Focusing on the classical or contemporary? Chinese science teacher educators' conceptions of Nature of Science content to be taught to pre-service science teachers

Abstract. Drawing from the phenomenographic perspective, an exploratory study investigated Chinese teacher educators' conceptions of teaching Nature of Science (NOS) to pre-service science teachers through semi-structured interviews. Five key dimensions emerged from the data. This paper focuses on the dimension, *NOS content to be taught to pre-service science teachers*. A total of twenty NOS elements were considered by the Chinese science teacher educators to be important ideas to be taught. It was also found that among these educators, whether focusing on the classical or contemporary NOS elements in NOS instruction was a prominent controversy. After explaining the criteria for differentiating between classical and contemporary NOS elements, this paper reports the specific NOS elements suggested by Chinese science teacher educators in this study. Afterward, it describes how all educators in this study were categorized in term of NOS content taught by them to pre-service science teachers. In the end, it discusses three factors influencing the decision on NOS content to be taught, i.e. view of the concept of NOS itself, vision of teaching NOS, and belief in general philosophy.

Key words: Nature of science; China; Science teacher educators; Conception

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 (Wan et al. 2013; Clough 2006; Irzik & Nola 2011; Osborne, Collins, Ratcliffe, & Duschl 2003). Recent decades have witnessed an increasing number of Western curriculum reform documents advocating the significance of teaching about NOS to both science teachers and school students (e.g., AAAS 1990; CMEC 1997; NRC 1996)[1]. Actually, the earliest statement of this objective can be traced back to the beginning of last century. For example, Lederman (1992) recalled that in 1907 the Central Association of Science and Math Teachers in America had stressed the importance of scientific method and processes of science in science teaching and learning.

In recent years, the soaring economy in China has brought tremendous changes in people's lives and at the same time prompted the government to look for strategies to sustain long-term development of the country, which include investing in education that can nurture and prepare the future generations for the competitive economy in the 21st century. 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 (Wei and Thomas 2005). NOS, as one of the components of scientific literacy, has started to become a topic of interests and concerns. It appears in the science curriculum reform documents (e.g.,

[1] 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 2012a; b; c)[2]. Discussion on NOS instruction has also emerged in some recent Chinese academic articles (e.g., Chen & Pang 2005; Ding 2002; Xiang 2002; Yuan 2009) and some textbooks for training science teachers (e.g., Liu 2004; Yu 2002; Zhang 2004).

Since scholars in Western countries and regions have studied and reported NOS instruction for a number of decades, Western views of NOS education can, to some extent, be informed by analyzing the existing literature. However, until now we still know little about how the teaching of NOS is perceived in China, a country with her unique social, political and historical background. Therefore, an exploratory study was conducted to investigate Chinese teacher educators' conceptions of teaching NOS to pre-service science teachers, in which five key dimensions emerged from the data. This paper focuses on reporting one of them, i.e. NOS content to be taught to pre-service science teachers. Other dimensions will be reported in separate papers.

Since late 1980's, drawing from the phenomenographic perspective (Marton 1981), a branch of research has investigated the conceptions of teaching in general, focusing on categorizing the descriptions made by the university lecturers and school teachers on their own views of teaching (e.g., Christensen, Massey, Isaacs, & Synott 1995; Gao & Watkins 2002; Kember 1997; Martin & Balla 1990; Law, Joughin, Kennedy, Tse, & Yu 2007; Pratt 1992; Prosser, Trigwell, & Taylor 1994; Samuelowicz & Bain 1992; Virtanen & Lindblom-Ylänne 2010). An important feature of these studies is to generate, through theoretical study or by direct abstracting from data collected in their research, several key dimensions to characterize the investigated conception. In these studies, it is common to further describe those key dimensions by using few categories or extremes within this dimension. This study followed this phenomenographic tradition.

THE CONTESTED NATURE OF NOS

Although NOS has been one of the commonly discussed and researched topics in science education, there are also many disputes on what science really are (Allchin 2011). Early in the 1960s, it is claimed by Herron (1969) that no sound and precise description exists concerning the nature and structure of science. This claim is echoed later by Meichtry (1993) who notes that the "lack of agreement which has occurred" (p.432) in describing NOS may be due to disagreement over "what characteristics typify the complex and ever-changing field of science" (p.432). After conducting a study to investigate how philosophers of science viewed NOS, Alters (1997a) concludes that "we should acknowledge that no one agreed-on NOS exists" (p.48).

Given the contested nature of NOS, two different opinions can be found in the literature on the NOS content to be taught (Wan et al., 2011). According to the pluralistic view, the controversies in NOS should not be avoided in NOS teaching. Instead, the different and sometimes even conflicting views of science should be included in NOS instruction so as to give a real picture of science (Alters 1997b; Jenkin 1996; Siegel 1993). For instance, in Nott and Wellington's (1993; 1998) NOS courses, science teachers were encouraged to discuss a number of statements about science. These statements were classified and presented in terms of relativism versus positivism, inductivism versus deductivism, contextualism versus decontexualism, instrumentalism versus realism, and process versus content. Such a way of presentation explicitly embodied the contested NOS to their students.

However, other scholars believe that despite the debate regarding the ultimate fine details of nature of science, there exists a considerable consensus regarding NOS content to be taught (e.g., Lederman, Abd-El-Khalick, Bell, & Schwartz 2002; Osborne et al. 2003). In response to Alter (1997b), Smith, Lederman, Bell, McComas, & Clough (1997) contend that "a

[2] MOE is the Ministry of Education in the People's Republic of China.

remarkable level of agreement regarding the principal NOS elements" existed in current standard documents and that "too much is being made of disagreement concerning the NOS that involve tenets that are esoteric, inaccessible, and probably inappropriate for …instruction" (p.1102). Therefore, they do not think it is necessary to include the disputes among NOS views in their NOS teaching. On the contrary, they suggest teaching these agreed-on NOS tenets. These as summarized by Lederman et al. (2002) are

> [S]cientific knowledge is tentative; empirical; theory-laden; partly the product of human inference, imagination, and creativity; and socially and culturally embedded. Three additional aspects are the distinction between observation and inference, the lack of a universal recipe-like method for doing science, and the functions of and relationships between scientific theories and laws (p. 499).

Although, the contested feature of NOS, as reflected in the literature cited in the preceding three paragraphs, is a significant factor considered by some scholars in their decision on NOS content to be taught, it may not be the case for the others. Bianchini and Colburn (2000) report a study investigating Colburn' instruction of NOS in an inquiry oriented science course for pre-service elementary teachers. According to Colbum's account, his philosophical views about science are instrumentalist, which are rather consistent with the NOS content emphasized in his courses, consisting of the arguments that: (i) no one right way necessarily exists to solve a problem in science; (ii) scientists and students of science can seemingly be doing the same thing, but get different results; (iii) scientific knowledge is created and verified on the basis of evidence, rather than authority; (iv) other than the need for evidence, no single way exists to know definitively whether a conclusion is true; (v) the establishment of scientific truth ultimately includes a social component, and so knowledge is not created simply by collecting data; (vi) knowledge ultimately depends on how scientists interpret their results. As he argued, "each idea reflects, to some extent, the three courses goals" (p.187), i.e. helping students to like science, understand NOS, and become skilled at doing science. Although the relationship between these elements and the first and second goal was not further discussed, according to his argument, his visions of teaching may be an important factor influencing his decision on NOS content. However, with respect to the data reported, the contested feature of NOS does not seem to appear among the arguments for such decision. In this paper, Bianchini also commented on the NOS content, stating that although Colburn's representation of the nature of science was not disagreed with by her, she thought "the contextual aspects of science…equally compelling to share with students" (p.179), which consider the questions, methods, and claims of modern science as deeply embedded in the historical, political, cultural, and technological background of society. These arguments are further summarized as Feminist views of science and included as the major content of her NOS instruction by Bianchini in her subsequent works (e.g., Bianchini, Hilton-Brown, & Breton 2002; Bianchini, Johnston, Oram, & Cavazos 2003; Bianchini & Solomon 2003). In these works, the contested feature of NOS is also not found among the arguments for her decision on NOS content.

With reference to the above discussion, it can be found that the decision on NOS content to be taught is a complex issue. People may have rather different views on it. Given China's unique social context, it may be meaningful and interesting to probe what are the decisions on NOS content made by science education practitioners in China and what are the prominent factors influencing such decisions. The present study may, to some extent, answer these questions.

ASSESSMENT OF NOS UNDERSTANDINGS

The research on NOS education started with the assessment of students and science teachers' understandings of NOS. Most of the assessment tools used in these studies are the quantitative ones, such as the Science Process Inventory (Welch & Walberg 1967-68), the Test on Understanding of Science (Cooley & Klopfer 1961), the Nature of Science Scale (Kimball 1967-68), the Nature of Scientific Knowledge Scale (Rubba & Anderson 1978), and Views on Science and Education Questionnaire (Chen 2006). Some of them are qualitative, including Images of Science Probe (Driver, Leach, Miller, & Scott 1996), repertory grids (Shapiro 1996), and Views of the Nature of Science Questionnaire (Lederman et al. 2002).

In these studies, it is common to differentiate NOS understandings into levels, the naïve versus informed or inadequate versus or adequate (e.g. Lederman et al. 2002; Kimball 1967-68). The adequate or informed NOS understandings mainly refer to the postpositivistic views, consisting of the arguments that theories are the end result of creative work, there does not exist the scientific method, scientific interpretation depends on their prior knowledge and the prevailing research paradigm, and so on. On the contrary naïve or inadequate understanding normally refer to positivistic views (e.g., believing that the goal of scientific inquiry is to discover the truth in nature, there exist the scientific method, scientific knowledge progresses by an accumulation of observations) and some misunderstandings about science (e.g., believing that laws start as theories and eventually become laws when they are proven, scientific knowledge is absolute, experiment is anything that involves the act of collecting data). An intermediate level of NOS understanding is sometimes added to represent mixed NOS views or developing views held by the respondents (e.g. Abd-El-Khalick 1998). The findings in these studies consistently indicated that adequate or informed understandings of NOS had not been acquired by either students or science teachers.

However, it is cautioned by Wong and Hodson (2009, 2010) that the crude categorization of NOS views as "naïve or adequate" on the basis of a questionnaire response in the absence of thorough knowledge of the background and context underlying the responses could be unreliable. In their studies, they illustrated NOS through the reflective accounts of an eminent group of scientists on their authentic scientific practice. Their data showed that both naïve and informed views could well co-exist, which were indicative of a highly sophisticated NOS understanding rather than a mixed or developing views of NOS. It was found that "scientists' trust in using well-established scientific knowledge like special relativity in the search for newer knowledge" coexist with "their readiness to abandon those relatively loose and controversial theories accounting for the extinction of dinosaurs" (Wong and Hodson, p.124). Similarly, the so-called "naïve" view that "science is universal" (held by all the scientists) coexisted with the supposedly "adequate" view that science is socially and culturally embedded. Therefore, they argued that "since the different views are situated in specific and well-understood contexts, they might be better categorized as sophisticated understanding of NOS" (Wong and Hodson 2009, p.124).

METHODOLOGY

Subjects

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 get a comprehensive training of both science and education. On the contrary, the training of science and education is separated in the second mode. Students need first get a Bachelor degree of science, and then continue to study for Postgraduate Diploma in Education (PGDE) so as to get the qualification of being a science teacher. In

Mainland China, pre-service science teachers are mainly trained through the first mode. There are a large number of Normal Universities and Institutes of Education which are specialized in teacher educations. These universities and institutes also have specific divisions or faculties for different science subjects. Pre-service teachers of different science subjects are trained in corresponding science divisions or faculties. There is a course called integrated science for junior secondary students in some regions of Mainland China. No regulation has been made on which science division or faculty is responsible for training pre-service integrated science teachers in Mainland China. It depends on which division or faculty has applied for operating such program and got the approval from the Chinese Ministry of Education. In the first mode, Chinese science teacher educators are mainly responsible for teaching *Pedagogy of Science*, *History of Science* and *Science Laboratory in School* and sometimes science subject courses and experiments.

The science teacher educators in the study were from the Normal Universities or Institutes of Education in 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 participants 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. Upon completion of the interviews, each of the participants was asked to introduce other educators to the authors. Such snowballing process carried on throughout the whole process of data collection. A total of forty one educators had been approached by the authors and twenty four of them participated in the study (An overview of the background of participating Chinese science teacher educators can be found in Appendix 1). These participants include considerable variations in their age, the major discipline they teach, teaching experience, and academic position.

Data collection

As stated by Pajares (1992), conceptions can be inferred from what individuals write, say, and do. Accordingly, the most commonly used methods in education research, such as questionnaire, interview, and classroom observation, can all be used in the studies of conceptions. Most of the studies of teacher conception in the middle of 20th century adopted large-scale multiple-choice questionnaire (Richardson 1996). However, this kind of method has been criticized since it is constrained by the frameworks derived from the scholarly literature, which may not map on teachers' conceptions (Hoffman & Kugle 1982; O'Brien & Norton 1991; Pinnegar & Carter 1990). This is especially the case for the areas where the information of current situation is rather limited. The present study aimed to investigate Chinese science teacher educators' conceptions of teaching NOS, which is an area that has not been investigated and reported before. Given its exploratory nature, questionnaire was not adopted. Observation can be also used in combination with interview to investigate conceptions (Thompson 1992; Kagan 1992), but it needs much time and resources. Since the participants in the present study were geographically dispersed, it was rather difficult for the authors to observe all the participants' NOS teaching practice. As a result, observation was not adopted in the current research.

Two semi-structured interviews were conducted in Mandarin with each participant. The first one was a General Interview, during which a general open-ended question was used to probe their conceptions of teaching NOS: How do you teach NOS to your pre-service science teachers in your own course(s) and why? During the interview, the participants were asked to try to locate the discussion of teaching NOS within the real context of their own courses of teaching pre-service science teachers. When the participants discussed their NOS teaching practice, some follow-up questions covering various aspects of such practice might 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 kinds of assignments do you give for your NOS lessons”, and “how do you round up your NOS lessons”. Since the present interview was semi-structured, we avoided exerting too much control when conducting it. Consequently, a certain level of variation exists among the durations of interview with each educator. During the interview, part of educators would like to talk in detail about the specific accidents in their NOS instruction and other personal experience, which made the interview last as long as 100 minutes. On the contrary, some others just focused on the overall design of their NOS teaching, rather than the specific accidents. Therefore, the interviews with them were relatively short, the shortest of which was 45 minutes.

The second semi-structured interview was a Scenario-based Interview. During the interview, each of the science educators was provided with five examples of NOS teaching designs (one example is attached in the Appendix), 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 of the five NOS instructional designs, the science teacher 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). Due to the reasons similar to those introduced in general interview, the duration of this interview ranged from 40-120 minutes. According to Kagan (1992), the pre-existing conceptions held by the teachers serve as the filter through which they view and interpret the teaching performance of others. Therefore, the teacher educators’ reaction to others’ NOS teaching plan could also reflect their conceptions of teaching NOS. This interview served as another source of data to complement the data collected in the General Interview.

Data analysis

The exploratory approach (Stake, 1995) was adopted to analyze the data collected in this study. It was initially done by the first author. Regular meetings were held between the first and second authors to discuss on the codes and themes identified in the data. The interview was transcribed verbatim into Chinese, then read, coded and analyzed. Translation into English was done only to the selected transcripts. This is to ensure that ideas from the participants are preserved faithfully during the data analysis process.

The researchers roughly followed three phases to analyze the data: open coding, axial coding, and focused coding (Charmaz, 2000; Strauss & Corbin, 1990). For open coding, the transcripts of the interview were read line by line repeatedly and coded by the first author, during which several meetings were held between the first and second authors to discuss on these initial codes. In the end, a large number of initial codes were generated. In the second phase, the initial categories created in the first phase were further integrated by the first author. Several meetings between the first and second authors were held again, through which a number of broader categories were produced.

It was rather challenging to make the final decision on the focused codes, which needed to consider all the data and all the possible questions that might be answered in the present study holistically. It required the authors to constantly revisit the raw data, revise the original codes, and further analyze the existing categories based on the clues found in the literature to check if such clues could be the focus of this study. During this process, the first author went back to the literature on NOS and conceptions again, sensitized himself with the theoretical issues in this area, and generated some guiding questions that might be the focus and axial codes in the study. After then, he repetitively moved among the raw data, temporary categories, and guiding questions implied in the literature. After many rounds of such a repetitive move and discussions between the first and second authors, the focus codes gradually emerged. They were the five key dimensions of Chinese science teacher educators' conceptions of teaching NOS: (i) value of teaching NOS to pre-service science teachers, (ii) NOS content to be taught to pre-service science teachers, (iii) arrangement of NOS instruction in science teacher education courses, (iv) learning of NOS, and (v) role of the teacher in NOS teaching. This paper only focuses on reporting one dimension, i.e. NOS content to be taught to pre-service science teachers. The findings of values of teaching NOS has been published in an independent paper (Author et al., 2011), and other dimensions will be reported in coming separate papers.

CLASSIFYING NOS ELEMENTS INTO TWO GROUPS

As indicated in the data, a controversy emerged among Chinese science teacher educators on what NOS content should be taught. There were three different stances in Chinese science teacher educators' conceptions of NOS content to be taught to pre-service science teachers. Fourteen chose to focus their NOS instruction on *classical* NOS elements. Other eight preferred emphasizing the *contemporary* ones. As for the other two, a number of both classical and contemporary NOS elements were included, so they were somewhat mixed. In this section, a tentative discussion is made on how NOS elements suggested by Chinese science teacher educators in the present study were differentiated into two groups, namely the classical and contemporary. After then, educators' rationales for focusing on classical or contemporary NOS elements are reported in the subsequent section.

In the literature, different labels are used to differentiate NOS elements. Some labels are rather specific, like logic-empiricism versus post-positivism (Lin & Chen, 2002) and relativism versus realism (Good & Shymansky, 2001). Although this kind of label may be very effective to categorize NOS elements within philosophy of science, it was found that NOS elements found in this study were broader and hence could not be all included under this kind of label. Therefore, they were not used in the current study.

In addition to such specific labels, the labels *traditional versus contemporary*, whose meanings are broader, have been also used in the literature (e.g., Palmquist & Finley, 1997). However, such labels may imply a kind of evaluative instance (i.e., the contemporary ones are inherently better than the traditional ones), which is not the intention of this study. Therefore, the author decided to replace the word *traditional* with a more neutral word *classical*, so as to avoid such an evaluative instance in the wording.

Literally, the term *classical* refers to something originating in the relatively earlier stage in the historical development while the term *contemporary* means something originating in the relatively later stage. Taking the literal meaning of these two words, the time of the origin of a certain NOS element was taken as one of the criteria to classify whether a NOS element is categorized as classical or contemporary.

The development of ideas about science is usually divided into two periods in terms of Kuhn's (1962) *Structure of Scientific Revolution* (e.g., Abd-El-Khalick & Lederman, 2000a; Hung, 1997; Lin & Chen, 2002; Palmquist & Finley, 1997). Such a time criterion was also adopted in this study to classify NOS elements into classical or contemporary. Classical NOS elements generally refer to those originating before 1960s in the historical development of peoples' understanding about science while contemporary NOS elements are those originating in and after 1960s.

It should be noted that such a time criterion is just one of the criteria, but not the only one used in the present study. Actually, there are two major constraints if we just rely on it to classify NOS elements. First, it is acknowledged that the historical development of studies of science is not a linear process, but an interwoven and overlapped one, especially around 1960s. It is hence rather difficult to give an absolute line to demarcate the contemporary from the classical. Therefore, although there might be fewer controversies to a time criterion to classify NOS elements whose origins are far before or after 1960s, there might exist some controversies when classifying the NOS elements whose origins are around such period. For example, there still exist different opinions on whether Popper's arguments, which appeared around 1960s, should be grouped as classical or contemporary in the Philosophy of Science.

Second, it is also difficult to identify the very initial origin of every NOS element. Although we may find the origin of a certain NOS element in the published and preserved literature, we still cannot exclude the possibility of the existence of unpublished or unpreserved literature before the available published ones. Such difficulty has not posed a problem for the NOS elements that were considered as the classical, since the existence of earlier literature serve to add credibility on the classification of NOS elements as classical. However, for NOS elements that were classified as contemporary, they were prone to the possibility of earlier existence of literature unidentified by the author due to the above reasons.

Due to these two constraints, when classifying a specific NOS element, this study also considered its relationships with other NOS elements. If the meaning of a specific NOS element is more consistent with some classical NOS elements than the contemporary ones, it may be more appropriately to include this specific NOS element into the classical group. On the contrary, when the meaning of a specific NOS element is more consistent with some contemporary NOS elements, rather than the classical one, it may be more appropriately included into the contemporary group. For example, Popper's arguments were considered more consistent with the classical inductive-empiricism than the contemporary constructivism, so they were grouped into the classical rather than the contemporary.

With reference to these two differentiating criteria, NOS elements suggested by Chinese science teacher educators in this study were classified into either the classical or contemporary type. Due to the limitation of space, this paper just focuses on illustrating nine of them whose classification is relatively more difficult. The summary of the others can be found in Table 1 and 2. What should be noted is that the classification of NOS elements is still a rather controversial issue. There may exist different opinions on it. The classification made here is just a tentative one for generating a viable categorization to group Chinese science teachers' educators' conceptions of NOS content to be taught identified in this study. The extent to which it can be used in other studies should be evaluated by the researchers themselves.

Table 1 & 2 about here

Replicable nature of empirical evidence. The validity of the scientific knowledge needs not only be supported by the empirical evidence, but these evidences can also be replicated by other scientists. Otherwise, the validity of such scientific knowledge cannot be claimed. This element was also stated as NOS content to be taught by six Chinese science teacher educators in the present study. As illustrated by a biology teacher educator,

> Science requires that evidence should be replicable, which is another character of science. Any scientific observation should be repeated by others…It is unlike magic, which can only be done by magicians (but not replicable by non-magicians, my explanation). I feel the real scientific investigation should endure the testing conducted by others using the same research design and procedure. (STE13 GI p.1)[3]

[3] "STE13" means that this educator is the 13th Chinese science teacher educators in the present study. "GI"

It seems not easy to identify the very origin of this element in the literature. In order to classify this element, we may need to analyze its relationships with other NOS elements. On the one hand, we can find replicable nature of empirical evidence is a statement that further elaborates a classical NOS element, i.e., the empirical basis of scientific investigation. Both of them emphasize the objectivity of science. On the other hand, this NOS element can be challenged by some contemporary NOS elements like Hanson (1965)'s notion of theory-laden observation and Kuhn (1962)'s concept of research paradigm, which emphasizes the subjectivity of scientific observation and questions the replicability of empirical evidence. Considering its consistency with the classical NOS element and opposition to the contemporary one, the replicable nature of empirical evidence was regarded as the classical.

Logics in the scientific investigation. Just relying on the empirical data cannot give a full explanation of the development of scientific knowledge. In order to establish the validity of the scientific knowledge, it is necessary to provide a method to bridge between empirical data and scientific knowledge. Logics would serve such a purpose, which were considered by fifteen Chinese science teacher educators as a NOS element. It was depicted by an integrated science teacher educator,

> As stated by Bacon, we'd try to make neutral observation of the natural world, classify the information observed…identify the commonality in the data so as to generate hypotheses, and then test them. This is the inductive method of generating scientific knowledge…In addition, Popper suggested the deductive method. He thought that the process of creating hypotheses was not what we should concern. What was more important is the process of testing the hypothesis…We suggest some hypotheses, deduce some observable phenomena on the basis of the hypotheses, and then testing the hypothesis...Both the inductive and deductive logics are all important methods in scientific investigation. (STE24 GI p.3)

In the philosophy of science, the logic suggested in earlier age is induction, which appeared much earlier than the 1960s. Due to its early appearance in history, it should not be controversial to classify inductive logic in scientific investigation as classical. Although it is easier to classify the inductive logic, it is not so straightforward to decide whether the deductive logic is classical or contemporary. We can find its origin in Popper's famous work *The Logic of Scientific Discovery* (Popper 1959). It has sometimes been considered as contemporary since Popper's major arguments are different from traditional inductivism and appeared relatively later. However, we can find that Popper's deductivism has some similarities with inductivism. First, they both emphasize the importance of the role of human's observation and experiments in the process of scientific investigation. Second, although they have difference in the specific logic suggested in scientific investigation, they share the commonality of seeking the logic method in science. Comparatively speaking, less similarity can be found between Popper's deductivism and latter philosophy of science, like various versions of constructivism. Therefore, the deductive logic of scientific investigation was also grouped into the classical NOS elements.

General process of scientific investigation. In the present study, ten educators included general process of scientific investigation into their NOS content to be taught. It includes a number of general elements in the scientific investigation, such as "raising a question, posing some hypotheses, testing such hypotheses or arguments through observation or experiment, drawing some conclusions and communicating such conclusion so as to let people accept the

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means that this extract is from the general interview. "p.1" means that this extract is in 1st page of the transcripts.

conclusions" (STE9 SI p.5)[4]. In the history of philosophy of science, both inductive-empiricists and deductive-empiricists attempt to provide a scientific method. For inductive empiricists like Francis Bacon (1562-1626), the scientific method generally consists of four steps: observation and experimentation; classification; generalization; testing. But deductive-empiricists like Karl Poppers (1902-1994) think that the kind of empiricism advocated by Bacon is naive. For them, induction plays no part in science. The only logic that science requires is deductive logic. The method of science advocated by Popper is known as hypothetic-deductive method, which consists of the following steps: (Popper's methodology is given in detail in Popper 1959): (a) formulate a hypothesis (H); (b) deduce an empirical consequence (C) from H; (c) test C directly; (d) if C is acceptable under the scrutiny of sense experience, return to step (b) and obtain another C for the further testing of H; (d') If on the other hand, C is rejected, the H should be rejected as a consequence of modus tollen. Regardless of their differences in the specific steps included in the process of scientific investigation, the inductive-empiricists and deductive-empiricists are common in believing that there is a general method in science. Clearly, the general process of scientific investigation has a very early origin in the philosophy of science, which can be traced back to Bacon (1562-1626), so it was considered as classical.

Scientific ethos. Scientific ethos, sometimes named as the scientific habits of mind or the ethnic norms of science (AAAS 1990), is some qualities or values of scientists, such as intellectual honesty, tolerance of ambiguity, skepticism, and openness to new ideas (NRC 1996). In the present study, ten Chinese science teacher educators included similar qualities or values into their NOS content to be taught, including the ethos of "perseverance, daring to challenge the authority, being critical" (STE21 GI p.6), "skepticism, perseverance" (STE19 GI p.2), and "respecting the facts and daring to explore" (STE7 GI p.4) . It is very difficult to trace back to the very origin of discussing these qualities or value of scientists in the Western history. However, as stated by Merton (1973) in his book The Sociology of Science, there are countless writings on the scientific ethos before his write-up of this book. Clearly, the origin of discussing these qualities or value of scientists in the history will be much earlier than the publication of his book. Additionally, the literature indicates that there is a very long history of people' discussion on scientific ethos in China. According to Kwok (1965), the origin of the discussion on the scientific ethos by Chinese academics can be at least tracked back to the early 1920s. On the basis on such statement, we can also infer that the origin of scientific ethos is no later than such time. Considering the time of its early appearance, the scientific ethos was labeled as a classical NOS element.

Theory-laden observation. Theory-laden nature of observation was included into NOS content to be taught by eight science teacher educators in the present study. It means that human's observation of the world is not objective, but is influenced by their previous understandings of the world. An integrated science teacher educator described the theory-laden observation through comparing different scholars' observation of a cup.

> Scientists' observation is just human's observation. They are just human, not the God. Therefore, their observation will be unavoidably subjective and with limitation…Say, for observation of this cup [pointing to a cup on his desk], … artists will find its unconventional shape and splendid decoration. However, what physicists care more is the material that it's made of, its quality, and its heat retaining ability. For sociologists, they think more about the historical and social life reflected by it… It's clear that when observing the same thing, due to the influence

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

> of people's background, expertise and knowledge, what have been observed could be rather different. In a similar manner, when scientists observe, their observation will be unavoidably influenced by their knowledge background, cognitive tendency, and research interests… they're unavoidably to some extent subjective. (STE6 GI p.5)

The origin of the idea of theory-laden observation can be traced back to the great German philosophy Immanuel Kant's (1724-1804) claim that the mind plays an essential and indispensable role in perception (observation). It has been introduced and further elaborated by Hanson (1958) in the philosophy of science. Since the time of its entrance into the philosophy of science is around the 1960s, during which it is rather difficult to just rely on the time criterion to classify this NOS element into the classical or contemporary group, we should consider its relationships with other NOS elements to make such judgments. If human's observation is theory-laden and since individuals' previous understandings of the world might not be same, the natural conclusion is that the observation might not be replicable for different people. Thus, the theory-laden nature of observation contracts the classical NOS elements: the replicable nature of empirical evidence (which is introduced before). On the other hand, this NOS element has an apparent close relationship with Kuhn's theory (Chalmers 1999) (which is commonly regarded as the contemporary) as subjectivity of science is emphasized in both. As a result, considering its relationships with other classical and contemporary NOS elements, the theory-laden nature of observation was classified as a contemporary one.

Inferential nature of scientific knowledge. Eight Chinese science teacher educators introduced the inferential nature of scientific knowledge as one of NOS content through analyzing theoretical entity, the difference between law and theory, or the difference between observation and inference. As an integrated science teacher educator stated,

> Mendel' Laws are generalization of his observation of plants' inherited characteristics, but genetic theory is the explanation of such observation…Boyle's law is the generalization of the observation on the relationship among gas' temperature, volume and intensity of pressure. Theory of Molecular Motion is the explanation of such observation. Laws can be tested directly by observation…However, since theories are based on the inference and we can't see directly the entity that theories refer to, they can't be tested directly. (STE 5 GI p.7)

Actually, if the inferential nature of scientific knowledge is admitted, it is unavoidable to challenge the corresponding relationship between scientific knowledge and natural world. If some concepts in science are just inferred not observed, how can we know whether the entities represented by such concepts really exist or not? If we do not know whether such entities really exist or not, how can we believe that there is a corresponding relationship between scientific knowledge and natural world? Clearly, the inferential nature of scientific knowledge can bring a very serious challenge for the realists. The realism dominated in the early age of philosophy of science, and the challenge to realism in the philosophy of science, i.e., anti-realism, started to increase when constructivism began to thrive in the 1960s, which denied that theoretical terms have references. Considering the time of its origin, the inferential nature of scientific knowledge was considered as a contemporary NOS element.

Imagination in scientific investigation. Six Chinese science teacher educators also stated that they emphasized "the important role played by imagination or creation in scientific investigation" (STE16 GI p.3). This NOS element is actually considered as the NOS element that challenges some classical NOS elements, like empirical nature of scientific investigation, replicable nature of empirical evidence and logics in scientific investigation. These classical NOS elements have a similar tendency to describe scientific investigation as an objective process. On the contrary, emphasizing role of imagination in scientific investigation tends to give a subjective impression of scientific investigation. In addition, role of imagination in scientific investigation is commonly considered to have a close relationship with the inferential nature of scientific knowledge (Lederman 2000), which is originating in anti-realism philosophy of science and therefore as a contemporary NOS elements. It may not be easy to find the origin of this NOS element in the literature, but the above analysis of its relationships with other NOS elements indicates that it is fair to classify it into the contemporary group.

Tentativeness of scientific knowledge. This element was also mentioned by six Chinese educators as their NOS content to be taught. It means that

> There is not absolute scientific knowledge. Any knowledge might change in the future. (STE14 SI p.6)
>
> Scientific knowledge is temporary or tentative…Scientific knowledge that may be now considered as right might change several years later. (STE5 GI p.2)

Stating the accumulative or progressive nature of scientific knowledge is a typical argument in logic-empiricist philosophy of science, which started in the very early stage of the philosophy of science. The logic empiricists commonly conceive the development of science as a process that the replaced theories are reduced (and thus absorbed) into the replacing theory. For example, they take Newton's theory as being reduced to Einstein's theory. On the basis of such understanding, the development of scientific knowledge is naturally considered as cumulative and continuous. In contrast, it was thought by Kuhn (1970) that both normal science and scientific revolutions exist in the development of scientific knowledge. During the scientific revolutions, the old paradigm is replaced by the new one, and so the change happening in such period is a process of replacement and displacement, rather than replacement and absorption. In this sense, the development of scientific knowledge cannot be considered just as being accumulative. When educators just stated that scientific knowledge is tentative, this statement actually avoided the controversies of whether the development of scientific knowledge is progressive or not. Therefore, it was regarded as the NOS elements originating in latter stage of philosophy of science, i.e., the contemporary ones.

NO existence of the stereotype image of scientists. Myths of scientist were also stated by two Chinese science teacher's educators, which means "a distorted view of the scientist as objective, open-minded, precise, selfless" (STE17 GI p.5) and "being 40-year-old person, in white coat, serious without smile, and only male not female" (STE6 GI p.1). Actually these two educators emphasized two different kinds of myth about scientists. The myth about scientists stated by STE17 is related to the personality of scientist. It may be still remembered that this kind of elements has also been discussed before within scientific ethos. Of course, the tone used in the occasion of scientific ethos is rather different from what is used here. If these elements are described under the name of ethos, it means that they are believed as reality, but when they are considered as the myth, what is implied is that they are considered not to be always true for all scientists. As introduced before, the origin of the discussion on scientific ethos can be traced back at least to the 1920s, which is clearly the earlier time in the historical development of people' understandings of science. The origin of the myth of scientist in the aspect of personality is relatively later. It is roughly around the 1970s that the criticism of scientific ethos or norms began to appear in sociology of science. As those sociologists of science argued, there is little evidence that scientists adhere to these norms, to a greater extent than any other comparable social group, in context outside science, and the extent to which they are honored within science should be questioned (e.g. Barnes & Dolby 1970). Given the time of their origin, we can include the myth of scientist relevant to personality as the contemporary.

The myth about scientists stated by STE6 is related to the physical appearance, like age, gender and clothes. It is difficult to find the origin of these elements in the three major meta-studies of science, i.e., philosophy, history, and sociology of science. They might owe their origin to the science education literature in 1950s (e.g. Mead & Metraus 1957). In studies using the test of drawing a picture of scientists, such kind of myth of scientist in their physical appearance was usually revealed. Given that this NOS element originates around 1960s, it is not easy to just rely on the time criterion to group them into the classical or contemporary. However, we may find that these myths in physical appearance is placed under the same label (i.e., myth of scientists) with those in personality by the educators, so it indicates or at least believed by educators that they might be some similarities between them. If we compare their relationships with scientific ethos and the myths in personality as introduced above, they might have a closer relationship with the latter. Therefore, all these myths of scientist were perceived as contemporary.

CATEGORIZING CHINESE SCIENCE TEACHER EDUCATORS IN TERMS OF THEIR CONCEPTIONS OF NOS CONTENT TO BE TAUGHT TO PRE-SERVICE SCIENCE TEACHERS

After differentiating all the NOS elements, the authors further compared the specific NOS elements suggested by each science educator in their instruction. All the educators then were categorized into three groups in terms of their NOS content to be taught, i.e., focusing on the classical , focusing on the contemporary, and mixed (refer to Appendix 2 for the details of categorization). There are 58.3% educators (14 out of 24) in the present study focusing their NOS teaching on the classical NOS elements, and 33.3% educators (8 out of 24) on the contemporary. As for the other two (STE1, 20), a number of both classical and contemporary NOS elements are included, so they are somewhat mixed.

During the interview, a number of educators in the present study (twelve) explicitly stated their decisions on the focus of their NOS content to be taught to pre-service science teachers. For example, STE3 stated that

> In the Western world, the views on science can be classified into two periods…The first is before 1960s. This is the classical view, which can be summarized as the following points: science is based on the observation and facts; science is replicable, accumulative, and falsifiable…The second kind of view believes that observation cannot reflect the objective world, so the scientific theories are not objective. Instead, they are just the visions that scientists construct in their heads. They are the post-modernist views of science…I focus on teaching those classical views of science in my teaching. (STE3 SI p.4)

The above transcripts reflected that this educator explicitly classified the views on NOS into two groups, labeled as the classical and the contemporary. Then, she chose to focus her NOS teaching on the classical NOS elements. Another typical example is STE15, a biology teacher educator. He also separated NOS views into two groups, labeled as "the traditional and the contemporary" (STE15 GI p.2). However, he suggested the contemporary views of NOS as the focus of his teaching. Those elements suggested in his NOS teaching were tentativeness of scientific knowledge, inferential scientific knowledge, theory-laden nature of observation, no single scientific method, creation in scientific investigation, empirical basis of scientific investigation, bilateral influence of science on the society, social and cultural influence on science, and scientific community.

Since the controversy between focusing their NOS content to be taught on the classical NOS elements or the contemporary was explicitly discussed by these educators, such controversy might be consciously perceived by them.

FACTORS INFLUENCING CHINESE SCIENCE TEACHER EDUCATORS' CONCEPTIONS OF NOS CONTENT TO BE TAUGHT TO PRE-SERVICE SCIENCE TEACHERS

During the interviews, Chinese science teacher educators also spoke out the rationales for their decisions on NOS contents. From the participants' narrative, the authors identify three factors that affected what NOS elements they planned to teach, including their view of the concept of NOS itself, vision of teaching NOS, and belief in general philosophy.

Figure1 about here

View of the concept of NOS itself. It was emphasized by seven educators that the *nature* of science should be the features of science that can to some extent distinguish it from other thing. If a feature cannot meet such a requirement, it should be the *nature* of science. For example, as stated by a physics teacher educator,

> What is the nature of human? It should be related to language, thinking, tool, and labor… Of course, human also has eyes, needs to sleep, and breathe. But these features cannot be considered as the nature of human, since they can apply to almost all the animals. The nature of something should be the essential components of something that can differentiate itself from the others… Similarly, the nature of science should be the features that can differentiate science from other subjects. Otherwise, it may be the nature of something else. (STE9 GI p.3)

The demarcating issue has been long addressed in the literature (Ruse 1983). Although we may not be able to find an absolute dichotomy between science and non-science, it cannot be denied that there still exist some characteristics that can make a question or a field of study more scientific (Smith & Scharmann 1999). According to these Chinese teacher educators, these characteristics included "empirical methods, testability, accumulation of scientific knowledge, general process of scientific investigation" (STE9 GI p.3), "replicable nature of empirical evidence, and pursuit of truth" (STE13 GI p.2). It is clear that all these characteristics are the classical NOS elements. Therefore, when these educators adopted the demarcating criterion in their definition of NOS, they could just teach those classical NOS elements in their NOS teaching. On the contrary, if educators considered NOS broadly as any features of science, there existed a possibility for them to focus their NOS instruction on the contemporary NOS elements.

Of course, there may exist controversies on whether NOS should be defined as the features that can distinguish science from the others. Some may disagree with such an opinion. However, the arguments provided by STE9 cannot be considered to be totally irrational as the reasons that he provided are still logical. Since there is still not an agreed definition on NOS in the literature, it may be no harm to consider such a way of defining NOS as a view open to discussion.

Vision of teaching NOS. Although these educators have a common interest of teaching NOS, their visions of teaching NOS might not be the same. For example, a physics teacher educator (STE12) aimed to suppress superstition in Chinese society. She thought that "superstition was deeply rooted in Chinese feudal society and still very popular nowadays", so in order to achieve her goal of conquering superstition, she would like to teach "scientific worldviews and scientific rationality" (STE12 GI p.5), which are reflected in the classical NOS elements. Another chemistry educator (STE11) was eager to cultivate the scientific ethos of objectivity among Chinese people. It was stated that "Chinese people is lack of scientific ethos of pursuing the objectivity", so "Chinese research works value the metaphysical speculation and ignore the seeking for the evidence and the decision making depends on conjecture rather than going to the field to do investigation" (STE11 GI p.4). Therefore, he would teach those classical NOS elements so as to develop the scientific ethos of pursuing objectivity.

Different from those educators focusing on classical NOS elements, other educators tended to utilize the contemporary ones to achieve other visions. An integrated science teacher educator thought that "scientism is very serious in Chinese tradition". In other words, science is usually sanctified. With the goal of breaking the worship of science, he focused on teaching those contemporary NOS elements, which "reflect the subjectivity and limitation of science" (STE6 GI p.6). The ambition of overturning authoritarian submission in Chinese culture was emphasized by a physics teacher educator. He thought that "Confucian moral standards have a great influence on Chinese society", which emphasize three cardinal guides: ruler guides subject, father guides son, husband guides wife. "What is embedded in these cardinal guides is an absolute and blind obedience" (STE5 GI p.5). He hoped to embody the relativity of science through teaching contemporary NOS element so as make people realize that "even scientific knowledge, which might be considered as the most objective knowledge, is also the creation of human's subjectivity and has its limitation, so are there anything that can't be questionable, and are there any authorities who should be absolutely obeyed?" (STE5 GI p.5).

On the basis of the above examples, we can find that NOS elements have rich relationships with various issues in Chinese society, and different educators had rather different visions for their NOS teaching, which in turn influenced their decisions on whether the classical or contemporary NOS elements were emphasized in their teaching practice.

Belief in general philosophy. Another factor that influenced Chinese science teacher educators' decisions on NOS content was their belief in a specific kind of general philosophy, i.e. Marxism. Marxism is a sort of philosophy and well-known as the ideological basis of Communist Parties. It derived from the work of Karl Marx (1818 –1883) and Friedrich Engels (1820-1885). The introduction of Marxism into China might be tracked back to 1917- 1920 when October Revolution broke in Russia. The victory of the Chinese Communist Party in 1949 further made Marxism the dominating ideology in China. An important component in Marxism is materialism. The major arguments in materialism are rather similar to those in realism (Curtis 1970). Based on these materialistic ontological principles, the epistemology in Marxism is basically empiricism. As stated by an integrated science teacher educator, he "had been taught of Marxism in middle school, which has been deeply rooted in his mind…Marxism arguments are consistent with the classical schools in the philosophy of science", so he "did not believe those so-called post-modernism views about science". Given the existence of such belief, he "focused his NOS teaching on the classical NOS elements" (STE24 SI p.5). Similar statements were made by other three science educators (STE3, 9, and 18) who focused on teaching the classical NOS elements.

DISCUSSION AND CONCLUSIONS

NOS, as introduced previously, is a contested issue and two different views of NOS content to be taught can be found in the Western literature of NOS instruction, i.e., pluralism (e.g. Alters 1997a; Jenkin 1996; Siegel 1993) and essentialism (e.g. Osborne et al. 2003; Smith et al. 1997). Since the controversy between pluralism and essentialism has been explicitly discussed in the literature and considerable examples can be found for each view, it may be a prominent one in the literature. However, in this study, science teacher educators in this study seemed not to care much about this controversy since none of them were found to talk about it during the interviews. Besides, the pluralist view was not prominent in NOS content suggested by most of these educators. As indicated in the data, what they cared most was whether focusing on the classical or contemporary NOS elements. Comparatively speaking, the rationales for supporting pluralism or essentialism in literature are a bit more academic since they are related to the theoretical issues like the contested nature of science or the assumption of the existence of the consensus on NOS content. On the contrary, the rationales found in this study for science teacher educators' decision on NOS content were more personal since they were these educators' personal understandings of the concept of NOS itself, visions of teaching NOS, and beliefs in general philosophy. Such a variation may be caused by the difference of contexts where the controversies are identified. The first context is published journals and books, which are rather formal and public. What is discussed in it needs to be more theoretical. However, the second is the interviews on educators' own practice, which is less formal and more private, so what they said could be more personal, in other words, closer to their authentic thoughts. If the explanation was accepted, it would remind us to be cautious of the gap between the observation of literature and real practice. Of course, this is just a guess. Further study need to be done to see if similar findings can be found.

The prerequisite for essentialism is to achieve the consensus on what ideas about science should be taught (Osborne et al. 2003). The findings of this paper show that people's decision on NOS content may be very complicated since it is influenced by their views of the concept of NOS itself, visions of teaching NOS, and beliefs in general philosophy. Therefore, before getting the consensus on NOS content, it may be better to promote people within a certain region to achieve their agreement to some extent on these factors first. In this way, less difficulty may exist when people start to get the consensus on NOS content, and the agreed NOS elements may be more popularly accepted.

It was introduced in the section of literature review that NOS understanding has been commonly categorized into two levels (e.g. Abd-El-Khalick 1998; Kucuk 2008). The adequate or informed NOS understandings normally refer to the postpositivistic views while the naïve or inadequate understandings are mainly positivistic views and some misunderstandings about science. According to such a classification, classical NOS elements might be assessed as naïve or inadequate understanding of NOS, and contemporary NOS elements as informed or adequate ones. However, we should be aware that it may be unjust to use such labels to categorize the views of NOS content to be taught held by Chinese science teacher educators. For example, STE3, which is introduced in the preceding section of *Categorizing Chinese Science Teacher Educators in Terms of Their Conceptions of NOS Content to be Taught to Pre-service science teachers*, was well informed of the classical and contemporary NOS elements. In other words, she had *a highly sophisticated NOS understanding* (Author et al. 2009). However, she chose to focus on teaching the classical NOS elements in her courses. It is evident that focusing on classical NOS elements in NOS instruction does not necessarily imply a less informed understanding of NOS. On the contrary, some educators may have rather rich knowledge of NOS, but still choose to focus on teaching classical NOS elements due to their considerations related to the three factors introduced before.

Goal of teaching is a very significant issue in education. As stated by Matthews (2009), "if teachers no longer think seriously about the purpose of education and how they related to personal and social well being, then questions about the content and aims of science education become trivialized, or settled by reference to whatever is the passing educational fad"(p.33). The findings in this study indicate that teaching NOS may have a very complex relationship with various goals embedded in Chinese society. The classical NOS elements may be related to conquering superstition and cultivating the scientific ethos of objectivity in China, and the contemporary ones may contribute to mitigating scientism and overturning authoritarian submission in Chinese society. Actually, in addition to these positive relationships, some negative ones between certain NOS elements and these goals were also perceived by educators.

For example, it was argued by STE5 that in order to overturn authoritarian submission, people should first know the limitation of science, which made them realize the limitation of knowledge, and then they dared to question the authorities. Clearly, knowing the limitation of science is the first condition here for overturning authoritarian submission. However, what most of classical elements reflect is a rather positive impression of science, rather than the limitation of science. Thus when these classical NOS elements are emphasized, it may make it difficult to achieve the first condition of overturning authoritarian submission, which will in turn hamper the realization of this value. At the same time, as stated by STE13, the condition of suppressing superstition was to realize and then internalize the scientific rationality and realist worldview. However, the less rational aspects of science are reflected in contemporary NOS elements. In addition, the inferential nature of scientific knowledge, which is one of contemporary NOS elements, also reflects the anti-realism tendency. Therefore, if the contemporary NOS elements are emphasized, it may make it difficult for this educator to help students to perceive and then internalize scientific rationality and realist worldview, which in turn may make it difficult for him to realize the goal of suppressing superstition.

Given such a complicated connection existing between teaching NOS and various goals embedded in Chinese society, it may be rather challenging to make an appropriate plan to realize these goals in China. Before making such a plan, science teachers or teacher educators should consider systematically a number of questions. Which goals are more urgent? Which ones are less? Which goals can be more meaningfully and appropriately realized in science education? Which ones may be better realized in other contexts? Which goals should be realized to a larger extent? Which ones must be realized to a less extent? Which goals should be realized in the earlier stage of education? Which one need be handled in the later? All these questions cannot be easily answered. Therefore, it is significant to carry out explicit discussions among Chinese science teacher educators, curriculum designers, science teacher, and other relevant scholars on these questions. Although definite answers may not be achieved for all these questions within a short period, such communication can at least promote them to think about the complexity of teaching NOS in a more conscious and considerate manner. Until now, we do not know if such complex relationships between NOS elements and goals of teaching exits in other countries or regions, which may be an interesting question for future investigation.

Similar to science that is deeply embedded in the historical, political, cultural, and technological background of society (Bianchini, et al. 2003), people's views of NOS and its content to be taught are also shaped by various contextual factors in the society. Among these factors, four subjects, i.e. philosophy, history, sociology, and psychology of science, have been emphasized by McComas et al. (1998). As indicated in the study by Bianchini and Colburn (2000), NOS content taught by Colburn was consistent with his instrumentalist philosophical views about science. It is reflected in a series of work by Bianchini and her colleagues (e.g., Bianchini et al. 2002; Bianchini, et al. 2003; Bianchini & Solomon 2003), NOS elements emphasized in her courses for science teachers were determined by her beliefs in feminist philosophy of science. In the two examples introduced above, the influence of philosophy of science is prominent. The present study reminds that, in addition to the four subjects, general philosophy (Marxism in this study) may be another important one. Actually, Marxism is still very influential nowadays, which has been adopted in the academic study in a wide range of disciplines other than philosophy, including anthropology (e.g., Roseberry 1997), cultural studies (e.g. Carrington & McDonald 2009), education (e.g., Cole 2008), literature (e.g., Williams 1977), and media studies (e.g., Becker 1984). It is very popular in a large number of areas beyond China, such as Cuba, North Korea, Russia, eastern German, and north Europe. Hence we may need to do further research to probe whether or the extent to which the influence of Marxism on people’s views of NOS and its content to be taught can be found in these areas.

In this study, most educators were found to focus their NOS teaching on the classical NOS elements. Such a finding is consistent with a recent study (Ma, 2009) reporting that there exits the realist inclination in Chinese school science teachers’ understanding of NOS. Besides, as showed in Table 1 & 2, the most commonly suggested NOS elements are also the classical ones, including empirical basis of scientific investigation, logics in scientific investigation, progressive nature of scientific knowledge, realist views of mind and natural world, and general process of scientific investigation. They were included by more than a half of educators in their NOS content to be taught. On the contrary, such a tendency cannot be found in two relevant studies (McComas & Olson 1998; Osborne, Collins, Ratcliffe, & Duschl 2003) conducted in the West. It was discussed that the popularity of these elements may be caused by the prevalence of Marxism philosophy, defining NOS as the features distinguishing science from the other areas, and perceiving the goals of teaching NOS as conquering superstition and cultivating the scientific ethos of objectivity in China. Given the existence of these factors, there may be a considerable level of resistance if we want to emphasize the contemporary NOS elements in China. When someone wants to do so, before considering the methods of teaching them, it will be better to think more about some other crucial questions first. What resources do we have to handle such strong resistance? Can we persuade teachers to teach it? Is teaching these contemporary elements really urgent or meaningful? How can we promote the public to realize the meanings of teaching them? If we cannot get desirable answers to these questions, we may need to modify the list of these NOS elements itself.

There are two limitations of the sampling in this study. First, the participants only represent a specific group of science educators from the economically developed areas of Mainland China who have interest in talking about their conceptions of teaching NOS. Second, the snowballing sampling strategy was adapted in this study. Given personal relationships existing among these participants, they may belong to a group of educators with similar views in some aspects of teaching NOS. Further research is needed to include more educators from more cities.

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Table 1 Classical NOS elements and rationales for classification

NOS elements *(No.)*	Rationales for classification
Scientific investigation	
Empirical basis of scientific investigation *(20)* Empirical method is one of major features of scientific investigation since whether the results or arguments in science will be accepted or not will depend on the result of testing through observation or experiment… This is also the key feature for distinguishing science from other types of understanding. (STE13 GI p.3)	*Its origin is the empiricism in the philosophy of science, which can be traced back the work of the earlier philosophers like Bacon (1562-1626).*
Replicable nature of empirical evidence *(6)* The observation and experiment in science need to be replicable by other researchers in scientific community…It's not like art, where the observation and perception by different audience doesn't require to be the same or even similar. (STE18 GI p.2)	*It is consistent with the classical element, empirical basis of scientific investigation, and opposite to the contemporary element, theory-laden observation.*
Logics in scientific investigation *(15)* Both the inductive and deductive logics are all important methods in scientific investigation. Deduction is from the general theory or concepts to the specific conclusion or facts…On the contrary, induction is the reasoning from the specific conclusion or facts to the general theory or concepts (STE24 GI p.3)	*In the philosophy of science, the logic suggested in earlier age is induction, which appeared much earlier than 1960s. Deductivism and inductivism share the commonality to seek the logic method in science.*
General process of scientific investigation *(12)* There are some common points in scientific investigation, like raising a question, posing some hypotheses, testing such hypotheses or arguments through observation or experiment, drawing some conclusions and communicating such conclusion so as to let people accept the conclusions … Such a process is an important feature of science that distinguishes itself from other subjects. (STE9 GI p.5)	*The inductive-empiricists and deductive-empiricists are common in believing that there is a general method in science. The origin of this NOS element can be traced back to Bacon (1562-1626).*
Science as the pursuit of truth *(3)* The goal of scientific investigation is to pursue truth, to reflect the real picture of the objective world…Science is unlike the art. The art aims to pursue aesthetics, which allows departure from the fact and reality. But science investigation doesn't allow it. (STE3 GI p.3)	*It implicitly admits the existence of truth, and so is a realism view, whose origin is much before 1960s. The anti-realism trend begins to flourish at relatively latter stage in philosophy of science after the publication of The Structure of Scientific Revolution (Kuhn, 1962).*
Scientific knowledge	
Testable nature of scientific knowledge *(4)* The empirical nature of scientific investigation also requires all scientific arguments must be able to be tested by empirical evidence at least in a theoretical sense… Any ambiguous argument can't be scientific argument, like "it will not rain or rain tomorrow", since they can't be falsified. (STE5 SI p.4)	*It is closely interrelated to the classical element, empirical nature of scientific investigation, and owes its origin to empiricism, which started in the rather initial stage in the philosophy of sciences.*

Progressive nature of scientific knowledge *(14)* Another feature of science is its accumulation…Literature is not accumulative. Contemporary literature works needn't base on the previous ones. The quality of contemporary literature may not be better than those in Ancient Greece…The accumulative nature is a unique advantage of science. (STE10 GI p.2)	*It is a typical element originating in logic-empiricism, which conceives the development of science as a process of replacement and absorption. In contrast, it was thought by Kuhn (1962) that during the scientific revolutions, the change is a process of replacement and displacement.*
Truth-approaching nature of scientific knowledge *(8)* We should consider scientific knowledge as relative truth…Although it may never arrive at the state of the absolute truth, its development is a process of continuous progression towards the truth in the objective world. (STE9 SI p.3)	*It is a direct acknowledgement of the existence of the corresponding relationship between scientific knowledge and the real world, which is a realism view.*
Scientific worldview and ethos	
Realist views of mind and natural world *(13)* To conduct scientific investigation, we must be guided by some basic understandings of the world, like that the world is material, all matter in the world are connected, such connection are universal, matter are motioning, there are rules underlying such motion, and all these connection and rules are knowable to human being. (STE9 GI p.3)	*These understandings are very elaborate and systematical realism beliefs, whose origin is much before 1960s.*
Scientific ethos (10) Scientific ethos is the valuable qualities of scientists, including the ethos of perseverance, daring to challenge the authority, being critical, skepticism, perseverance, and respecting the facts and daring to explore. (STE7 GI p.4)	*There are countless writings on the scientific ethos before 1960s (Merton, 1973). The origin of the discussion on the scientific ethos by Chinese academics can be at least tracked back to the early 1920s (Kwok, 1965).*

Table 2 Contemporary NOS elements and rationales for classification

NOS elements (No.)	Rationales for classification
Scientific investigation	
Theory-laden nature of observation *(8)* Observation is unavoidably subjective and with limitation…Scientists' observation is also unavoidably influenced by their knowledge background, cognitive tendency, and research interests… they're unavoidably to some extent subjective. (STE6 GI p.5)	*It contradicts with the classical NOS element, the replicable nature of empirical evidence, and has an apparent close relationship with Kuhn's theory as subjectivity of science is emphasized in both.*
No single scientific method *(6)* Scientific investigation is open. There is no fixed method in science… Scientists can use any methods that can serve to answer the questions posed. The process of scientific investigation is a very flexible. The specific methods adopted by different scientists are rather diversified…depending on the questions that the scientists want to probe...If there is any similarities among them, it may be that they start with a question and end with an answer to the question. (STE15 GI p.2)	*It challenges the classical NOS view believing the existence of a scientific method. Such relativistic understanding of the scientific methodology mainly began to appear in 1970 (e.g., Feyerabend, 1975).*
Imagination in scientific investigation *(6)* There are a large number of scientific concepts that we can't directly observe, like electrovalent bond, force field, photon, atomic structure, so the generation of those concepts needs our creation and imagination…Posing a meaningful question also needs creation and imagination… Scientific investigation is not as rational and logical as we think. (STE16 GI p.3)	*It opposites to some classical NOS elements, like empirical nature of scientific investigation, replicable nature of empirical evidence and logics in scientific investigation, and has a close relationship with the inferential nature of scientific knowledge (Lederman et al., 2002)* .
Scientific knowledge	
Inferential nature of scientific knowledge *(8)* There are mainly two kinds of knowledge in science, law and theory…The laws are the generalization of the observation. On the contrary, theories are the explanation of observation…Laws can be tested directly by observation…Since theories are based on the inference and we can't see directly the entity that theories refer to, they can't be tested directly. We can just test them through the indirect measures. (STE 5 GI p.7)	*Emphasizing the inferential nature of scientific theory reflects the tendency of anti-realism, which began to thrive in 1960s. It is closely related with the imagination in scientific investigation.*
Tentative nature of scientific knowledge *(6)* There is not absolute scientific knowledge. Any knowledge might change in the future. (STE14 SI p.6)	*It avoids the controversies of whether the development of scientific knowledge is progressive or not, which reflects the views of the later philosophers of science like Kuhn (1962) and Feyerabend (1975).*

Scientist and scientific enterprise	
No existence of the stereotype image of scientists *(2)* In people's impression, there is a stereotype of scientists that they are precise, they are objective, and they are selfless. In fact, this isn't the real picture of scientist. Some scientists are selfish, they are also subjective, and they also make mistake. There is also a distorted view of the scientist as being 40-year-old person, in while coat, serious without smile, and only male not female. (STE17 GI p.5)	*The myth of scientists' personality reflects the criticism of scientific ethos form sociologists of science in 1970s'. Although the myth of scientists' physical appearance owes its origin to the science education literature in 1950s, it was grouped by educators with the myth of scientists' personality under the same label (i.e., myth of scientists).*
Understanding of scientific community *(9)* Until now, science has developed into a social enterprise. It has changed from the previous individual inquiry into the nature from personal interests into a profession…It needs government's investment. It needs the cooperation of many organizations…The scientist group becomes more complex. They're more professional. (STE8 GI p.4)	*It stems from the concept of Scientific community (Kuhn, 1962; Polanyi, 1958) in sociology of science. General speaking, sociology of science is younger than philosophy of science, and challenges objectivity of science, which is an image reflected in a number of classical NOS elements*
Bilateral influence of science on the society *(6)* What is the influence of science on the society? It has some positive influence on the society…like promoting economic development, increasing human's living standard, and enhancing the strength of our country…At the same time, it's also a two-blade sword. For example, it also was used wrongly in wars and caused environmental problems. (STE1 GI p.5)	*The sociology of science began to expand the vision of study from the scientific community to the relationship among science, technology and society (STS) in 1980s (McGinn, 1991). This element is part of STS content.*
Social and cultural influence on science *(10)* Science is a social enterprise, so it is affected by the factors in the society, including economic needs cultural tradition, religion and politics. (STE17 GI p.4)	*It owes to its origin to STS studies. Emphasizing social construction of science challenges the objectivity of science, which is reflected in a number of classical NOS elements.*
Relationship between science and technology (3) Science and technology are two distinctive and also interrelated concepts... Their goals are different. Science aims to know the world, but technology aims to solve problems…The development of technology can improve the tools in scientific investigation, and the development in science can also provide the theoretical basis of technological innovation. (STE4 GI p.5)	*It originates from STS, which is a relatively young branch in sociology of science.*