see value in inquiry-based approaches, they may not find it easy to reconcile those beliefs with long-held traditional beliefs that reflect the ways in which science were taught during their own school experiences.

The Nature of Science Should Be Part of the Curriculum of Teacher Professional Development Program

Given that the nature of science has been largely missing from Chinese science teachers' professional development programs, especially in pre-service teacher preparation programs, there is an urgent need to foster teachers' beliefs through systemic professional development. Furthermore, a systemic reform effort in normal universities could address the problems inherent in the "reconciling" process as described. That teachers teach the way they were taught is a common understanding among teacher educators, and this reality needs to be addressed systematically in the places where new teachers are prepared to become the future educators.

There Is an Enthusiastic Interest in Inquiry-Based Science Teaching among Chinese Science Teachers as Well as Science Teacher Educators

The participants in this study realized that inquiry-based science approaches are a good way to teach science. The state government promotes mandatory inquiry-based science in some schools, and participants described real actions in implementing and experimenting with inquiry-based science in middle and high schools. Teachers were seen to be in a transition period between holding only traditional beliefs and understandings about science teaching to developing beliefs and understandings that are non-traditional, and they seemed especially interested in inquiry-based teaching.

The Challenges Were Serious for Adopting Inquiry-Based Science Approach in Practice

Although Chinese science educators embraced the idea of constructivist theories and practices, in reality, very few of them had actually practised such teaching. Five major challenges to adopting inquiry-based science learning and teaching approaches in Chinese schools were identified in this study. First, college entrance exams have the biggest influence on the way science is taught and learned. The college entrance examination could diminish educational reform gains if the exam does not also undergo reform. Traditionally, exam scores have been used almost exclusively as the criterion for college admission. Unless the exam evaluates the results of inquiry-based science, it will be difficult to change teaching practices, and to justify those changes. Further, students' performance in formative and summative assessment at all grade levels, especially at high school, should be considered for college admission, which is currently not common.

Second, systemic reform needs to happen in order for inquiry-based science to be beneficial to students. This includes a change in the curriculum plan, curriculum materials and relevant resources, and teacher professional development. Third, pre-service teacher preparation was identified as lagging behind the current educational reform in China. Fourth, large class sizes (average class size was 48 ± 6 from our sample) complicated classroom management and teacher individual feedback.

Fifth, although our participants were mostly from urban schools and from wealthier areas, they identified that materials, resources, teacher preparation, and student experiences as factors that affected the implementation of inquiry-based science teaching and learning in their schools. Because a majority of Chinese students attend rural schools, this lack of resources and materials will pose additional challenges to implementing inquiry practices in many more Chinese schools than were represented in this study.

In summary, this study was the first attempt to characterize Chinese science teachers' beliefs about science and science education. We found that Chinese science teachers, science teacher educators, and researchers' beliefs about science and science education were in transition from traditional to constructivist thinking. However, the implementation of constructivist approaches to science education was a serious challenge for participants due to the lack of systemic support within the current Chinese social and education system. Primary concerns include administration and curricula, teacher preparation, students' expectations, evaluation of students, the teaching environment and available resources. Clearly there is no simple process of implementing inquiry-based approaches that involves only presenting ideas to teachers, teacher educators, and researchers. This study provides evidence that Chinese educators recognize the potential of inquiry-based approaches, and that they are enthusiastic about such approaches, but that the barriers they face are a reality that affects implementation of inquiry-based science teaching and learning in Chinese schools.

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APPENDIX. REPRESENTATIVE STATEMENTS AND QUESTIONS

The Nature of Science (Questionnaire I)

- The process of scientific discovery often involves an ability to look at nature phenomena in ways that are not commonly accepted.
- There are some scientific studies which are considered valid and significant which are not based on experimentation.
- Insofar as a theory cannot be tested by experience, it ought to be revised so that its predictions are restricted to observable phenomena.
- Science is a set of practices and a body of knowledge developed by a specific community of people.

- The purpose of science is to establish intellectual control over experience in terms of precise laws which can be formally set out and empirically tested.
- In science education, a few concepts explored deeply are more desirable as a goal than a broad overview.
- A big weakness of discovery activities in science education is the difficulty in getting the children to come up with the right answers.
- It is important that students have the correct concepts before going on in their science learning.

Inquiry-Based Teaching and Learning (Questionnaire II)

- Scientific knowledge is subjective and changeable so that we can not expect any problem will have only one solution.
- Students need to collaborate while doing inquiry. They need to discuss, negotiate about what they are learning to help them build understanding of the concepts and principles.
- The scientific knowledge that students learn are facts and methods that have been tested by scientists. Therefore, it's accurate and unproblematic.
- To help students learn science, it is important to engage them to do scientific practices that are similar to those of real scientists.
- Students should find what they are learning in science class meaningful and valuable to their lives.
- As a faculty in my normal university (or as a science teacher now), I think the curricula and education we have for pre-service teachers are sufficient for inquiry-based science teaching in K-12 schools in China.
- In my school and/or school district, I think the following teaching and learning theories and practices are innovative and have the potential to improve student science learning.

Interview Questions

- Have you ever learned something about "the nature of science"? If yes, when and how?
- How do you define the term "the nature of science"?
- Could you please describe a typical class that your teach? Considering this kind of daily practice, how does it help students develop substantive understanding of science content and process?
- What do you do in you teaching that is similar to what you heard today?

- Are you going to do something differently to promote students' scientific inquiry after today's presentation? What will you do?
- Do you think classroom environment will affect how inquiry-based science will be implemented? For example, how teachers and students' desks are arranged in classrooms.
- The following items are from your pre- and post-questionnaires, I want to clarify the answers with you.

NOTES

[1] We searched the literature in two time periods – 1994–2000 and 2001–2003. In 2001, the State Council of China officially encouraged schools to adopt inquiry-based, K-12 teaching approaches. Typically, official documents have a major impact on practice in Chinese schools.

[2] In this paper, we use "constructivist views" and "nontraditional view" interchangeably. We also use "empiricist view" and "traditional views" interchangeably.

[3] In order of attendance, the participants were from: Beijing, Guangdong, Shanghai, Jiangsu, Chongqing, Sichuan, Shanxi, Zhejiang, Jiangxi, Shandong, Hubei, Hebei, and Fujian provinces.

[4] The first author has been both a classroom teacher and a pre-service teacher educator, is Chinese, and has an understanding of Chinese science teachers' cultural backgrounds and educational experiences.

[5] *Classroom teachers* refer to participants who teach in K-12 schools. *Teacher educators* and *researchers* refer to both in-service teacher educators and pre-service teacher educators. In-service teacher educators are from local teachers' colleges and pre-service teacher educators are from normal universities.

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