When Nature of Science Meets Marxism: Aspects of Nature of Science Taught by Chinese Science Teacher Educators to Prospective Science Teachers

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Abstract. Nature of science (NOS) is beginning to find its place in the science education in China. In a study which investigated Chinese science teacher educators' conceptions of teaching NOS to prospective 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 prospective science teachers*. Among a total of twenty NOS elements considered by the Chinese science teacher educators to be important ideas to be taught, five were suggested by no less than a half of the educators. They are (i) empirical basis of scientific investigation, (ii) logics in scientific investigation, (iii) general process of scientific investigation , (iv) progressive nature of scientific knowledge, and (v) realist views of mind and natural world. This paper discusses the influence of Marxism, a special socio-cultural factor in China, on Chinese science teacher educators' conceptions of NOS content to be taught to prospective science teachers. We argue the importance of considering ideological traditions (mainly those in general philosophy and religion) when interpreting views of NOS or its content to be taught in different countries and regions and understanding students' conceptual ecology of learning NOS.

Introduction

Teaching about the nature of science has found its place in recent science education reform documents in the Western World (AAAS 1990a; CMEC 1997; NRC 1996)[1]. The earliest statements of this objective in the literature can be traced back to the beginning of the last century. As recalled by Lederman (1992), the importance of scientific method and processes of science in science teaching and learning have been stressed by the Central Association of Science and Math Teachers (CASMT) in America in as early as 1907.

Compared with the Western world, science education had a rather late start in China. It was not until the end of the 19th century that Western science education was introduced into China (Lewin 1987; Wang 1997). However, the ensuing political and social unrests in China further hindered its development for almost a century. 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 strategies include reforming education that can nurture and prepare the future generations for its development. 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 with the emphasis on scientific literacy as an important goal of Chinese school science education (Wei and Thomas 2005). NOS, as one of the components of scientific literacy (Matthews 1998a), has started to become a topic of concerns in some science curriculum reform documents (e.g., MOE 2001a; 2001b)[2], Chinese academic articles

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

(e.g., Chen 2006; Ding 2002; Liang 2007; Xiang 2002; Yuan 2009), as well as textbooks for training science teachers (e.g., Liu 2004; Yu 2002; Zhang 2004).

During the past six decades, extensive research has been conducted on NOS. A comprehensive review of these studies can be found in Lederman's works in 2007. The Western science education practitioners' views of NOS teaching hence can be, to some extent, informed in the literature. However, we still know little about how the teaching of NOS is perceived by the practitioners in China. Given the unique social and cultural backgrounds of China, there may exist some differences between Chinese people's views or perspectives and the ones reflected in Western literature. Therefore, an exploratory study was conducted to investigate Chinese teacher educators' conceptions of teaching NOS to prospective 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 prospective science teachers.

The Contested Meaning of 'Nature of Science'

Although NOS has been one of the commonly discussed and researched topics in science education, there is not a unified way to define the phrase of NOS in the literature. On some occasions, NOS is defined as epistemology of science or nature of scientific knowledge (e.g., Abd-El-Khalick and Lederman 2000; Lederman 2007). In contrast to delimiting NOS discussion within epistemology of science, some recent literature encompasses a much broader range of contents. As stated by McComas and his colleagues (1998),

> The nature of science is a fertile hybrid arena which blends aspects of various social studies of science including the *history, sociology, and philosophy* of science combined with research from the cognitive sciences such as *psychology* into a rich description of what science is, how it works, how scientists operate as a social group

> and how society itself both directs and reacts to scientific endeavors. (p.4) (*authors' emphasis*)

In this definition, the scope of NOS has apparently expanded from the previous definition dominated by one area of the study on science (philosophy of science), into four areas, i.e. history, sociology, psychology and philosophy of science.

In Wong and Hodson's (2009; 2010) recent works on scientists' views about science, the authors also adopt a broader meaning of NOS in common with definitions adopted by Osborne et al. (2003) and Clough (2006). The phrase NOS used in their work encompasses the characteristics of scientific inquiry, the role and status of the scientific knowledge it generates, how scientists work as a social group, and how science impacts, and is impacted by, the social context in which it is located.

Most recently, Irzik and Nola (2011) propose a family resemblance approach to NOS by comprehensively and systematically organizing the cognitive aspects of science into four categories: (i) activities (scientific inquiry), (ii) aims and values, (iii) methodologies and methodological rules, and, (iv) products (scientific knowledge). The authors further elaborate that the four categories of the cognitive aspects of science could be extended to accommodate the non-cognitive institutional and social norms which are operative in science and influence science.

It is evident that there are different meanings associated with the phrase NOS even among scholars in the West. Hence, the research in the present study has avoided adopting a fixed definition of NOS during the process of probing Chinese science teacher educators' conceptions. An open stance to any possible differences in their views about the conceptions and meaning associated with the phrase NOS has been adopted to encourage the educators to speak out their mind.

Besides the difference in the scope of the meaning associated with the phrase NOS, there are also many disputes among the contents that are to be included in these definitions (Deng et al. 2011). Early in 1960s, Herron (1969) maintains that no sound and precise description existing concerning the nature and structure of science. This view is echoed later by Meichtry (1993), who notes that the "lack of agreement which has occurred" (p.432) in defining 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, Alter (1997a) concludes that "we should acknowledge that no one agreed-on NOS exists" (p.48).

Given the contested nature of NOS, there are broadly two different opinions found in the literature on the NOS content to be taught, i.e. pluralism and essentialism. 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 the teaching of NOS so as to give a real picture of science (e.g., Alters 1997b; Jenkin 1996; Siegel 1993). For instance, Nott and Wellington's (1993; 1998) state that their NOS course encouraged the learners to discuss the statements about science. The authors classified and presented these statements in terms of 'relativism versus positivism', 'inductivism versus deductivism', 'contextualism versus decontexualism', 'instrumentalism versus realism', and 'process versus content'.

However, when facing the same contested NOS, some others hold that regardless the debates on the ultimate NOS, there exists a considerable consensus regarding NOS content to be taught to school students (Lederman et al. 2002; Osborne et al. 2003). Hence they suggest to focus NOS instruction on these consensus NOS tenets, which are summarized by Lederman and his colleagues (2002) as:

> [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).

The basic assumption of essentialism is that the consensus does exist among people on what ideas about science should be taught. Two studies relevant to this assumption have been conducted, whose findings are summarized in Table 1. The first one was conducted by McComas and Olson (1998), which reviewed eight science standards documents in the Western world, including the United States, Australia, Canada, England and New Zealand. In this study, the authors identified thirty statements about the nature of science from the documents and further identified thirteen statements that were found in six or more national curriculum documents (i.e. more than seventy five percent). Another study was conducted by Osborne and his colleagues (2003). The participants of this study were twenty-three Western leading scientists, historians, philosophers and sociologists of science; science teacher educators; experts engaged in the public understanding of science or science communication; and expert science teachers. A three-stage Delphi questionnaire was employed to solicit the views of the participants what they thought should be taught about the methods of science, the nature of scientific knowledge, and the institutions and social activities of science. Nine themes emerged as important for inclusion in the science curriculum

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Table 1 about here

As indicated in the above table, similarity can be found between the specific NOS elements in the two columns, such as “science knowledge is tentative” and “science and certainty", "science is an attempt to explain phenomena" and "analysis and interpretation of data", as well as "scientists are creative" and "creativity". Besides, the two columns include a good number of NOS elements that are relevant to scientific investigation. A prominent difference between the findings in these two studies is that the former covers a rich list of features of science in the social dimensions while the latter has only one. This comparison of the findings of these two studies conducted in the West reflects many common NOS features but also certain differences in the views about NOS elements that should be taught in the school science curriculum. Would the differences be more significant when compared with the findings in the counties or regions of other cultures? What are the similarities and differences, and what would be the possible causes for the differences? Before we report on the findings related to these questions, we first elaborate the considerable influence of Marxism on the ideologies held by the people in Mainland China. Awareness of such an influence has been crucial in making sense of the interview data and our interpretation of the data.

Marxism and China

Marxism was originally developed in the middle of 19th century by two German philosophers, Karl Marx (1818 –1883) and Friedrich Engels (1820-1885), and now is still playing important roles in contemporary society. Anderson (1976) distinguishes between two major traditions of Marxism, i.e. Classical Tradition and Western Marxism. The Classical Tradition stemmed from the original works of Marx and Engels, and includes all well-known Marxists, such as Lenin, Stalin, Luxemburg, Bukharin and Trotsky (Skordoulis 2009). Western Marxism refers to more Hegelian and critical forms of Marxism in Western Europe, which develop the theories of culture, social institutions, psychology, and other themes that were not systematically engaged by the earlier generations of Marxists (Kellner 2005). In

China, the Marxism published in textbooks mainly belongs to the Classical Tradition, which is heavily based on the works of Marxists in former Soviet Union. What is discussed in the present paper is also the influence of this version of Marxism on Chinese science teacher educators' views. Therefore, the following sections focus on reviewing the contents in it that are the most relevant to interpreting the data of this study.

Marxist Basic Philosophical Standpoints

The key and basic question of all philosophy is on the origin of the world (Engels 1976a). Is it the mind or the matter? Different answers to this question split philosophers into two prominent camps. According to idealists, the only things we can know are our own ideas and senses, but we cannot know if there is anything beyond them in the world. Thus, the origin of the world is mind, and material objects are in the mind or associated with our fundamental sense which is dependent upon the mind. For example, they believe that we know the existence of an apple because we have senses about it, including the visual appearance, weigh, touch, taste and smell. However, apart from knowing the existence of these senses, we cannot ascertain that a material entity named as apple really exists in the world. Its existence is just dependent on our mind. Such idealist views are totally rejected in Marxism, which holds materialist ontological views. Marxism believes that the material world is the only reality, it is independent of our mind, it is the source of mind, and mind is just a reflection of the material world (Engels 1976a).

On the basis of their materialist ontology, Marxists also hold the realist epistemology (Curtis 1970; Farr1991; Murray 1990), which admits the knowability of the material world. It is believed that "the world and all its laws are fully knowable …there are no things in the world which are unknowable, but only things which are as yet not known" (Stalin 1985, p.18). When admitting the knowability of the material world, it is actually suggesting that it is possible for humans to get true knowledge of the world. Therefore, Marxists have no hesitation to use truth to discuss human's thought or knowledge. For instance, as stated by Lenin (1977), "the limits of approximation of our knowledge to objective, absolute *truth* are historically conditional, but the existence of such *truth* is unconditional, and the fact that we are approaching nearer to it is also unconditional" (p.136) (*authors' emphasis*).

Practice is the crucial concept in Marxism, which is considered as the starting point, the basis, the criterion, and even the purpose of all knowledge (Mao 1986)[3]. As stated by Marx (1976), "the question whether objective truth can be attributed to human thinking is not a question of theory but is a *practical* question … the` dispute over the reality or non-reality of thinking that is isolated from *practice* is a purely scholastic question (p.3)" (*authors' emphasis*). Here, *practice*, in plain words, means the activity of applying mind into reality. For example, when some hypotheses are generated during the process of doing scientific investigation, we need to predict what phenomena are to be observed if the hypotheses are correct. On the basis of such predictions, appropriate scientific experiments are designed. The results of the scientific experiments are the evidence of supporting or refuting such hypotheses. The action of designing and doing experiments is a process of applying ideas into reality, so it is a kind of *practice*. During the process of teaching, we use a certain kind of educational theory to guide the design of our teaching activities. If we find that students learn better, such a result is the evidence to support this educational theory. This kind of teaching activity is also *practice*. In fact, during the process of applying our mind into reality, we can, at the same time, get the responses from the reality through our sense experience, which can be not only empirical evidence to support or refute our mind, but the resources of generating new ideas. It is not difficult to note that empirical evidence, which is emphasized by

[3] Mao Zhe Dong first elaborates the concept of practice in his classic article "On Practice: on the relation between knowledge and practice, between knowing and doing" written in July 1937, which is collected in various versions of Selected Works of Mao Zhe Dong. The specific article cited here is this one included in Mao (1986).

empiricist epistemology, is implicitly integrated into the concept of *practice* in Marxism. Thus it is believed that Marxist philosophy, to a large extent, is consistent with empiricist epistemology (Creaven 2001).

Marxists call their materialism as *dialectical* materialism so as to differentiate it from mechanical materialism whose mode of thinking is thought by them to be static and rigid (Engels 1976b). Three viewpoints are emphasized in the dialectics of Marxism. The first is the law of the unity of opposites. It holds that the contradicting parts are inherent in all things and phenomena in the world. For example, attractive and repulsive forces both exist among molecules. The qualitative and quantitative change can be both found in the process of development. What happens during the qualitative change is not a complete negation. Rather, there is a unity of opposites between affirmation and negation. When a seed grows into the wheat plant, although the seed disappears, the plant keeps its gene and will produce more seeds in the future. Chinese traditional concept of *yin and yang* (陰陽), representing contrary forces that are interconnected and interdependent, is also consistent with the idea of the unity of opposites.

The law of the unity of opposites is very important since it makes Marxism considerably flexible in handling the attacks from idealism. For example, the above paragraphs on Marxism mainly illustrate the objectivity of human knowledge. They hold that the material world exists independently of our mind, it is the source of mind, our mind can know the objective world, and the validity of our knowledge can be tested by *practice*. However, idealists may challenge that human is unavoidably subjective, human's *practice* is limited, and so human knowledge may not be reliable. When facing such challenges, Marxism argues that

> Human thought is just as much sovereign as not sovereign, and its capacity for knowledge just as much unlimited as limited. It is sovereign and unlimited in its

> disposition, its vocation, its possibilities and its final historical goal; it is not sovereign and it is limited in its individual fulfillment and in reality at any particular moment. (Engels 1976c, p.109-110)

In the above quotation, human thought or knowledge is illustrated as the unity of absoluteness and relativity. When the target of human thought, i.e. the material world existing outside, is considered and the development of humankind is perceived as a whole, the objectivity of human's knowledge is absolute. At the same time, if we focus on the individual level or the specific period of human history, it is also relative or subjective. It can be found that by using such a dialectical way of thinking, Marxist theory appropriately defends itself from the challenges of idealists, and maintain its fundamental materialist framework at the same time.

The second viewpoint emphasized in dialectics is that the world is an integral whole, in which all the things are interrelated with and interdependent on each other. Given the interconnection and interdependence of the world, it is considered necessary to understand phenomena from their surrounding conditions. This point is consistent with Marxist interpretation of human history in terms of productive forces and their corresponding social relations in the society, instead of other abstract concepts. The third viewpoint of dialectics holds that the world is in a state of continuous movement and change. It is believed that the change is the inherent feature of the things in the world. Hence the phenomena in the world should be thought about not only from the standpoint of their interconnection, but also from the perspective of their movement.

When combining these three viewpoints of dialectics together, Marxism presents a dynamic, fluid and flexible way of thinking, which is rather different from the static way of thinking reflected in mechanical materialism.

Nature of Science in Marxism

Although there is not a systematic treatise on science in Marxist works, a number of statements about science still can be found in these works (Skordoulis 2009). An attempt is made in this section to use these statements to portray NOS in Marxism.

One of the important aspects of science that is explicitly discussed in Marxism is the role played by philosophy in science. It is believed by Marxists that since scientists should use and produce human thought in their work, they should know what human thought is and how it is generated, which is an essential issue of philosophy. Therefore, as stated by Engels (1976b), "natural scientists may adopt whatever attitude they please, they will still be under the domination of philosophy of science. It is only a question whether they want to be dominated by a bad, fashionable philosophy or by a form of theoretical thought with rest on acquaintance with the history of thought and its achievement" (p.558). Since Marxism, especially dialectical materialism, is believed by Marxists to reflect the real world, they considered it as the right philosophy or worldview to guide scientists.

As introduced in the above section, *practice*, in which the concept of empirical evidence is implicitly integrated, is a crucial concept in Marxism epistemology. It is considered as the basis and criterion of all knowledge. In consistency with such an understanding, Marx (1977) also explicitly states that "sense-experience must be the basis of all science" (p.94). Of course, due to its own theoretical framework, the term *practice* is used much more frequently than the statements about sense-experience in Marxists' works.

In addition to sense experience, logical methods in scientific investigation are also discussed by Engels (1976b). Although there are some controversies between inductivism and deductivism in the history of philosophy of science, Engels did not take them as conflicting logics. Instead, they were considered as a unity of the opposites. "Induction and deduction belong together…Instead of one-sidedly raising one to the heavens at the cost of the other, one should seek to apply each of them in its place, and that each completes the others" (Engels 1976b, p.519)

Similar to their realist understanding of knowledge in general introduced before, Marxists also have no hesitation to use the word truth to describe scientific knowledge. As stated by Lenin (1977),

> Human thought then by its nature is capable of giving, and does give, absolute truth, which is compounded of a sum-total of relative truths. Each step in the development of science adds new grains to the sum of absolute truth, but the limits of the truth of each scientific proposition are relative, now expanding, now shrinking with the growth of knowledge (p.135).

It can be found in the above sentences that scientific knowledge at a certain period of human history is considered as relative truth. At the same time, the development of scientific knowledge as a whole is a progressive process approaching the absolute truth in the world. Briefly speaking, scientific knowledge is a unity of relative and absolute truth.

Since Marxists insist on the necessity to understand phenomena from their surrounding conditions, they also believe that science should be understood in its broad social context. It is stated that "where would natural science be without industry and commerce? Even this 'pure' natural science is provided with an aim, as with its material, only through trade and industry" (Marx & Engels 1970, p.121). However, it should be noted that the emphasis on the influence of the social context on scientific activities does not lead Marxism in the anti-rationalism that characterizes various branches in the contemporary philosophy of science. Instead, the social influence on science is just considered as the opposite of and in a unity with rationality or objectivity of science. Moreover, given the materialist tradition in Marxism, the former occupies a less important status than the latter within the unity.

Marxism in China

The introduction of Marxism into China might be tracked back to 1917- 1920 when October Revolution broke in Russia. When Mao Zedong summed up the history of Chinese Revolution and announced China's basic policy in *On the people's Democratic Dictatorship*, he said, "the salvos of the October Revolution brought us Marxism-Leninism" (Mao 1986, p.677). The victory of 1949 further made Marxism the dominating ideology of society and the guiding thought of China, which has been believed in and admired until now by millions throughout the country. It was considered as the worldview that can help us reach the truth of the world (Mao 1990).

Given such an important status of Marxism in China, it is a formal component in Chinese education. *Ideology and Politics* is a compulsory course in the middle school. It is also one of the courses in Chinese College Entrance Examination. As explicitly stated in the High School Curriculum Standard of this course (MOE 2004), students are required to "acquire preliminarily the basic principles and methods of Marxist Philosophy" (p.2), which mainly include the law of the unity of opposites, and a number of the Marxism tenets, such as "the world is made of matter, the matter is changing, all those changes have rules" (p.15); "the objective rules can be known and grasped by human" (p.15); "*practice* is the basis of our cognition and plays crucial roles in finding, testing, and developing truth" (p.16). After entering the college or university, all Chinese students need to take a compulsory course named *Basic Principles of Marxism.* In this course, Marxism is systematically introduced, which covers its major philosophical, historical, and political theories. If some students want to continue their studies for master and doctoral degrees in Mainland China, they may need to study this course very hard since Marxism is also included in Chinese entrance examinations of higher degrees. Since almost all science teacher educators have a higher degree, they all participated in such examinations. For science teachers who do not have a higher degree, they also need to study the course of *Basic Principles of Marxism* for their first degree.

Interviews with Chinese Science Teacher Educators

The participants in this study were Chinese 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 of them participated on a voluntary basis. The snowballing strategy was the major sampling strategy adopted in the present study. The authors first contacted Chinese science teacher 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 join in this study. 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. As indicated in Table 1, these participants include considerable variations in their age, the major discipline they teach, teaching experience, and academic position. We acknowledge that the participants in the present study only represent a specific group of science teacher educators from the economically developed areas of Mainland China who have interest in talking about their conceptions of teaching NOS.

Table 2 about here

We targeted our investigation on teacher educators' conceptions because they will have a direct bearing on the future development of science education in China through training prospective science teachers. In addition, some of the teacher educators in this study are authors of school science textbooks and/or textbooks for training science teachers. A few of them have also participated in the development of the National Curriculum Standards. Given these important roles taken up by this group of science teacher educators, their views are also likely to be influential in shaping the views of in-service science teachers and possibly some science teacher educators in other less developed parts of China.

Two face-to-face semi-structured interviews were conducted in Putonghua with each participant. The first one 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 prospective science teachers in your own course(s) and why? When raising this question, the participants were asked to try to situate the discussion of teaching NOS within the real context of their own courses of teaching prospective 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". The interview time of each participant ranged from 45 to 100 minutes.

The second semi-structured interview was a Scenario-based Interview. During the interview, each of the science teacher educators was provided with five examples of NOS teaching designs, which were constructed on the base of NOS instructional designs reported in the literature on teaching NOS to science teachers (Abd-El-Khalick and Akerson 2004; Abell 2001; Lin and Chen 2002; McComas 1998; Nott and Wellington 1998). After careful reading of the five NOS instructional designs (one example is attached in the Appendix), 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 prospective science teachers in their own course(s). This interview lasted for 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 with the data collected in the General Interview.

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. This is to ensure that ideas from the participants are preserved faithfully during the data analysis process.

Corresponding to the interpretive approach adopted in the data collection, the explorative approach (Stake 1995) was adopted to analyze the data collected in this study. For generating a holistic picture of educators' conception of teaching NOS to prospective science teachers, the researchers followed three phases to analyze the data: open coding, axial coding, and focused coding (Charmaz 2000; Strauss and Corbin 1990). Like many interpretive studies, these three phases did not follow in a simple linear progression, but a repetitive process of coding, comparing, and refining until the common themes emerge from the data (Strauss and Corbin 1990). Regular meetings were held between the first and second authors to discuss on the codes and themes identified in the data. In the end, the common themes emerging are five key aspects of teaching NOS. They were: *value of teaching NOS to prospective science teachers, NOS content to be taught to prospective science teachers, arrangement of NOS instruction in science teacher education courses, learning of NOS, and role of teacher in NOS teaching*. This paper only focuses on reporting one dimension, i.e. NOS content to be taught to prospective science teachers. The findings of values of teaching NOS has been published in an independent paper (Wan and Wong 2011), and other dimensions will be reported in coming separate papers.

Results

The NOS elements suggested by the Chinese science teacher educators to be taught to prospective science teachers can be broadly grouped into four key categories: (i) scientific investigation, (ii) scientific knowledge, (iii) scientific enterprise, (iv) scientific worldview and ethos. The NOS elements grouped under each of the four categories are summarized in Table 3. There are five NOS elements suggested by no less than half of the educators. They are empirical basis of scientific investigation, logics in scientific investigation, general process of scientific investigation, progressive nature of scientific knowledge, and realist views of mind and natural world. Three NOS elements are not commonly found contemporary Western works of science education, including realist views of mind and natural world, science as the pursuit of truth, and truth approaching nature of scientific knowledge. When describing these NOS elements, we also discuss the epistemological tendency embedded in them so as to lay a foundation to discuss their relationship with Marxism.

Table 3 about here

Empirical Basis of Scientific Investigation

The empirical basis of scientific investigation emphasizes the role played by observation and experiment in the process of scientific investigation. It has been explicitly included as one of the NOS elements in almost all curriculum documents of science education in the Western (e.g., AAAS 1990b; AEC 1994; CMEC 1997; EDE 1995; NRC 1996)[4] and most academic publications on NOS studies (e.g., Lederman et al. 2002; Rubba and Anderson 1978). Twenty educators in this study mentioned this NOS element when talking about NOS content taught by them. As described by a biology teacher educator, "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" (STE13 GI p.3)[5]. A similar description was also provided by an integrated science teacher educator, "Scientific research should be based on empirical evidence, should endure the testing through observation and experiment" (STE24 GI p.2). The origin of the empirical nature of scientific investigation can be traced back to the empiricism in the philosophy of science. In the philosophy of science, there are two types of empiricism in the philosophy of science. The first is the inductive-empiricism, and the second is deductive-empiricism. Regardless of the controversies between these two types of empiricism on the exact role played by the observation and experiments in the process of scientific investigation, all of them share the commonality of emphasizing the crucial role of human senses in the generation of scientific knowledge. Such an argument was clearly reflected in the above descriptions on empirical basis of scientific investigation provided by the educator.

Logics in Scientific Investigation

Although logics in the scientific investigation are not prominent within the typical reported consensus NOS aspects (e.g., McComas and Olson 1998; Osborne et al. 2003), it is not

[4] AEC is the Australian Education Council. EDE is the England Department of Education.

[5] "STE13" means that this educator is the 13th Chinese science teacher educators in the present study. "GI" means that this extract is from the general interview. "p.3" means that this extract is in 3rd page of the transcripts of general interview.

uncommon to find it in Western curriculum documents (e.g., AAAS 1990b; AEC 1994; CMEC 1997; NRC 1996). For example, NRC (1996) considered it as one of the features of science to distinguish it from other body of knowledge, as it stated that "science distinguishes itself from other ways of knowing and from other body of knowledge through the use of empirical standards, logical arguments, and skepticism" (p.202). The logics in scientific investigation were considered by fifteen Chinese science teacher educators in the present study as an NOS element. As depicted by a Chemistry teacher educator,

> Induction and deduction are both important logical 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…I feel human understanding of the world is an endless process from the specific to the general, and then to higher level of the specific. It is a spiral process. (STE18 GI p.6)

Just relying on the empirical data cannot give a full explanation of the development of the 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. The empiricist philosophers of science suggested that logics would serve such a purpose. Therefore, logics in the scientific investigation are also an empiricist NOS element.

General Process of Scientific Investigation

General process of scientific investigation (sometimes called scientific process or method) and NOS are two interwoven concepts. In the very early report by American Central Association of Science and Mathematics (1907), understanding NOS is equivalent to understanding scientific process. However, these two concepts start to be differentiated in recent decades. As suggested by Lederman et al. (2002), "we considered scientific processes to be activities related to the collection and interpretation of data, and the derivations of conclusions. NOS, by comparison, is concerned with the values and epistemological assumptions underlying these activities" (Lederman et al. 2002, p. 499). Hence, they think that we should only consider the understandings about such process (like the lack of a universal recipe-like method for doing science) as NOS element, rather than the scientific processes themselves. In the present study, twelve educators included general process of scientific investigation into their NOS content to be taught. The following excerpt is an example of the description of this element, provided by a chemistry teacher educator.

> The general process of scientific investigation is another aspect of science … Such process usually starts with a question, proceeds then with proposing some hypotheses or arguments to the question, testing such hypotheses or arguments through observation or experiment, drawing some conclusions and at the end communicating such conclusion so as to convince people of the conclusions…Generally speaking, such a process still can be found if we take the historical development of science as a whole . (STE1 GI p.3)

Actually, the discussion on general process or method of science can find its origin in empiricist 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 Popper (1902-1994), think that 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: (detailed description of Popper's methodology is given 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 tollens. Regardless 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 should be a general process of scientific investigation.

Progressive Nature of Scientific Knowledge

Tentativeness and progressiveness are two related but different two concepts. Although both imply change, for the tentativeness whether such change is positive or accumulative is unknown and the progressiveness at the same time means so. The tentative nature of the scientific knowledge is one of the most commonly stated NOS elements in Western curriculum documents (e.g., AAAS 1990b; AEC 1994; CMEC 1997; EDE 1995; NRC 1996) and academic publications on NOS studies (e.g., Abd-El-Khalick 2005; Clough 1998; Palmquist and Finley 1997). On the contrary, it is not very common to find such literature listing the progressive nature of scientific knowledge as one of NOS elements to be taught. It was found that more than half (fourteen) Chinese science teacher educators in this study included this element as one of their NOS content to be taught. As stated by a biology teacher educator, “another feature of science is its accumulation...With accumulation of its empirical evidence, scientific knowledge make its progress” (STE10 SI p.4)[6]. Similarly argued by a chemistry teacher educator,

> Science accumulates and progresses in its own self-correcting process. Most of other subjects do not have such a feature…The typical example is art. If anyone

[6] “SI” means that this extract is from the scenario-based interview.

> wants to revise de Vinci's Mona Lisa, who can produce a one better than the original? (STE18 GI p.2)

Stating the development of scientific knowledge is an accumulative or a progressive process is a typical stance originating in empiricism philosophy of science. The 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 kind of understanding, the development of scientific knowledge is naturally considered as cumulative and continuous. In contrast with the understanding of the development of scientific knowledge as a process of replacement and absorption, it was thought by Kuhn (1970) that *scientific revolutions* also exist in the development of scientific knowledge, during which a process of replacement and displacement happens, rather than replacement and absorption. In this sense, the development of scientific knowledge cannot be considered just as being accumulative.

Realist Views of Mind and Natural world

Scientific worldviews are not commonly stated as an area of NOS in the recent Western literature of science education (e.g., Abd-El-Khalick 2005; Dawkins and Glatthorn 1998; Palmquist and Finley 1997). They are scientists' beliefs about mind and world. More specifically, it includes the following statements.

> The world is understandable…Science presumes that the things and events in the universe occur in consistent patterns that are comprehensible through careful, systematic study. Scientists believe that through the use of the intellect, and with the aid of instruments that extend the sense, people can discover patterns in all of nature. … Scientist also assumes that the universe is, as its name implies, a vast

> single system in which the basic rules are everywhere the same. Knowledge gained from studying one part of the universe is applicable to the parts (AAAS 1990b, p.2).

These statements are very elaborate arguments of realist views of mind and natural world. In addition to *Science for All American* (AAAS 1990b), two fairly old papers (Billeh and Hasan 1975; Welch and Walberg 1967-68) also state similar arguments under the label of *assumption of science*. As indicated in the data, thirteen Chinese science teacher educators also mentioned scientific worldviews, and included them as NOS elements.

> One aspect of NOS is some basic thoughts guiding scientific investigation, including basic understanding of matter, motion…These scientific worldviews included understandings that the world is made of matter, the matter is changing, all those changes have rules, and all these rules are knowable…Without such beliefs, how can you conduct scientific investigation…These understandings are not knowledge, they are of higher level than knowledge. These thoughts or worldviews are the guidance of our discovery of scientific knowledge. (STE20 GI p.4)

Although there may exist minor difference between the wording in the above excerpt and the *Science for All Americans*, they both included several core elaborated realist statements: (a) the existence of an external world; (b) the universality and constancy of connection in the world; (c) the possibility of our mind to know the external world and connections within it. These three statements are the prerequisites to arrive at the final and core argument of realism, i.e. the existence of the corresponding relationship between scientific knowledge and natural world. Without the existence of an independent material world, it is meaningless to discuss the relationship between scientific knowledge and natural world. The major form of the scientific knowledge is the universal and constant connection between variables, so if it is believed that there is no such universal and constant connection existing in the real world, the natural conclusion will be that such corresponding relationship cannot possibly exist between scientific knowledge and natural world. Even with the conditions of (a) and (b), if we do not admit that we can, through the use of the intellect and with the aid of instruments that extend the sense, discover such connection in the world, such a corresponding relationship is still problematic. On the basis of the above explanation, we can find the crucial role played by these three statements in the realist belief system.

Science as the Pursuit of Truth

Science as the pursuit of truth is not explicitly stated when the nature of scientific investigation is discussed in most of recent Western science curriculum documents (e.g., AAAS 1990b; AEC 1994; CMEC 1997; EDE 1995) and academic publications on NOS studies (e.g., Abd-El-Khalick 2005; Dawkins and Glatthorn 1998; Hodson 1986; Palmquist and Finley 1997; Wong et al. 2009). Nonetheless, three Chinese science teacher educators seemed not to have such hesitation to consider science as the pursuit of truth and included it as a NOS element. The examples below reflected their claims of science as the pursuit of truth.

> 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 does not allow it. (STE3 GI p.3)
>
> Science is to seek for truth. It means that the ultimate destination of scientific investigation is to reflect the objective rules in the natural world, to find the truth in the natural world. (STE9 GI p.2)

The relationship between scientific knowledge and reality is a controversial issue in the philosophy of science. There are two kinds of opinions on this issue. The realists claim that the scientific knowledge refers to real entities and so the scientific knowledge is likely to be true or at least approximately true. This kind of realist argument is dominant in the earlier period of the philosophy of science (actually, almost all the early empiricists are the realists). On the contrary, the anti-realism denies the corresponding relationship between scientific knowledge and reality. They think that the scientific knowledge is only a "mental construct", and it is inappropriate to state whether scientific knowledge is true or not. Seeing the scientific investigation as a means to discover the truth in the nature implies a belief of a correspondent relationship between scientific knowledge and natural world. Such a belief reflects a philosophical stance of realism among science teacher educators in Mainland China.

Truth Approaching Nature of Scientific Knowledge

It is not common to find in most recent science education curriculum in the West (e.g., AAAS 1990b; AEC 1994; CMEC 1997; EDE 1995; NRC 1996) and academic publications on NOS studies (e.g., Abd-El-Khalick 2005; Dawkins and Glatthorn 1998; Hodson 1986; Palmquist and Finley 1997) to include truth-approaching nature of scientific knowledge as a NOS element to be taught. The author only found in one American science curriculum document, Science for All Americans (AAAS 1990b) that this NOS aspect has been touched on in a rather cautious tone: "scientists assume that even if there is no way to secure complete and absolute truth, increasingly accurate approximations can be made to account for the world and how it works (p.2)". The use of the word '*assume'* helps to avoid an explicit indication of stance held by the writer on whether such statement is right or wrong. However, eight Chinese science teacher educators spelt out the truth-approaching nature of scientific knowledge in a concrete manner.

> We should consider scientific knowledge as relative truth…Although it may never arrive at the state of absolute truth, its development is a process of continuous progression towards the truth in the objective world. (STE9 SI p.3)

> Scientific investigation is a process of exploring nature…During the process of exploring the Nature, some accepted knowledge might be rejected, and some new are generated. It is a ceaseless process. There is no end of this process. In such a process, human finds the temporary truths. They are relative truths. It is a process of increasingly approaching the absolute truths. (STE11 GI p.2)

Admitting that the scientific knowledge can, to some extent, approach to the truth means a direct acknowledgement of the existence of the corresponding relationship between scientific knowledge and the real world. Again, the truth-approaching nature of scientific investigation is reflection of the philosophical stance of realism.

Based on the above discussion, we can find that among the five NOS elements suggested by more than a half of educators, there were four reflecting empiricist views, including empirical basis of scientific investigation, logics in scientific investigation, general process of scientific investigation, and progressive nature of scientific knowledge. The last one was realist views of mind and natural world. All the three NOS elements that are not commonly found in the NOS content to be taught Western literature on NOS instruction embody realist views. They are science as the pursuit of truth, truth approaching nature of scientific knowledge, and realist views of mind and natural world.

Influence of Marxism on Chinese Science Teacher Educators' Conceptions

Although, during the interviews in this study, the factors of influencing Chinese science teacher educators' views of NOS had not been intentionally asked, three science teacher educators explicitly stated that their NOS views are influenced by Marxism, especially dialectical materialism, which had been taught since their school time. It was stated by an integrated science teacher educator that,

> My understanding of NOS is influenced by my early education of dialectical materialism. I had been taught of Marxism when I was in the school. It is common for the people grown up under the Red Flag[7] like me. Although it is too politicized in China, I feel most of its arguments are right, especially for those on natural philosophy…When I started to read the literature on NOS, I made use of my knowledge of dialectical materialism to understand it. (STE3 SI p.6)

In addition to such general arguments, the influence of Marxism on Chinese science teacher educators' conceptions in NOS content to be taught is reflected in some specific aspects of the findings in this study.

In this study, realist understandings of mind and natural world were considered by more than half of Chinese science teacher educators as scientific worldview and suggested by them as NOS content to be taught. On the contrary, it is rather rare to find this NOS element in the Western literature on NOS instruction. Even when it is found in *Science for All American* (AAAS 1990b), the only one found by the authors, the tone adopted to present it is very assumptive, which is rather different from the affirmative one adopted by Chinese science teacher educators. This tendency is rather consistent with Marxist tradition. As introduced in the literature review, realist epistemology is a core component of Marxist philosophy, which

[7] Red Flag means the flag of Chinese communist party. Actually, red is the color of all communist parties. The people grown up under the Red Flag refer to the people that are under influence of communist party.

in turn is believed by Marxists as the right philosophy or worldview to guide scientists. Therefore, it is not unexpected that they consider (rather than assume) that realist understandings of mind and natural world, which are part of Marxist philosophy, is the scientific worldview.

Besides, the wording used by Chinese science teacher educators to present this NOS element also reflected the origin of Marxism, which is typified by the following excerpt.

> *The world is material*, all matters in world are *connected*, such connections are universal, *matters are in constant motion*, there are rules underlying such motion, and all these connection and rules are knowable to human being. (STE14 GI p.3)

Although the core meanings of the excerpts are similar to the popular realist statements, there is still some difference. First, emphasizing that the world is material may reflect a materialist tendency, which is not necessarily held by realists. Second, the concepts of connection and change, which are not commonly included in the popular realist statements, are obviously emphasized in the above excerpts. As introduced before, the concepts of connection and change are the basic points of dialectics in Marxism, and so some popular Chinese textbooks of Marxism integrate them with materialism and realist arguments so as to make a summary of Marxism principles. Therefore, although we cannot totally exclude the possibility that the appearance of this NOS element and its high frequency may be the result of the influence of other philosophical theories, the above clues indicate that it might more possibly be the outcome of the influence of Marxism.

There are also other two realist NOS elements found in this study, i.e. truth-approaching nature of scientific knowledge and science as the pursuit of truth, whose meanings are very similar. Although they were not suggested as frequently as the scientific worldview, if we counter together the number of educators who have suggested them, there will be a total of ten[8], which is not a small number. However, in the Western literature on NOS instruction, these two elements are hardly found. Such a difference may also be an influence of Marxism. During the interview, it was found that the terms *relative truth* and *absolute truth* were used in pair by Chinese science teacher educators to describe truth approaching nature of scientific knowledge, the example of which can be found in the excerpts used to exemplify it in result section. Although truth is important issues in philosophy, it is uncommon to use these two terms in pair to discuss the nature of knowledge in the literature. On the contrary, the use of the two terms by Lenin in his work *Materialism and Empirio-criticism* (Lenin 1977), they have been popularly used among Marxists. They can be found in almost all the Chinese books on Marxism. Therefore, the appearance of this pair of terms is another indication of the influence of Marxism on Chinese science teacher educators' conception.

Logics in scientific investigation were considered by fifteen Chinese science teacher educators as methods of science and suggested by them as NOS content to be taught. On the contrary, it is uncommon to find it in the Western literature on NOS instruction. And even if it is found, few elaboration is made. The caution of elaborating this element in the West may be due to the controversies between inductivism and deductivism in the philosophy of science. However, as reflected in the excerpts used to exemplify it in the result section, Chinese science teacher educators did not seem to concern conflicts between them. On the contrary, deduction and induction were considered as something like a unity of the opposite. This point is rather similar to Engels' view introduced in the section of discussing NOS in Marxism. Moreover, as indicated in the same excerpts, the development of knowledge was described as a ceaseless and spiral process, which also reflects a major point of dialectics in Marxism that the world is in a state of continuous movement and change.

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[8] An educator suggested both truth-approaching nature of scientific knowledge and science as the pursuit of truth in his NOS content taught to prospective science teachers. Therefore, the total is ten, rather than eleven (i.e. eight plus three).

It can be found in Table 3 that except realist understanding of mind and natural world, the other four NOS elements suggested by more than a half of the educators in this study as NOS content to be taught are all NOS elements related to empiricism. Some interview data indicated that such a tendency might also be partly caused by Marxism. As explicitly stated by two educators during the interview, "I believed dialectical materialism since I was young…I think it's consistent with the realist and empiricist philosophy of science" (STE18 GI p.5), so "I choose to focus on these classical NOS elements in my teaching" (STE9 GI p.3). Of course, except the logics in scientific investigation, no additional clue in the wording can be found for the other three NOS elements to link their origin of Marxism. They may be influenced by Marxism in a more indirect manner.

Discussion and Conclusions

Comparing the NOS elements which were suggested by more than a half of the educators in this study as NOS content to be taught in Table 1, we find that they are to some extent similar in the sense that all of them include a good number of NOS elements that are relevant to scientific investigation. However, two different aspects can also be identified. First, none of the elements of high frequency in this study falls into the social dimensions of science, which is rather different from the consensus list of McComas and Olson's (1998) study that have a rich of features of science in the social dimensions. Second and more importantly, there is a distinctive positivist trend in the top five high frequency elements in this study, among which four are the empiricist and one is the realist. Such a positivist tendency is not easily identified in both studies included in Table 1. The findings in this study indicate that some aspects of the consensus on NOS content to be taught achieved in a specific country or region may be generalized into other countries and regions while some other aspects may not. Actually, McComas and his colleagues' (1998) conceptual model of NOS has given some insights into the factors that may influence such a generalizability. As illustrated in their model, NOS views are mainly from four areas of studies of science, i.e. philosophy, history, sociology, and psychology of science. As we know, there exist different and even conflicting views among different schools in these studies. In different countries and regions, these different schools may not be evenly distributed. On the contrary, some may dominate in certain areas, and so influence the views of NOS as well as its content to be taught in those areas.

The present study reminds us that in addition to the dominating tradition in the four areas of social studies of science, such generalizability may also be embedded in a kind of broader ideology, i.e. general philosophy (which, in China, may be Marxism). Actually, general philosophy has a much longer history and is rooted deeply and widely in people's mind. Since ontology and epistemology are the crucial issues in philosophy, such content in the dominating general philosophy in a specific place has the potential to influence directly and significantly its people's views of corresponding aspects about science and then their views on NOS content to be taught. Among general public, such influence might be even greater than the ones from social studies of science since people are more familiar with the former. For example, social studies of science are relatively new in the Chinese academic community, so few courses on these studies are offered in the colleges and universities in China, but *Basic Principles of Marxism,* a branch of general philosophy, is one of the compulsory courses for all college or university students. In addition, the development of social studies of science in a certain area is also to some extent affected by the dominating general philosophy in such area. Thus, through the mediation of these studies, people's views on NOS and its content to be taught can also be affected, although indirectly, by the dominating general philosophy in society.

In addition to general philosophy, we want to point out that religion may be also an important factor although it is not reflected in the data reported here. All the religions, similar to philosophy, have their ontological stances, most of which are idealism, and some even has epistemological ones, so the dominating religion in a certain area may also contribute to shapeing the views on NOS and its content to be taught of its people. Besides, generally speaking, religion is even more popular than philosophy for general public and plays more important role in their thinking. Therefore, if its influence exists, such influence may be rather strong.

On basis of the above discussion, Figure 1 is developed based on McComas and his colleagues' (1998) model to illustrate the factors that may potentially play important roles in explaining the views of NOS as well as its content to be taught. The dashed lines mean that communication can exist among them. Although only general philosophy and religion are placed at the outer layer, it does not necessarily mean that we have excluded the existence of other influential ideological factors. The outer layer may be enriched by future study.

Figure 1 about here

With the process of globalization, NOS education has attracted scholars' attention in a large number of Western and Eastern countries and regions, including the U.S. (e.g., Lederman et al. 2002), Great Britain (e.g., Drivers et al. 1996), Australia (e.g., Matthews 1998b), New Zealand (e.g., Hodson 1986) , Turkey (e.g., Irez 2009), Hong Kong (e.g. Wong and Hodson 2009), Mainland China (e.g., Wan and Wong 2011), South Korea (e.g., Kim and Nehm 2011), South Africa (e.g., Linneman et al. 2003), and etc. Given the diversified social-cultural backgrounds, there may exist some differences or even conflicts among views of NOS or its content to be taught in these regions. Besides, even within the same area, such differences or conflicts may exist among individuals due to their varied understandings of the world. When we are confronted with different views of NOS or its content to be taught, it will be unfair to make judgment just with reference to our own views. Rather, we need to think about the origins of other views. When probing them in depth, we may find that some of them are very reasonable and coherent. If it is the case, such a variety should be respected. The model suggested above may have the potential to provide some clues to the direction of such thinking.

As noted by Green (1971), beliefs are held by people in clusters, and these clusters may be protected from each other. Since there are little cross-fertilizations among these clusters, beliefs that are incompatible may exist in different clusters. Similar views are also echoed by Schutz (1970) and Bryan (2003). It is alerted by Green (1971) that if we have not intentionally put together these incompatible beliefs and examine their consistency, the incompatibility may not disappear. Although as suggested in this paper, NOS, general philosophy and religion are interrelated, they are actually qualitatively different areas. In other ways, beliefs of them may be in different clusters. Therefore, inconsistency may exist among our beliefs of them. In order to find such inconsistency, it is necessary for us to consciously set our own views in these three areas side by side and ponder on them.

What NOS elements should be included in the formal curriculum is a significant and also challenging topic in NOS education. The common method relies on the agreement of a number of experts. When such a consensus list is preliminarily produced, before making it public, we may be able to anticipate the potential level of acceptance and rejection to this list through analyzing the prominent ideology in our society, which can, to some extent, guide the afterward action. For example, in China, Marxism is dominant. There may be a high level of acceptance of empiricist, realist and materialist NOS views. If the consensus list is occupied by them, we should not worry about the resistance from the public. More efforts can be made in designing the effective methods to teach these elements. However, when the consensus list is dominated by the instrumentalist and idealist elements, the situation will be rather different. There might be a considerable level of resistance since it is conflicting with the dominating ideology, i.e. Marxism. Thus, before considering the methods of teaching them, we must think more about some other crucial questions first. What resources do we have to handle the likely strong resistance? What are the values of teaching these elements in our society? Are these values really urgent or meaningful? How can we promote the public to realize these values? Are there plans for provision of teacher professional development course for teachers to appreciate the vision and ways to realize the new curriculum goal? If we cannot get desirable answers to these questions, we may need to reconsider and modify the list itself.

Knowing learners' existing understandings is crucial for teaching. Besides getting information on their current conceptions of the content to be taught, we should also consider their views in the relevant areas that may influence learning, which are called as *Conceptual Ecology* (Posner et al. 1982). The present study reminds us that general philosophy and religion may be within the conceptual ecology of learning NOS. For instance, Christianity and Catholicism are guiding the worldviews of many areas in the world, where most people hold the views of creationism and resist evolutionism (Kim and Nehm 2011). When facing learners in such areas, if we want to teach realist NOS elements like "the truth approaching nature of scientific knowledge", which encourage trust in evidence from the nature and consider evolutionism as part of true knowledge, given their fundamental beliefs are at stake, the learners may reject the learning of such elements.

Although NOS is still a contested topic in science education, it is commonly agreed that teaching NOS is a meaningful endeavor. Drivers and her colleagues (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 and Wong (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. As for those countries and regions intending to do so, there is a great deal of international literature of NOS education that can be the reference for their NOS teaching. However, we should note that until now most of such literature is from Western countries, which have their unique social background. It is helpful for people in other regions to learn their experiences, but it is risky to directly copy them since successful experience in a certain context may fail in a different one. When we refer to NOS instructions reported in the international literature, it may be better to first contemplate the factors that contribute to shaping them, which may include those related to general philosophy and religion. After that, we need to think about the similar factors in our own society and then come up with a design that can better meet our requirements.

Because this study aimed to explore educators' conceptions of teaching NOS as a whole, the authors did not intend to force the interviewees to discuss any questions that are explicitly related to the specific dimensions of conceptions of teaching NOS. Instead, the interview questions just focused on their practice of teaching NOS, like "how do you start your NOS lessons", "what are your major teacher and learning activities", "what teacher materials have you used", and so on. Therefore, the data available in this study are limited for getting a holistic picture of the factors that influence the educators' decision on NOS content to be taught. The arguments made here should be tested in more in-depth and focused studies.

As introduced in the literature review, Marxists also notice the influence of society on science. However, it is found in the present study that this NOS element was included by ten Chinese science teacher educators, a little less than a half of the total. One of the possible explanations may be its status in Marxist philosophy. As for Marxism, the most fundamental question in philosophy is the ontological one, and so materialism and its corresponding realist and empiricist epistemology are systematically discussed in its theory. On the contrary, the viewpoint that science is influenced by the society may not be the most central one in Marxist philosophy, and so not elaborated. Consequently, not so many educators chose to emphasize it in their teaching. Of course, the decision on NOS content to be taught is not a simply issue. Many other factors can influence such a decision. It is a pity that due to the limitation introduced above, such complexity cannot be revealed in this study. Further research should be conducted to probe it.

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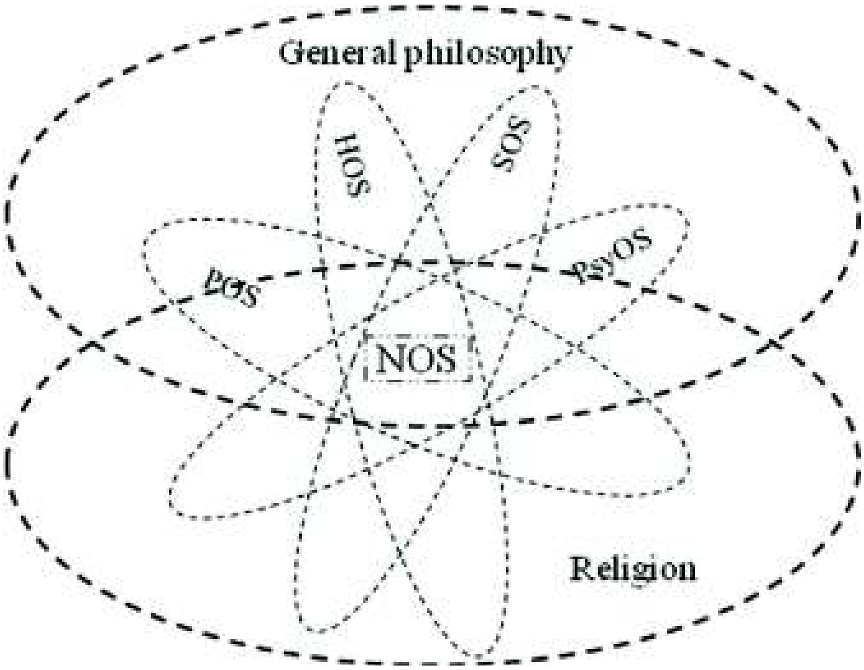
Figure 1 A hypothetic model of factors influencing views of NOS as well as its content to be taught



POS= Philosophy of Science
HOS=History of Science
SOS=Sociology of Science
PsyOS=Psychology of science

Table 1: Comparison of agreed NOS elements indicated in two previous studies

McComas & Olson (1998) (N=8)	**Osborne et al. (2003) (Max=5)**
Scientific knowledge	
Scientific knowledge is tentative (8)	Science and Certainty (4.0)
Change in science occur gradually (7)	Historical development of scientific knowledge (4.2)
Scientific investigation	
Science is an attempt to explain phenomena (7)	Analysis and interpretation of data (4.2)
Scientist are creative (6)	Creativity (4.4)
Science relies on empirical evidence (6)	Scientific method and critical testing (4.4)
Scientists require replicability and truthful reporting (7)	Science and questioning (4.2)
New knowledge must be reported clearly and openly (6)	Hypothesis and predication (4.2)
	Diversity of scientific thinking (4.2)
Scientific enterprise	
Science is part of social tradition (8)	
Science has played an important role in technology (6)	
Scientific ideas have been affected by their social and historical milieu (6)	Cooperation and collaboration in science (4.2)
All culture contributes to science (6)	
Scientists make ethical decision (8)	
Science have global implication (7)	

Table 2 An overview of the background of participating Chinese science teacher educators

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

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

Table 3 NOS elements suggested by Chinese science teacher educators as NOS content to be taught to prospective science teachers

NOS elements	Frequency (N=24)
Scientific investigation	
Empirical basis of scientific investigation Scientific investigation is based on observation and experiments. The validity of scientific claims aims to be settled by these empirical data.	20
Logics in scientific investigation Scientific investigation relies on inductive and deductive logics to bridge between empirical data and scientific knowledge.	15
General process of scientific investigation Generally speaking, there exist a process of scientific investigation, like raising questioning, hypothesizing, collecting data, analyzing data, drawing conclusion and communicating.	12
Theory-laden nature of observation Human' observation cannot be absolutely objective. It is unavoidably influenced by the observers' theoretical and discipline commitments, beliefs, prior knowledge, training, experiences, and expectations. This is the same for the scientists.	8
No single scientific method There is no one method of science applicable at all times that can guarantee the development of infallible knowledge.	6
Replicable nature of empirical evidence Not only the validity of scientific claims needs to be supported by empirical evidence, but also such evidence should be replicable by other scientists. Otherwise, the validity of such scientific claims is incredible.	6
Imagination in scientific investigation Creation and imagination is indispensable for the success of scientific investigation.	6
Science as the pursuit of truth The goal of the scientific investigation is to discover the truth in the nature.	3

Scientific knowledge

Progressive nature of scientific knowledge The development of scientific knowledge is an accumulative and progressive process.	*14*
Truth-approaching nature of scientific knowledge The development of scientific knowledge is a process of increasingly approaching to the truth.	8
Inferential nature of scientific knowledge There are a number of concepts and theories in scientific knowledge, whose corresponding entity cannot be directly observed. Therefore, these concepts and theories are in essence inferential.	8
Tentative nature of scientific knowledge There is not absolute scientific knowledge. Any knowledge might change in the future.	6
Testable nature of scientific knowledge There should be a possibility for any scientific claims to be able to be refuted by the evidence. Otherwise, such claims cannot be regarded as the scientific claims.	4

Scientific enterprise

Social and cultural influence on science Science is not separate from society but is a part of society. The development of science is influenced a complex social and cultural factors.	10
Understanding of scientific community Science is being carried out in the cooperation among different scientists in modern society and scientists are also grouped into different institutions.	9
Bilateral influence of science on the society Science has both positive (like improving living quality) and negative (like environment problems and wars) influence on human society.	6
Relationship between science and technology Science and technology are different and at the same time, closely related. Science is aimed to understand the natural world, and the technology is to meet human's needs and solve problems. The improvement of technology can contribute to the breakthrough of science and new science knowledge can be the basis of technological innovation.	3

No existence of the stereotype image of scientists Public stereotype impression of scientist is distorted. They may not be so objective, open-minded, unbiased, and possess infallible method for ascertaining the truth about the universe.	2
Scientific worldview and ethos	
Realist views of mind and natural world Human inquiry into the nature is guided by realist beliefs of mind and nature, like the existence of an external world that is independent of the observer, the universality and constancy of connection in the world, the possibility of our mind to know the external world and connections within it.	*13*
Scientific ethos The development of science requires a number of celebratory qualities for scientists, like perseverance, skepticism, objectivity, intellectual honesty, and selflessness.	10

Appendix: 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 discussions 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.

* Scenario A was designed on the basis of the paper by Abd-El-Khalick, & Akerson (2004).