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As an infused or a separated theme? Chinese science teacher educators' conceptions of incorporating Nature of Science instruction in the courses of training pre-service science teachers

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ABSTRACT: Teaching nature of science (NOS) is beginning to find its place in science education in China. This exploratory study interviewed twenty-four Chinese science teacher educators about their conceptions of teaching NOS to pre-service science teachers. Although five dimensions emerged, this paper mainly focuses on reporting the findings relevant to one dimension, i.e., incorporating NOS instruction in the courses of training pre-service science teachers. There were two preferences: twelve out of the twenty-four educators preferred having NOS instruction infused into the teaching of various course components, including inquiry-based science teaching approach, history of science, science subject content, and school science textbook analysis. The others chose to have a separated NOS module in their courses, though they indicated NOS might be also touched upon in other course components. It was found that three factors influenced their preference; the textbooks currently used by Chinese science teacher educators to train pre-service science teachers, their views of NOS content to be taught, and their vision of teaching NOS. We argue that the findings in this study provide some hints on ways to encourage science teacher educators to give higher priority to NOS instruction in their courses, which is believed necessary for achieving the goal of developing public's scientific literacy.

KEY WORDS: Nature of Science, teacher educator, teacher education, pre-service science teacher

INTRODUCTION

Nature of science refers to various aspects of science, including the characteristics of scientific inquiry, the role and status of scientific knowledge, how scientists work as a social group, and how science impacts and is impacted by the social context in which it is located (Wong & Hodson, 2009, 2010; Clough, 2006; Irzik & Nola, 2011). There has been a long history in Western science education to advocate the goal of developing NOS understanding. The earliest statements of this objective can be found

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at the beginning of the last century (Hodson, 1991), while in recent decades, the objective of developing NOS understanding has begun to be explicitly emphasized in science education reform documents in the Western World (AAAS, 1990; CMEC, 1997; NRC, 1996)[§].

Although NOS has been one of the commonly researched topics in science education, there are also many disputes on what NOS really is (Alters, 1997). It is typical to classify the different views of science broadly into two groups in terms of Kuhn's (1962) Structure of Scientific Revolution (e.g., Lin & Chen, 2002; Palmquist & Finley, 1997). Different paired labels are used when making such differentiation, including logic-empiricism versus post-positivism (Lin & Chen, 2002), realism versus relativism (Good & Shymansky, 2001), and traditional versus contemporary (Palmquist & Finley, 1997). The logic-empiricist, realist or traditional NOS views generally refer to those originating before 1960s, consisting of beliefs that the goal of a scientist is to discover the truth in nature, there exist the scientific method, and scientific knowledge progresses by an accumulation of observations, etc. On the contrary, the post-positivist, relativist or contemporary views roughly refer to those originating in and after 1960s, comprising the arguments that theories are the result of creative work, a single scientific method does not exist, scientific interpretations depend on their prior knowledge and the prevailing research paradigm, etc.

Prompted by the soaring economy in recent years, which has brought tremendous changes in people's lives, the Chinese government started to look for strategies to sustain long-term development of the country. These include investing in education that can nurture and prepare the future generations for the competitive global economy (Wan, Wong, & Yung, 2011; Wan, Wong, & Zhan, 2012). Within science education in China, in parallel with the international trend, there is a transition from a more elite to a more future citizenry-oriented school science curriculum, coupled with the emphasis on scientific literacy as the goals of Chinese school science education (Yung, Lo, Wong, & Fu, 2010). NOS, as one of the components of scientific literacy, has also begun to find its place in science education in China as it appears in Chinese science curriculum reform documents (e.g., MOE, 2003a; 2003b)[**]. Explicit discussion on NOS and related issues has also emerged in recent Chinese academic journals (e.g., Xiang, 2002; Yuan, 2009) and some textbooks for training science teachers (e.g., Liu, 2004; Yuan & Cai, 2003; Zhang, 2004).

NOS instruction has been studied and reported in the Western world for a number of decades, so Western science education practitioners' views of NOS education can, to some extent, be informed from the litera-

[§] AAAS is American Association for the Advancement of Science. CMEC is Council of Ministers of Education, Canada. NRC is the National Research Council of America.
[**] MOE is the Ministry of Education in the People's Republic of China.

ture. However, little is known about how the teaching of NOS is perceived in China, which has its own unique social, political and historical background. An exploratory study was conducted to investigate Chinese teacher educators' conceptions of teaching NOS to pre-service science teachers. Five key dimensions emerged from the data. This paper focuses on reporting one dimension, i.e. incorporation of NOS instruction in science teacher education courses.

TRAINING PRE-SERVICE SCIENCE TEACHERS IN CHINA

Generally speaking, there exist two different modes of training pre-service science teachers. For the first mode, in order to be science teachers, students need to enroll in a 3 or 4 year program, in which they receive a comprehensive training in both science and education. In the second mode the training of science and education is separated. Students first obtain a Bachelor degree in science, and then continue to study for a Postgraduate Diploma in Education (PGDE) to become qualified as a science teacher. In Mainland China, pre-service science teachers are mainly trained through the first mode in a large number of Normal Universities and Institutes of Education which specialize in teacher education. These universities and institutes also have specific divisions or faculties for different science subjects and pre-service teachers of different science subjects are trained in the corresponding science divisions or faculties, although there is no regulation as to which science division or faculty is responsible for training pre-service integrated science teachers in Mainland China. All depends on which division or faculty has applied to operate such programs and obtained approval from the Chinese Ministry of Education.

Although the programs of training Chinese pre-service science teachers may differ in the detailed arrangement, they similarity comprise of three major components. The first is general courses, including English, Physical education, Information Technology, Politics, Art, and etc. These courses are common for college students of all majors, taking up about thirty percent of total credits. The second and also biggest component is science courses and experiments, which aims to enhance students' understanding of their science subject. This part occupies about forty percent of total credits. The last component of the training programs for Chinese pre-service science teachers is oriented to education, covering about thirty percent of total credits. It normally consists of courses on education in general (e.g., Basics Education Theories, Educational Psychology, and Educational Technology), the courses relevant to science education (e.g., Pedagogy of Science, History of Science, Science Laboratory in School), as well as eight to ten weeks for teaching practicum. Among these education-oriented courses, Basics Education Theories, Educational Psychology, and Pedagogy of Science are compulsory, while Educational Technology, History of Science and Science Laboratory in School are elective. Chinese science teacher educators are mainly responsible for teaching this last component. At the same time, some also need to teach science courses and experiments.

RESEARCH METHODS

Participants

The subjects in this study are science teacher educators from the most economically developed regions in China, including Shanghai, Beijing, and cities in provinces of Jiangsu, Zhejiang, and Guangdong. Given considerable time and efforts needed in the present study, all the subjects participated on a voluntary basis. The snowballing strategy was the major sampling strategy adopted in the present study. The authors first contacted Chinese science educators that they knew in person and invited them to participate in the study. On completion of the interviews, each of the participants was asked to introduce other educators for us to invite as subjects of this study. Such snowballing process continued throughout the whole process of data collection. In total, forty one educators were approached by the authors and twenty four of them participated in the study. As shown in Appendix 1, these participants include considerable variations in age, major discipline taught, teaching experience and academic position.

Data collection

Interview was adopted as the research method in this study because of its efficiency and flexibility. Two semi-structured interviews were conducted in Mandarin with each participant from 2007 to 2008. The first was a general interview, during which a general open-ended question was used to probe their conception of teaching NOS: How do you teach NOS to your pre-service science teachers in your own course(s) and why? When they explained their NOS teaching practice, follow-up questions covering some aspects of such practice could be asked, including "how do you start your NOS lessons," "what are your major teaching and learning activities," "what teaching materials do you use," "what types of assignments do you give for your NOS lessons," and "how do you conclude your NOS lessons." The interview time for each educator ranged from 45 to 100 minutes.

The second semi-structured interview was a Scenario-based Interview. During the interview, each science educators was provided with five examples of NOS teaching designs (one example is attached in Appendix 2), which were constructed based on NOS instructional designs reported in the literature on teaching NOS to science teachers (Abd-El-Khalick & Akerson, 2004; Abell, 2001; Lin & Chen, 2002; McComas, 1998; Nott &

Wellington, 1998). After careful reading the 5 NOS instructional designs, the science educators were asked to talk about each of the instructional designs and how they are similar to and/or different from how they teach NOS to their pre-service science teachers in their own course(s). This interview lasted for 40-120 minutes.

Data analysis

The interview was transcribed verbatim into Chinese, then read, coded and analyzed. Translation into English was done only to the transcripts that were selected for inclusion in this paper. The explorative approach (Charmaz, 2000; Stake, 1995; Strauss & Corbin, 1990) was adopted to analyze the data collected in this study. There were roughly three phrases. Initially, the first author read the transcripts of the interview line by line repeatedly to get himself familiar with these data. Since there were too many codes in the first phrase, it was too challenging for the authors to analyze all the codes at the same time for identifying the variations embedded in the data. In order to facilitate the later analysis, the first author further grouped the initial codes in the second phrase and created a tentative label for each group.

The third phrase was the most crucial since it generated the major dimensions and the variations within them that could meaningfully characterize educators' conceptions. In this phrase, the first author, on the basis of the grouping of codes made before, continued to identify the qualitative differences in each group. Once a qualitative difference was identified, it was checked as to whether the original label of the corresponding group could cover such difference and the initial codes had reflected such difference. If inconsistence was found, further revisions were made. When the codes, groups and variations were temporarily stabilized, discussion meetings were held between the authors. Through many rounds of meeting between the authors and adopting a number of revisions, the change of code, groups and variations gradually decreased and eventually all were stabilized. In addition, during the process of data analysis the authors exposed findings and their decisions to their colleagues. Comments and acknowledgements from them for data analysis enhanced the validity and reliability of the research. The final five dimensions which emerged from the data were (i) value of teaching NOS to preservice science teachers, (ii) NOS content to be taught to preservice science teachers, (iii) incorporation of NOS instruction in science teacher education courses, (iv) learning about NOS, and (v) role of the teacher in NOS teaching. The current paper focuses on the findings relevant to only one dimension, i.e. incorporation of NOS instruction in science teacher education courses. The findings on values of teaching NOS and NOS content have been published in two independent papers (Wan, Wong, & Yung, 2011; Wan, Wong, & Zhan, 2012), and in the future the other findings will be reported.

RESULTS

As indicated in the data, there were two typical preferred arrangements for NOS instruction in courses by Chinese science teacher educators. The first was NOS instruction infused into the teaching of various course components, leading to NOS instruction as an infused theme in their courses. The other was to have a separate NOS session in their courses, which was focused on teaching NOS, though NOS might also be touched upon in other course components. Thus, in this case, NOS instruction was a separate theme in their course. It was found that half of educators incorporated NOS instruction into their courses as an infused component, while the other half taught NOS as a discrete theme. The specific arrangement of each educator can be found in Appendix 3.

NOS as an infused theme

Two kinds of experience can be used to develop NOS understanding, i.e. the first-hand experience of conducting scientific investigations and the second-hand experience of such processes through learning the history of science (Nott & Wellington, 1998). In fact, these two kinds of experience can also be used to teach other important ideas covered in other components in science teacher educators' courses. Therefore, sometimes, NOS instruction can be infused by educators into their teaching of these components. Table 1 illustrated four such components which were stated by some educators in this study, as well as the corresponding courses and learning experience used.

Table 1. Components used by educators to infuse NOS instruction

Components used by educators to infused NOS instruction	Inquiry based science teaching	History of science	Science subject content	School science textbook analysis
Courses	Pedagogy of Science Science Laboratory in School	History of Science	Science	Pedagogy of Science
Experience used	Hands-on activity	Scientific history	Scientific history	Scientific history

However, it should be noted that when NOS instruction is infused into the teaching of other components, the priority of arranging teaching activities are given to these components. For example, the sequence of overall teaching activities may be steered towards the focus of the other components in the courses. Besides, the discussion before and after hands-on activities or/and learning history of science may mainly focus on the issues of the other components rather than NOS.

NOS instruction as infused into the teaching of inquiry-based science teaching approach

In recent decades, an inquiry-based science teaching approach has been introduced into China and gained a very important status in all the newly issued Chinese science curriculum documents (e.g. MOE, 2003a; 2003b; 2003c). As indicated in the data, the inquiry-based science teaching approach was also taught by Chinese science teacher educators in their courses and, at the same time, NOS instruction was infused into such teaching.

For example, a physics teacher educator explicitly stated that "I won't use a separate session to teach the nature of science…mainly incorporate my NOS instruction into my teaching of the inquiry approach in my course of Physics Laboratory in School" (Isabella, Physics, GI)[††]. The course of Physics Laboratory in School is a selected course for pre-service science teachers in Chinese Normal Universities. Similar courses also can be found in BEd programs of training chemistry, biology and integrated science teachers. "The major goal of the course was aimed to develop student's skills of designing and teaching science laboratory in schools" (Isabella, Physics, GI). The following is her arrangement for NOS instruction in this course.

During Isabella's teaching of inquiry approach, she asked student teachers to undertake a number of explorative laboratory activities. Each time, after such exploratory laboratory work, these student teachers were guided to discuss the inquiry-based science teaching approach, such as what are features of an inquiry-based science teaching approach, how does an inquiry-based science teaching approach differ from previous laboratory teaching, what should be noted when conducting an inquiry-based science teaching approach, why do we need to carry out an inquiry-based science teaching approach, and what are its strengths and limitations. When students discuss these issues:

> I also will guide them to discuss relevant NOS content … For example, when discussing how the inquiry-based science teaching approach is different from previous laboratory teaching, I'll also discuss with students the myth of a scientific method…When I discuss with students why we need to carry out an inquiry-based science teaching approach, the tentative nature of scientific knowledge is also covered. (Isabella, Physics, GI)

As showed in Isabella's arrangement, she intended to teach inquiry-based science teaching approaches in this course and at same time incorporate

[††] "GI" means that this extract is from the general interview.

NOS instruction into her teaching of an inquiry approach. Her description also reflected that most of the discussion after the laboratory work was focused on a number of issues in an inquiry approach, like the features, strengths and limitations of this approach, etc. NOS elements were just brought in when they were relevant to these issues. Obviously, the priority in her arrangement of teaching activities was primarily given to an inquiry-based science teaching approach and NOS instruction was just infused as a secondary objective in her teaching of inquiry approaches.

NOS instruction as infused into the teaching of history of science

History study has been long valued in Chinese culture, and the teaching of History of Science emphasized from a Chinese prospective in science teacher training program. The earliest inclusion of a course on the History of Science in Chinese prospective science teacher program could be traced back to 1950s, when Beijing Normal University incorporated the course of History of Chemistry as an elective course for prospective chemistry student teachers (Liu, 2005). In the present study, NOS instruction was incorporated by some Chinese educators into their teaching of history of science in this course. The following is an example.

In Tom's course of History of Chemistry, he first illustrated the chronicle development of Chemistry. At the same time, he also asked the students to discuss the development of some specific themes in chemistry. For instance, when teaching the periodic table of chemical elements,

> I'll ask the students to find relevant materials to determine what research work had been done on chemical element before Mendeleev's periodic table of chemical elements, what was the social background, what motivated Mendeleev to do such research, how he did such research, what controversies appeared after this table was published, and what made people to accept such a table…I'll ask student to talk about them in the lessons. After their discussion on those issues, students can also be guided to further think about a scientific spirit… the scientific worldviews… and logic methods in the scientific investigation in examples of history of science. (Tom, Chemistry, SI) [‡‡]

The major resource in the course of History of Science is the stories of scientists and scientific ideas. Although such resource can be used to achieve various kinds of goals, the understanding of the historical development of science is intrinsically worthwhile in itself (Matthews, 1994). In Tom's course, the stories of scientists and scientific ideas were used here to achieve two goals, the history of science itself and NOS. According to the educator's description, before the lessons, students were asked to think about a number of key elements of the history of science, such as

[‡‡] "SI" means that this extract is from the scenario-based interview.

why a scientific issue was raised, what was the historical and social background to raise such a question, what had been done before such a question was raised, how the scientist studied such questions, etc. During the lesson, his students were expected to first discuss these issues and then, to discuss relevant NOS aspects. Apparently, such a teaching design emphasized the teaching of history of science itself more than promoting an in-depth appreciation of the relevant NOS aspects. Again, the infused NOS instruction was merely a side-product of the teaching of history of science.

NOS instruction as infused into the teaching of science subject content

As Chinese science teacher educators are working in science departments of Normal Universities or Institutes of Education, some teach science content course to pre-service science teachers. This course was also mentioned by some educators in this study as a context to infuse certain NOS features in their instruction. The following is an elaboration provided by a physics teacher educator. As he stated:

> When I teach Physics courses, I don't want to just teach physics knowledge, but also expect students to know the history of science…Since the content of the history of physics is too broad, I'll just focus on the historical development of several classic physics areas of knowledge, like Newton's laws of force and motion, law of electromagnetic induction and the wave-particle duality of light. (Joseph, Physics, GI)

When teaching these topics, Joseph asked the student to make presentations in the classroom on those classic content areas. Two aspects were expected to be included in the presentation. The first was the historical development of the content itself, i.e. the past and the present aspects. The second was what lessons they could learn from the historical development. After the student's presentation, he also organized students' discussion on those issues. After discussing those issues, students were guided to talk about the relevant NOS content.

> The history of wave-particle duality of light can be used to discuss the accumulative nature of scientific knowledge. Testability can be also taught … The role of empirical data in scientific investigation is…also reflected in such history. (Joseph, Physics, GI)

According to Joseph's arrangement, the history of science was used for three purposes in his Physics courses. The first was to enhance the understanding of science content. Since this is a science course, this goal is a must in their teaching. The second was to develop the understanding of the history of science itself. The last was to enhance students' understanding of NOS. As indicated in the above excerpts, this educator planned to first ask the students to undertake a presentation on the two issues related to science subject content and history of science, discuss with students on these issues, and then teach relevant NOS to student. Since students were asked to present on history of science in lessons, they might be also required to think about it before the lessons. It was clear that the sequence of all activities described above was arranged more according to the need of teaching science subject content and history of science than teaching NOS, which makes NOS instruction a supplementary objective.

NOS instruction as infused into the teaching of school science textbook analysis

Books, especially textbooks, play a very important role in Chinese education. In Chinese, teaching is commonly called "jiao shu" (which can be translated literally as teaching book) while learning is called "du shu" (which can be translated literally as reading book). Given the important role played by textbooks in education in China, school science textbook analysis is an important part in prospective teacher training. As stated by several educators in the present study, a module on school science textbook analysis was included in their courses of Pedagogy of Science, and they would infuse their NOS instruction there. The following is an example from a biology teacher educator:

As introduced by Andy, in his course of School Biology Curriculum and Instruction, a module focused on teaching school textbook analysis. His teaching of NOS was embedded in this module. He first taught the basic theories of textbook analysis, such as aspects of textbooks to analyze, how to analyze a textbook from the psychological perspective, how to analyze the content of a textbook, how to analyze the structure of a textbook and how to analyze the teaching methods in a textbook. After that, he asked students to analyze some sections of different textbooks and submit the result of their analysis. Andy explained:

> One of important differences among different versions of school biology textbooks is the content related to the history of science…By using the material in the textbooks, I'll guide students to discuss why we need to include such content, what is the difference in the ways used in different textbooks to include such content, how much content in the textbook is appropriate, etc… During such process of discussion, I also guide the students to discuss issues related to the nature of science. (Andy, Biology, GI)

Here, the resource of teaching NOS was also the history of science materials in the school textbook. Such resource was first used in the discussion on including the history of science material in textbooks, covering its quantity, goal and specific way of doing it. At the same time, relevant NOS elements were introduced during the discussions. If we consider holistically the whole module of school textbook analysis, we can find that the discussion on including history of science material was just a session of this module, and hence where the teaching of NOS infused in the textbook analysis was a small part of a session.

NOS as a separated theme

Twelve out of the twenty-four educators in this study preferred to hold a separate session to teach NOS and they all placed this separate session in the course of Pedagogy of Science, which is a compulsory course in the program of training prospective teachers. The aims and content of this course are similar to that of the Science Methods Course in the West. There are a large number of elements that are commonly included in this course, which can be classified into three kinds. The first is theory oriented knowledge on science teaching, like history of science curriculum, direction and goals of science teaching, science learning and teaching theories, assessment in science education, science teacher professional development, etc. The second is tacit-oriented knowledge of science teaching, including science lesson plans, school science textbook analysis, basic teaching strategies (like lecture, questioning, recitation, discussion, demonstration), classroom management, using computers in science teaching, and so on. The last is student teachers' micro-teaching, which is aimed to help students relate the above stated knowledge within science teaching practice.

NOS instruction arranged at the early stage of Pedagogy of Science course

There was slight difference among the educators on the timing of NOS sessions in their courses of Pedagogy of Science. Ten educators, with preference of incorporating NOS instruction as a discrete theme in this course, choose to arrange NOS session at the early stage of this course. The following is an integrated science teacher educator's description of her arrangement and the rationale underlying such an arrangement.

Fiona's Curriculum and Instruction course could be separated into three parts. The first was the basic theories of science teaching, such as nature of science, science curriculum, theories of science teaching and learning. The second was regarding the skill oriented knowledge. They were basic science teaching strategies, basic science teaching skills, textbook analysis, lesson plan design, and classroom and laboratory management. The last was micro-teaching. It was argued that:

> I think NOS content should be taught in the first part…because nature of science actually can related to every aspect of science teaching, so if it is taught at the beginning of this course, its relation to other aspects can be also taught when those aspects are taught in the latter stage. (Fiona, Integrated Science, SI)

Fiona's arrangement reflected that she regarded NOS as a fundamental component which is related to many aspects in science teaching, including the design of science textbook, scientific teaching strategy, assessment, and so on. Therefore, if the NOS session was arranged at the starting part of the course of Pedagogy of Science, it could help include NOS into the discussion of subsequent topics. Similar views were shared by the other educators who preferred teaching NOS in the beginning of this course.

NOS instruction arranged at the later stage of Pedagogy of Science course

Two educators in this study thought that arranging NOS instruction at the early stage in Pedagogy of Science course might cause problems. As emphasized by them, pre-service science teachers have not acquired basic knowledge and skills of science teaching, so it is too demanding and unrealistic to teach NOS to them before they developed considerable levels of such knowledge and skills. Thus they thought that it is better to teach NOS at the later stage of the course of science curriculum & instruction. This was explained by Peter:

> NOS is a rather abstract and difficult content area…At the starting part of course, the students have not acquired a basic understanding and experience of science teaching … Only when people can master some relatively lower-level learning can they have the ability to deal with higher aspects…At the start of this course, students are still extremely nervous when these student teachers stand at the front of the classroom…If they can clearly and smoothly finish a lesson in such a situation, their performance can be considered as excellent… If we also require them to consider the nature of science in this initial stage of their science teaching practice…it is too demanding. (Peter, Chemistry, SI)

Factors influencing the incorporation of NOS instruction in courses

It was found that half the educators arranged NOS instruction into their courses as an infused component, and at the same time another half made it as a discrete theme. When the educators talked about the rationales behind their ways of NOS instruction, three factors were found to be influential to their preference. The textbooks currently used by the Chinese science teacher educators to train pre-service science teachers emerged as prominent. The other two factors are their views of the NOS content to be taught, and their visions of teaching NOS.

Currently used textbooks of training Chinese pre-service science teachers

Textbooks currently used in their institutes were explicitly stated by educators as one of the factors influencing whether they arranged NOS instruction as a separated theme in their courses. For example, as stated by a physics teacher educator:

> In our currently used textbooks, there is not a separated section to introduce NOS…NOS is very theoretical and abstract…If there is not a separate section in the currently used textbooks to introduce it…when I arrange a separate session in my course to teach it, students may not be willing to learn such a session … Hence, I choose to infuse my NOS instruction into other existing components in my course, like inquiry-based science teaching, history of science. (Mark, Physics, GI)

In China, the textbook still played a very important role in education at university level. The universities commonly assign a formal textbook for each course and such textbook is also distributed to all the students enrolled in this course. Moreover, such textbooks are also the major reference in the examination, although the teachers have some freedom when designing such examinations. Given the important role played by the textbook in Chinese university education, it is reasonable for the educator to worry that students would not be willing to learn NOS in a separate session if no separate NOS section existed in the textbooks currently used.

After asking all educators included in the study on the textbooks that they were using in training pre-service science teachers, we found that only some textbooks for the course of Science Curriculum & Instruction had a separate section for NOS and no textbooks for other courses had such a section. As for the textbooks for the course of Science Instruction & Curriculum mentioned by the educators (e.g., Yuan & Cai, 2003; Zhang, 2004), all textbooks for the course of Curriculum and Instruction of Integrated Science had a separate chapter to introducing NOS. Beside, one updated and very popular textbook of Biology Instruction & Curriculum (Liu, 2004) had a separate section to introduce NOS, though the others do not. But none of the textbooks for physics and chemistry instruction & curriculum has a separate section to introduce NOS.

Fifteen educators in our study used a textbook without a separate NOS section. Among them, twelve (80%) incorporated their NOS instruction as an infused theme in their courses and three (20%) arranged their NOS instruction as a separated theme. This suggests that if educators cannot find a separate NOS section in the textbook they are using, there will be a relatively high possibility for them to infuse NOS instruction into other content. On the contrary, for the other nine educators, who found a separate NOS section in the textbook used by them, they all arranged their NOS instruction as a separate theme. As stated by a biology teacher educator, he was "prompted to arrange his NOS instruction as a separate theme in his course after he had changed to a new textbook of biology instruction & curriculum, which has a separate NOS section." (Philip, Biology, SI). In brief, textbooks used by Chinese science teacher educators have very strong constraining and promoting effects on whether educators organize their NOS instruction into a separated session.

Views of NOS content to be taught

Although the textbooks used by educators had a very strong influence on whether or not the educators organize their NOS instruction into a separate session, such effect was not the absolutely determining factor. Three educators whose textbooks were without a separate NOS component still incorporated their NOS instruction as a discrete theme in their courses. As stated by these educators;

> I have a separate session in my course of physics curriculum and instruction to teach NOS. Of course, I also touch on it on other occasions…Most NOS content I'll teach hasn't existed in our previous textbook. It is the new content in my course. It should be emphasized by using a separate session. (Andrew, Physics, GI)

> This content (his NOS content to be taught) is very new to students. It has not appeared in previous courses … If we just infuse it into other content, the student may not notice it. (Peter, Chemistry, GI)

Apparently these three educators shared the same commitment to teach NOS even though their textbooks have not included a separate session. They thought that their NOS content to be taught was new to the students and had not appeared in their courses before, so they wereobliged to highlight NOS in a separate session to more effectively bring out these 'new' NOS ideas to their students.

In fact, all these educators focused their NOS content to be taught on the contemporary NOS elements. Most of these elements (like theory-laden nature of observation, imaginative nature of scientific investigation, and myth of scientific method, the tentative and inferential nature of scientific knowledge, the social practice of scientific community, social and cultural influence on science, and myths of scientist) have just started to appear in the Chinese science education literature in recent years, and so are hard to find in Chinese updated science curriculum document. On the contrary, most of the traditional NOS elements (like empirical basis of scientific investigation, logics in scientific investigation, accumulative/progressive, and truth-approaching nature of scientific knowledge), "have been infused into Chinese science educators' courses of training science teachers long before." (Tom, Chemistry, GI), although they were not explicitly termed as NOS elements. Therefore, if educators want to highlight such new content, there might be a need to use a separate NOS session to teach these contemporary NOS elements.

Visions of teaching NOS

Although it was reported in the preceding section that, for the educators who used textbooks without a separated NOS section, their views of NOS content to be taught played an important role in their decision of arranging NOS instruction in their courses, one exceptional case was also found. Isabella's textbooks did not have a separate NOS section. She focused her NOS content to be taught on the contemporary NOS elements. However, she still arranged her NOS instruction as an infused theme. As stated by Isabella,

> There is a large number of topic in my courses on training pre-service science teachers…I might not find additional time to add a new session to teach NOS in my course. To infuse it into teaching of other contents is more practical. (Isabella, Physics, GI)

The major argument suggested by Isabella was the time constraint. However, it is common for science teacher educators to fight with time constraint given the numerous topics needed for training science teachers. While facing the same constraint, the three educators introduced in the above section were on the need to highlight contemporary NOS elements in their course as a new component. Thus the rationale underlying the different decisions among these four educators might not be the constraint of time. Rather, it seems to be the difference in their visions of teaching NOS.

Isabella's visions of teaching NOS included "enriching content to be taught in school science" and "transforming traditional science teaching methods." In fact, these values within science teaching mentioned by her "can also be achieved by teaching other content which is common in the science teacher training program." For example, "we can change the teaching methods by developing the teachers' understanding of instructional theories. We can enrich the science teaching content through increasing the teacher's knowledge of scientists' life stories." (Isabella, Physics, GI). If the value of something can be easily replaced by others, compared with those that are difficult to be replaced, such values might not be so important. Consequently, although she saw the values of NOS within science teaching, such values might not be so important for her. Without such perceived importance, she was not motivated enough to modify the time plan of her courses so as to establish a separate session to teach NOS.

On the contrary, the three educators introduced in the above section (i.e., Andrew, Peter, Matthew), perceived richer values of teaching NOS. In addition to the rationales of teaching NOS within science teaching, like enriching content to be taught in school science and transforming traditional science teaching methods, they further emphasized cultural, national development and utilitarian arguments. For example, as stated by Matthew, "scientism is very serious in Chinese traditional culture". In other words, science is usually sanctified. With the goal of breaking the superstition of science in Chinese traditional culture, he focused on teaching those contemporary NOS elements, which "reflect the subjectivity and limitation of science." (Matthew, Physics, GI). Actually, all these cultural, national development and utilitarian values of teaching NOS are somewhat unique and so may be more important in science teacher training programs than others that can be easily replaced by teaching other content.. As a result, these three educators, who were with such perceived importance, had a need to highlight their contemporary NOS content to be taught by arranging a separate session. They were motivated enough to do so.

DISCUSSION AND CONCLUSIONS

The implicit and the explicit approaches to teaching NOS have been discussed in the Western literature. The implicit approach believes that an understanding of NOS is a learning outcome that can be facilitated directly through utilizing science process skills instruction and/or scientific inquiry activities or manipulating certain aspects of the learning environment (Haukoos & Penick, 1985; Rowe, 1974). However, some science educators (e.g. Akindehin, 1988; Wong, Yung, & Cheng, 2010; Bell, Lederman, & Abd-El-Khalick, 1998) suggest that NOS as an enterprise is a reflective one, and embodies the collective attempts of scholars of investigating the history and activities of science. It is unrealistic to expect the learners, including science teachers, to be able to generate their NOS understanding automatically by themselves through reading the records of history of science or/and participating in the scientific activities. On the contrary, learners should be promoted to intentionally reflect the relevant NOS embedded in these records and practice.

Although the implicit and explicit approaches are named as approaches to teaching NOS, which focus on ways of teaching, they can still imply two different ways of incorporating NOS instruction in courses. If the educator adapted the implicit approaches to teaching NOS, the incorporation of NOS instruction is actually an implicit theme. At the same time, when the educator adapted the explicit approaches to teaching NOS, the arrangement of NOS instruction is actually as an explicit theme. In other words, there are two layers of meanings for the implicit-versus-explicit categorization. The first is related to the ways of teaching and the second is related to the incorporation of NOS instruction in courses. However, the controversy between implicit and explicit approaches seems not prominent among Chinese science teacher educators' conceptions since none of them adopted the implicit approach, or arrangement of NOS instruction as an implicit theme. The absence of the implicit approach in this study may be partly explained by the influence of Vygotskian theory in China.

"Psychological tools" is a typical term and key concept in Lev Vygotsky's work (Kozulin, & Presseisenm, 1995), which refers to symbolic systems consisting of signs, symbols, maps, charts, models, pictures and, above all, language (Vygotsky, 1986). These symbolic systems are called tools, because Vygotskian theory holds that they are inventions in the long history of human development and high-level thought must be mediated by them. Since they are inventions through a long period in the history, they cannot be easily generated. It is hence believed that psychological tools should be communicated by teachers rather than discovered by learners themselves. When explaining why the implicit approach was not adopted, some educators explicitly mention the concept of psychological tools. As they state, "NOS elements are the theorized understandings about science." (James, Biology, SI). These understandings "should be conceptualized through psychological tools, which are invented through a very long history of the academic studies about science." (Andrew, Physics, SI). Hence, "it was impossible for students to generate these psychological tools simply through the experience of scientific inquiry and learning history of science." (Sophia, Biology, SI).

It is well known that Chinese education have long been influenced by the former Soviet Union and Vygotskian theory have been widely accepted by academics in China. If Chinese science teacher educators in this study adopted Vygotskian theory and applied the concept of psychological tools in the context of NOS instruction, as the lingual presentations of NOS elements can be also considered as psychological tools, they could readily achieve an agreement consistent with the explicit approach that NOS should be also communicated to learners by teachers rather than taught in an implicit manner. The implicit approach hence could not be found among them. Of course, we cannot exclude the possibility of the existence of other factors that also contribute to causing the absence of the implicit approach in this study, but the available data at least indicates that the influence of Vygotskian theory should be an important one.

In the present study, whether incorporating NOS instruction as an infused or a separated theme in their courses is a prominent variation among Chinese science teacher educators. We can find considerable numbers of educators who held either view. In addition, the rationales for holding either view are also explicitly discussed by them. The appearance of such variation could be explained in terms of the fact that China is just at the starting stage of formally introducing NOS in science education. Actually, the terminology NOS has just begun to appear in China in the last ten years. Among Chinese science curriculum documents published recently, only one, i.e. Integrated Science Curriculum Standards (7-9 years) (MOE, 2003c), intentionally discusses this topic. It is argued in its first chapter, “the curriculum is designed on the basis of the contemporary views of nature of science, and aims to develop the students’ understanding of the nature of science” (p. 2). After then, it uses a session to illustrate what are its NOS views. On the contrary, when NOS appears in others curriculum documents (e.g. MOE, 2003a; 2003b), it is simply mentioned. For example, when Chemistry Curriculum Standards (7-9 year) illustrates the values of doing scientific inquiry, it says that “through scientific inquiry, students learn the scientific knowledge, gain the scientific skills, experience the scientific process, and understand the nature of science” (p. 8), but no further elaboration on NOS can be found afterwards. Since NOS is not a prominent topic in most curriculum documents, and as introduced before, does not appear as a separated section in most textbooks for training Chinese science teachers, when teaching such a topic, Chinese science teacher educators need to formulate their own decisions on how to incorporate NOS instruction in their courses. Thus different arrangements can be found among them.

A good number of Chinese science teacher educators were found in this study to just infuse their NOS instruction in the teaching of other contents. It should be noted that when science teachers are taught about NOS, they do not only need to get very solid understanding of NOS itself, but also are expected to have the capacity to teach NOS to their students, which requires them to have a very clear picture of values of teaching NOS, the strategies of handling the relationship between NOS and other components in their lessons, as well as the specific pedagogical skills of teaching specific NOS elements. When there was not an occasion in these science teacher educators’ courses to focus on teaching these issues as a whole, their pre-service science teachers might not be competent enough to enhance their future school students’ understanding of NOS in an appropriate and coherent manner, which would in turn compromise the ultimate goal of developing Chinese public’s scientific literacy . Therefore, we argue that these educators should give higher priority to NOS instruction and make it not only an explicit, but also a separate theme in their courses.

As indicated by the findings of this study, we should first try to make NOS a prominent section in the textbooks currently used to train Chinese science teachers in each science subject. Of course, it is not easy to change the existing textbooks within a short period. We should also consider achieving the goal through influencing educators’ views on NOS content to be taught and their visions of teaching NOS. When planning events to encourage science teacher educators to teach NOS, we can design activities to allow sharing of views of NOS content to be taught and their visions of teaching NOS. The exposure to wider perspectives may result in greater appreciation in promoting more sophisticated and comprehensive NOS understanding and values of teaching NOS, which may in turn influence their decisions in putting higher priority in NOS instruction in their courses.

As reported in the result section, even among the educators who incorporated NOS instruction as separated theme in their courses, there still exist different opinions on the timing of teaching NOS in the course of Pedagogy of Science. Most of them (ten out of twelve) chose the early stage while two chose the later stage. Although such controversy has not been explicitly discussed in the literature, examples of both types still can be found. Similar to the findings in this study, most of reported prospective science teacher training programs in the West (e.g. Akindehin, 1988; Palmquist & Finley, 1997) arrange a separated NOS session at the early stage of Science Methods Course. For example, Palmquist and Finley (1997) report their 15-month science teaching program in the University of Minnesota. The major goal of the program was to integrate educational theory with classroom practice. A 2-hour NOS lesson was taught at the starting stage of this program. After then, it continued to teach curriculum planning, lesson planning, and teaching technique.

On the contrary, it is very uncommon in the programs of training prospective science teacher reported in the literature to find a separated NOS session arranged at the later stage of Science Methods Course. The only one found is a summer training course reported by Billeh & Hasan (1975). The first part of this course was a lecture and demonstration on methods of teaching science and science content included in secondary school. The second part was laboratory investigation in secondary school science, emphasizing a guided discovery approach. The third part was enrichment activities, including supplementary reading in science books and viewing relevant science films, which was for further understanding of science concepts and with a vivid picture of scientist at work. In the end were twelve 50-minute lectures on NOS.

It may be too early to make judgment on which kind of arrangement is better. Both may have their strengths and limitations. If NOS instruction is placed at the early stage, it is too challenging for pre-service science teachers to handle various issues at the same time when the course of Pedagogy of Science is just started. When putting NOS instruction in the later stage, we may not have enough time to teach how to incorporate NOS in their science lessons. Nonetheless, the findings reported here at least remind us that this issue may be an important one to be consciously pondered by science teacher educators in order to come to a more well-thought-out arrangement of NOS instruction and learning outcome.

Although NOS is still a contested topic in science education, it is commonly agreed that teaching NOS is a meaningful endeavor. Drivers et al. (1996) have discussed in detail the democratic, cultural, moral, utilitarian and science learning arguments for teaching NOS. A list of Chinese science teacher educators views of the values of teaching NOS can be found in Wan, Wong, and Yung (2011). Given such rich values of teaching NOS for both science education itself and the broader society, there will be an increasing number of countries and regions to introduce NOS education in the future. For these countries or regions that are or will be at the starting stage of formally introducing NOS in science education, the different conceptions between incorporation of NOS instruction as a infused them or separate theme may also exist among science teacher educators and even science teachers. The findings in this paper on the factors influencing their conceptions in this aspect may provide hints to the measures of changing such conceptions in these countries or regions, such as revising textbooks, changing views of NOS contents to be taught, and enriching visions of teaching NOS.

Since implicit versus explicit approaches to teaching NOS have been explicitly discussed in the Western literature on teaching NOS, they might be considered as major variations of conceptions of teaching NOS of Western educators who have contributed to such literature. However, as indicated in the present study, in Chinese teacher educators' conceptions of teaching NOS to prospective science teachers, due to the influence of the influence of Vygotskian theory, this variation did not emerge as major variations in the data. On the contrary, since China is just at the starting stage of formally introducing NOS in science education, another variation emerges, i.e. the one between infusing NOS features into various course components and singling out NOS teaching by introducing a separated course component in the arrangement of NOS instruction. Such a difference in major variations of a specific conception (here, conceptions of teaching NOS) in different contexts may be another vivid annotation of the argument that conceptions are context dependent (e.g. Gao & Watkins, 2001; Marton, 1981; Samuelowicz & Bain, 1992).

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APPENDIX 1

Table A. An overview of the background of participating Chinese science teacher educators

Age	*>50*	9
	40-50	11
	30-40	4
Gender	*M*	*15*
	F	9
Science subject of their students	*Phys.*	7
	Chem.	7
	Bio.	5
	Int. sci.	5
Academic position	*Prof.*	7
	Associate Prof.	13
	*Instructor**	4
Year of training science teachers	*>20*	10
	Oct-20	9
	5-Oct	5

* In China, instructor is the lowest title in academic positions.

APPENDIX 2

Scenario A

(A) Use questionnaire to assess students' understandings of NOS.

(B) Ask students to comment on, explain, and identify similarities and difference between their responses to the questionnaire.

(C) Assign students to read several papers on NOS.

(D) Engage students into a number of inquiry activities.

(E) Organize discussion on relevant NOS themes after each activity.

(F) Assign students to read more NOS papers and ask them to write a reflection essay on these papers.

Appendix 3

Table B. Profiles of Chinese science teacher educators' preference of incorporating NOS instruction in courses (Categorization of science teacher educators' conceptions of arrangement of NOS instruction in courses indicates A - As an infused component theme and B - As a separated component.)

No.	STE	Gen.	Sub.	Pos.	Incorporation of NOS instruction in courses	Cat.
1	Emily	F	Chem.	Ass. Prof.	▪ Infused into the teaching of inquiry-based science teaching approach ▪ Infused into the teaching of history of science	A
2	Michael	M	Phy.	Ass. Prof.	▪ Infused into the teaching of history of science ▪ Infused into the teaching of school science textbook analysis	A
3	Ava	F	Int. Sci.	Prof.	▪ Infused into the teaching of inquiry-based science teaching approach ▪ Infused into the teaching of history of science ▪ A separate session at the ***early*** stage of science curriculum & instruction course	B
4	Daniel	M	Int. Sci.	Prof.	▪ Infused into the teaching of history of science ▪ A separate session at the ***early*** stage of science curriculum & instruction course	B
5	Andrew	M	Phy.	Ass. Prof.	▪ A separate session at the ***later*** stage of science curriculum & instruction course	B

6	John	M	Int. Sci.	Ass. Prof.	▪ Infused into the teaching of science contents ▪ A separate session at the ***early*** stage of science curriculum & instruction course	B
7	Mark	M	Phy.	Ass. Prof.	▪ Infused into the teaching of inquiry-based science teaching approach ▪ Infused into the teaching of history of science	A
8	Peter	M	Chem.	Ass. Prof.	▪ Infused into the teaching of history of science ▪ A separate session at the ***later*** stage of science curriculum & instruction course	B
9	Joseph	M	Phy.	Instr.	▪ Infused into the teaching of history of science ▪ Infused into the teaching of school science textbook analysis	A
10	Sophia	F	Bio.	Instr.	▪ Infused into the teaching of inquiry-based science teaching approach ▪ A separate session at the ***early*** stage of science curriculum & instruction course	B
11	David	M	Chem.	Prof.	▪ Infused into the teaching of inquiry-based science teaching approach ▪ Infused into the teaching of science contents	A

12	Grace	F	Phy.	Prof.	▪ Infused into the teaching of inquiry-based science teaching approach ▪ Infused into the teaching of history of science ▪ Infused into the teaching of school science textbook analysis	A
13	James	M	Bio.	Prof.	▪ Infused into the teaching of inquiry-based science teaching approach ▪ A separate session at the ***early*** stage of science curriculum & instruction course	B
14	Matthew	M	Phy.	Prof.	▪ Infused into the teaching of history of science ▪ A separate session at the ***early*** stage of science curriculum & instruction course	B
15	Bob	M	Bio.	Ass. Prof.	▪ Infused into the teaching of inquiry-based science teaching approach ▪ Infused into the teaching of history of science ▪ A separate session at the ***early*** stage of science curriculum & instruction course	B
16	Isabella	F	Phy.	Ass. Prof.	▪ Infused into the teaching of inquiry-based science teaching approach ▪ Infused into the teaching of history of science	A

17	Fiona	F	Int. Sci.	Prof.	▪ Infused into the teaching of inquiry-based science teaching approach ▪ A separate session at the ***early*** stage of science curriculum & instruction course	B
18	Paul	M	Chem.	Ass. Prof.	▪ Infused into the teaching of inquiry-based science teaching approach ▪ Infused into the teaching of school science textbook analysis	A
19	Tom	M	Chem.	Ass. Prof.	▪ Infused into the teaching of history of science	A
20	Jane	F	Chem.	Ass. Prof.	▪ Infused into the teaching of history of science ▪ Infused into the teaching of school science textbook analysis	A
21	Alice	F	Chem.	Ass. Prof.	▪ Infused into the teaching of inquiry-based science teaching approach ▪ Infused into the teaching of science contents	A
22	Andy	M	Bio.	Instr.	▪ Infused into the teaching of inquiry-based science teaching approach ▪ Infused into the teaching of school science textbook analysis	A
23	Philip	M	Bio.	Instr.	▪ A separate session at the ***early*** stage of science curriculum & instruction course	B

24	Samuel	M	Int. Sci.	Ass. Prof.	▪ Infused into the teaching of history of science ▪ A separate session at the ***early*** stage of science curriculum & instruction course	B