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Teaching Nature of Science to Preservice Science Teachers: A Phenomenographic Study of Chinese Teacher Educators' Conceptions

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Abstract Drawing from the phenomenographic perspective, this study investigated Chinese science teacher educators' conceptions of teaching nature of science (NOS) to preservice science teachers through two semi-structured interviews. The subjects were twenty-four science teacher educators in the developed regions in China. Five key dimensions emerged from the data on the conceptions of teaching NOS, including value of teaching NOS, NOS content to be taught, incorporation of NOS instruction in courses, learning of NOS, and role of the teacher. While some of these dimensions share much similarity with those reported in the studies of conceptions of teaching in general, some are distinctively different, which is embedded in some unique features of teaching NOS to preservice science teachers. These key dimensions can constitute the valuable components of the module or course to train science teachers or teacher educators to teach NOS, provide a framework to interpret the practice of teaching NOS, as well as lay a foundation for probing the conceptions of teaching NOS of other groups of subjects (e.g., school teachers' conceptions of teaching NOS) or in other contexts (e.g., teaching NOS to in-service teacher).

1 Introduction

Research into teachers' beliefs or conceptions is perhaps the youngest branch of research into teacher's thought process (Clark and Peterson 1986). The major justification of these studies is that teachers' conceptions have a strong influence on how they teach. Since late 1980s, a branch of these studies, drawing from the phenomenographic perspective,

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investigated the conceptions of teaching in general, focusing on categorizing the descriptions made by the university lecturers and school teachers on their own experience of teaching. Until now, this kind of phenomenographic research has been popular in Australia, the United Kingdom, Hong Kong and Scandinavian countries (Akerlind 2005; Boon et al. 2007).

Nature of science (NOS) in its broader sense means various aspects of science, consisting of the characteristics of scientific inquiry, the role and status of the 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.[1] There has been a long history in Western science education to advocate the goal of developing school students and science teachers' understanding of nature of science. Currently, it has also begun to find its place in science education in China as it appears in the goals of Chinese science curriculum reform documents [e.g., Ministry of Education (MOE) 2012a, b, c], Chinese academic articles (e.g., Chen and Pang 2005; Ding 2002; Xiang 2002) and textbooks of training science teachers (e.g., Yu 2002; Yuan and Cai 2003).

NOS is a special issue in science education. Compared with science content, it is more abstract, controversial, and relatively newer for teachers and even their educators. Given these unique features of NOS, science teachers or their educators' conceptions of teaching it may be different from their conceptions of teaching in general. However, until now little studies can be found to investigate such conceptions. The lack of findings in this area may make us miss a valuable component in the module or course to train teacher educators or science teachers to teach NOS and a useful framework to interpret the practice of teaching NOS. In order to fill in such a research gap, an exploratory phenomenographic study was conducted to investigate Chinese teacher educators' conceptions of teaching NOS to preservice science teachers.

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 preservice 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.

2 Literature Review

2.1 What NOS Should be Taught?

Although NOS has been long and commonly discussed in science education, there are still very active debates over NOS itself (Rudolph 2000, 2003). Early in 1960s, it is claimed by Herron (1969) that no sound and precise description existing 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 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, Alters

[1] See for example Wong and Hodson (2009, 2010), Bianchini et al. (2003), Bianchini and Solomon (2003), Clough (2006), Irzik and Nola (2011), McComas et al. (1998).

(1997a) concludes that "we should acknowledge that no one agreed-on NOS exists" (p. 48). Indeed, over the last four decades, disagreements concerning the specific characteristics of NOS have become more contentious and more pressing than they were previously, sometimes described as "science wars" (Matthews 1998, p. 162).

Given the contested nature of NOS, there are two different opinions that can be found in the literature on the NOS content to be taught, i.e. pluralism and essentialism (Wan et al. 2011, 2012). 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 (1993, 1998) state that their NOS course encouraged the learners to discuss the statements about science. They classified and presented these statements in terms of relativism versus positivism, inductivism versus deductivism, contextualism versus decontexualism, instrumentalism versus realism, process versus content. Obviously, the differences and conflicts in NOS were reflected in such a way of presentation.

However, when facing the same contested NOS, some other scholars hold the essentialist view. They believe that there exists a considerable consensus regarding NOS content to be taught and ignore the debate regarding the ultimate fine details of nature of science. Hence they do not bother to include the many disputes among NOS views in their NOS teaching. Rather, they suggest emphasizing on these agreed-on NOS tenets. These as summarized by Lederman and his colleagues are

> [S]cientific knowledge is tentative; empirical; theory-laden; partly the product of human inference, imagination, and creativity; and social 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 (Lederman et al. 2002, p. 499).

2.2 Implicit and Explicit Approaches to Teaching NOS

A widely discussed topic in NOS instruction is the implicit and explicit approaches to teaching NOS. As noted by Abd-El-Khalick and Lederman (2000), "the basic difference between implicit and explicit approaches, is not a matter of the kind of activities used to promote understanding of NOS" … but "lies in the extent to which learners are provided (or helped to come to grips) with the conceptual tools, such as some key aspects of NOS that would enable them to think about and reflect on the activities in which they engaged" (p. 690). The implicit one is advocated by science educators such as Haukoos and Penick (1983, 1985), Lawson (1982) and Rowe (1974), suggesting that an understanding of NOS is a learning outcome that can be facilitated directly through utilizing science process skills instruction and/or scientific inquiry activities or manipulated certain aspects of the learning environment. This conceptions can be reflected in a number of NOS instruction designs.[2] On the contrary, the advocates of explicit approach (e.g., Akindehin 1988; Wong et al. 2008; Bell et al. 1998) suggest that NOS as an enterprise is a reflective one, and reflects the collective attempts of scholars of investigating the history and activities of science. It is unrealistic to expect the learners, including science teachers, to be able to generate their NOS understanding automatically by themselves through reading the records of history of science or/and participating in the scientific activities. On the contrary, in such a process of learning NOS, learners should be promoted to intentionally reflect the relevant NOS

[2] See for example Barufaldi et al. (1977), Riley (1979), Shapiro (1996), Trembath (1972).

embedded in these records and practice. The explicit approach can be found in a number of papers on teaching NOS.[3]

2.3 Phenomenography and Its Research

Phenomenography was originated from the works by Ference Marton, Roger Säljö, Lars-Öwe Dahlgren, and Lennart Svensson in early 1970s. It represents "a research method adopted for mapping the qualitative different ways in which people experience, conceptualize, perceive, and understand various aspects of, and phenomena in, the world around them" (Marton 1986, p. 31).

There are three main standpoints in phenomenographic research. First, it concentrates on discovering the subject's experience of the phenomenon, rather than the essence of the phenomenon itself (which is the focus of phenomenological research) (Bowden 2000). For instance, a phenomenographic study of teachers' conceptions of teaching intends to produce a rich and detailed expression of the varied ways in which teacher perceive and experience teaching, instead of a description of teaching itself.

Second, phenomenographic researchers take a second-order perspective, so the perceptions of the subjects of study are the paramount for these researchers, rather than their own predetermined perceptions (Richardson 1999). In order to map the experience or perceptions of the subject, interview questions in phenomenographic research should be as open-ended as possible. Its data analysis also requires the investigators to maintain an open mind as far as possible, which helps to minimize the predetermined views and avoid too rapid foreclosure in the process of categorizing the data.

Third, phenomenographic studies seek to discover the variations in the experience of a phenomenon, which are regarded as "focus awareness" since they are foremost in the subjects' mind and perceived as the most important (Åkerlind 2005). In order to reveal such variations, the focus of data analysis in phenomenographic research is not on the individual experience, but the collective one. This means that the investigators should interpret every transcript within the context of the group of transcripts or meanings as a whole, in terms of similarities to and differences from other transcripts or meanings. No interview transcript can be understood in isolation from the other transcripts.

In the literature, several terms have been used to represent teachers' thinking, including orientation, beliefs, conceptions, intention, perspectives, theories and stance. Among these terms, "conceptions" is the one commonly used by phenomenographic researchers. As defined by Pratt that,

> Conceptions are specific meanings attached to phenomena which mediate our response to situations involving those phenomena. We form conceptions of virtually every aspect of our perceived world, and in so doing, use those abstract representations to delimit something from, and relate it to, other aspects of our world. In effect, we view the world through the lenses of our conceptions, interpreting and acting according with our understanding (Pratt 1992, p. 204).

This definition of "conceptions" is adopted in the present study, indicating its phenomenographic origination.

Phenomenographic research started with Marton and his colleagues' work on conceptions of learning, and latter expands into the conceptions in the various areas, such as information literacy (Boon et al. 2007), statistics (Reid and Petocz 2002), physical limitations (Pihl et al. 2011), and organizational change (Dunkin 2000). In late 1980s, a branch

[3] See for example Abd-El-Khalick and Akerson (2004), Akindehin (1988), Billeh and Hasan (1975), Lavach (1969), Meichtry (1999), Palmquist and Finley (1997), Schwartz et al. (2004).

of phenomenographic researchers started to investigate the conceptions of teaching in general. A large number of studies have been done until now. Kember (1997) made a comprehensive review of these studies. An important feature of these studies is to generate, through theoretical study or by direct abstraction from data collected in their research, several key dimensions to characterize the investigated conception. Following the phenomenographic tradition, it is common in these studies to define a dimension by generating few qualitatively different categories or extremes within it. For example, Samuelowicz and Bain's study (1992) use two categories, the teacher-controlled and the student-controlled, to differentiate conceptions of teaching contents. In Gao and Watkins' studies (2001), five different goals of teaching are suggested (i.e. conduct guidance, attitude promotion, ability development, exam preparation, and knowledge delivery), which are further conceptualized into two categories, i.e. moulding and cultivating.

Although all these studies are similar in describing the dimensions by using few categories or extremes within this dimension, the specific dimensions appearing in each study, as indicated in the Table 1 are rather different. For example, Fox (1983) suggests as many as nine dimensions derived from his data, including verbs commonly used, the subject matter, the student, the teacher, standard teaching methods, monitoring progress, teachers' explanations of failure, students' explanations of failure, and attitude to training. At the same time, only two, i.e. intention and strategy, are put forward by Trigwell et al. (1994). Between them, five dimensions are proposed by Kember (1997) on the basis of the review of thirteen past studies, consisting of teacher, teaching, student, content and knowledge. Such inconsistency existing among different studies might be caused by the contextual-dependent feature of conceptions (Marton 1981). We can find that the contexts of the above studies are rather different. Some is at the school level while other is the university;

Table 1 Dimensions of conceptions of teaching suggested in previous research

Study	Dimension	No.
Christensen et al. (1995)	Learning approach; characteristics of teacher; ideal teacher; self as teacher; path to teaching	5
Dall'Alba (1990)	Focus of teaching; role of teacher; teachers' expected outcomes among students; view of teaching	4
Fox (1983)	Verbs commonly used; the subject matter; the student; the teacher; standard teaching methods; monitoring progress; teacher's explanations of failure; students' explanations of failure; attitude to training	9
Gao and Watkins (2002)	Learning and learner; nature of learning; role of teacher; expected outcomes; teaching content;	6
Gow and Kember (1993)	What teacher try to achieve; goal of higher education; the end product of teaching; role as a teacher; nature of teaching; image of a good teacher	5
Kember (1997)	Teacher; teaching; student; content; knowledge	5
Martin and Balla (1990)	Role of teacher, content of teaching; focus of teaching; role of students; view of learning	5
Pratt (1992)	Content; learners; teachers; ideas; context	5
Trigwell et al. (1994)	Intention; strategy	2
Samuelowicz and Bain (1992)	The expected outcome of learning; the knowledge gained or constructed by a student; students' existing conceptions; directionality of teaching; control of content	5

some are on the experienced teacher and some others are on the novice. Given the change of the context, the major variations may be different in the conception of teaching, which will cause the shifts of the dimension generated by the researchers.

Since NOS is somewhat different from other content taught in school or college classrooms, given the contextual-dependent feature of conceptions, it may be meaningful to investigate the extent to which the key dimensions of the conceptions of teaching NOS are similar or different from those of conceptions of teaching in general. The relevant findings may enrich our understanding of teaching NOS from the practitioners' perceptions.

3 Training Preservice Science Teachers in China

Generally speaking, there exist two different modes of training preservice science teachers. In 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 to get a Bachelor degree in science first, 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, although a small part of preservice science teachers are trained through the second mode, they are mainly trained through the first. There are a large number of Normal Universities and Institutes of Education which are specialized in teacher education. These universities and institutes also have specific divisions or faculties for different science subjects. Preservice teachers of different science subjects are trained in corresponding science divisions or faculties. There is no regulation on which science division or faculty is responsible for training preservice integrated science teachers in Mainland China. It depends on which division or faculty has applied for offering such a program and obtained approval.

Although the first-mode programs of training Chinese preservice science teachers, which are the context of investigating science teacher educators' conceptions in this study, may be diverse in the detailed arrangement, they similarly comprise of three major components. The first is general courses, including English, Physical education, Information Technology, Politics, and Art. These courses are common for college students of all majors, taking up about thirty percent of total credits of the program. The second and also biggest component is science courses and experiments, which aim to enhance students' understanding of their science subject. This part occupies about forty percent of total credits. The last component of the training programs of Chinese preservice science teachers is oriented to education, covering about thirty percent of total credits. It normally consists of the courses of education in general (e.g., Basics Education Theories, Educational Psychology, and Educational Technology), the courses relevant to science education (e.g., Science Curriculum and Instruction, History of Science, Science Laboratory in School), as well as 4–10 week teaching practicum. Among these education-oriented courses, Basics Education Theories, Educational Psychology, and Science Curriculum and Instruction are compulsory while Educational Technology, History of Science and Science Laboratory in School are elective. Chinese science teacher educators are mainly responsible for teaching Science Curriculum and Instruction, History of Science and Science Laboratory in School and sometimes science subject courses and experiments.

4 Methodology

4.1 Subjects

The participants in this study were science teacher educators from the most economically developed regions in China, including Shanghai, Beijing, and cities in provinces of Jiangsu, Zhejiang, and Guangdong. Given considerable time and efforts needed in the present study, all the participants should participate 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 us as potential participants of 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 (Table 2).

4.2 Data Collection

The interview is the primary method of phenomenogrphic data collection (Bowden 2000; Marton 1981). Two interviews were conducted by the first author in Putonghua with each participant, i.e. the General Interview and Scenario-based Interview. Since the present study was a phenomenographic one, during the interviews the first author tried not to force educators to discuss any questions that are explicitly related to the specific dimensions of

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

Characteristic	Number of educators
Age	
>50	9
40–50	11
30–40	4
Gender	
M	*15*
F	9
Science subject of their students	
Physics	7
Chemistry	7
Biology	5
Integrated science	5
Academic position	
Professor	7
Associate professor	13
Instructor[a]	4
Year of training science teachers	
>20	10
10–20	9
5–10	5

[a] In China, instructor is the lowest title in academic positions

conceptions of teaching NOS. Rather, the interview questions just focused on their experience of teaching NOS.

In the General Interview, a general open-ended question was used to probe their conceptions of teaching NOS: How do you teach NOS to your preservice science teachers in your own course(s) and why? During the interview, the educators were asked to try to locate the discussion of teaching NOS within the real context of their own courses of teaching preservice science teachers. When they discussed their NOS teaching practice, some follow-up questions covering some 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". Besides, the interviewer may also ask educators to clarify what they have said by using questions such as "could you explain it further", "what do you mean by that", and "is there anything else you would like to say about this aspect". The interview time of each educator ranged from 45 to 100 min.

During the Scenario-based 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 five papers on teaching NOS to science teachers.[4] Since the examples are just a tool to promote educators to speak more about their NOS teaching, we just summarized the major steps in each instructional design, rather than describing the detailed activities. In the interviews, the science teacher educators, after careful reading of the five NOS instructional designs, 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 preservice science teachers in their own course(s). This interview lasted for 40–120 min. According to Kagan (1992), the pre-existing conceptions 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 should also reflect their conceptions of teaching NOS. This interview served as another source of data to complement the data collected in the General Interview.

4.3 Data Analysis

Before analyzing the data, the first author transcribed the interview verbatim into Chinese. Translation into English was done only to the transcripts that were selected to be reported in this paper. This is to ensure that ideas from the participants are preserved faithfully during the process of data analysis.

According to Marton (1986), the process of data analysis in phenomnographic research "is tedious, time-consuming, labor-intensive, and interactive" (Marton 1986, p. 42). It needs the continual sorting of data and repetitively test and adjust the definitions of categories until the rate of change decreases to a point where the whole system of meaning is stabilized. Such a complex process was also reflected in the data analysis of this study. There were roughly three phases in data analysis. Initially, the first author read the transcripts of the interview line by line repeatedly to get himself familiarized with these data in order to create the initial categories, during which several meetings were held between the authors to discuss on these initial codes. In the end, a large number of initial codes were generated, like empirical basis of scientific investigation, enriching content taught in

[4] See for example Abd-El-Khalick and Akerson (2004), Abell (2001), Lin and Chen (2002), McComas (1998), Nott and Wellington (1998).

school science, infusing NOS instruction in the teaching of science content, peer discussion, and so on.

Since there were too many codes at the first phase, it was too challenging for the authors to analyze all the codes at the same time for identifying the variations embedded in the data. In order to facilitate the later analysis, the first author further grouped the initial codes created in the first phase and created a tentative label for each group. Since all the groups and labels generated in it might be changed in the later stage, this phase can be considered as an intermediate step.

The third phase was most crucial since it generated the major dimensions and the variations within them that could meaningfully characterize educators' conceptions. In this phase, the first author, on the basis of the grouping of codes made before, continued to identify the qualitative differences in each group. Once a qualitative difference was identified, he would check whether the original label of the corresponding group could cover such difference and the initial codes had reflected such difference. If inconsistence was found, further revisions would be made. In the process of reading the codes in each group, the first author also needed to think about whether the present groups could be integrated and whether other groups could be further generated.

When the codes, groups and variations were temporarily stabilized, a meeting would be held between the authors to discuss them. After collecting the comments and suggestions in the meeting, the first author would get back to the data and codes again to do the revisions. Through many rounds of meeting between the authors and many times of revisions made by the first author, the change of code, groups and variations gradually decreased and eventually all of them were stabilized. The final five dimensions emerging from the data were (1) value of teaching NOS to preservice science teachers, (2) NOS content to be taught to preservice science teachers, (3) incorporation of NOS instruction in science teacher education courses, (4) learning of NOS, and (5) role of the teacher in NOS teaching. Their corresponding variations and exemplifying codes are list in Table 3.

5 Findings: Chinese Science Teacher Educators' Conceptions of Teaching NOS to Preservice Science Teachers

The major findings of this study were the five key dimensions of Chinese science teacher educators' conceptions of teaching and the variations within them. A detailed description of these dimensions as well as their variations is provided in the following sections.

5.1 NOS Contents to be Taught

It is typical in the literature to classify the different or even conflicting views of science broadly into two groups and different paired labels are used when making such differentiation, including logic-empiricism versus post-positivism (Lin and Chen 2002), realism versus relativism (Good and Shymansky 2001), and traditional versus contemporary (Palmquist and Finley 1997). The logic-empiricist, realist or traditional NOS views generally refer to those originating before 1960s, for example, beliefs that the goal of a scientist is to discover the truth in nature, there exist the scientific methods, and scientific knowledge progress by an accumulation of observations. On the contrary, the post-positivist, relativist or contemporary ones roughly refer to those originating in

Table 3 Five dimensions of Chinese science teacher educators' conceptions of teaching NOS to prospective science teachers

Dimension	Variation and code of each dimension (no.)		
NOS content to be taught	*Focusing on classical NOS elements (14)*	*Mixed (2)*	*Focusing on contemporary NOS elements (8)*
	Empirical basis of scientific investigation; Replicable nature of empirical evidence; Science as the pursuit of truth; Testable nature of scientific knowledge; Truth-approaching nature of scientific knowledge; Realism views of mind and natural world…	A number of both classical and contemporary NOS elements were included.	Theory-laden nature of observation; Myth of the scientific method; Role of imagination in scientific investigation; Tentativeness of scientific knowledge; Bilateral influence of science on the society…
Value of teaching NOS	*Within science teaching (9)*	*Beyond science teaching (15)*	
	Enriching content to be taught in school science; Transforming traditional science teaching methods; Increasing interest in science teaching; …	Discriminating pseudoscience in individual's daily life; Overturning authoritarian submission; Promoting national development…	
Incorporation of NOS instruction in courses	*As an infused theme (12)*	*As a separated theme (12)*	
	NOS instruction infused into the teaching of inquiry-based science teaching approach; NOS instruction infused into the teaching of science subject content; instruction infused into the teaching of history of science…	NOS instruction arranged at the early stage of Science Curriculum and Instruction Course; NOS instruction arranged at the later stage of Science Curriculum and Instruction Course…	
Learning of NOS	*As a process of change (14)*	*As a process of accumulation (10)*	
	Statement of NOS learning as a process of change; Statement of the existence of students' previous understanding of NOS; Strategy exposing students' previous understanding of NOS…	Statement of no existence of students' previous understanding of NOS; Starting instruction with activities introducing targeted NOS content…	
Role of the teacher	*Transmitter (8)*	*Guider (9)*	*Facilitator (7)*
	Metaphor of feeding; Metaphor of marching; Lecturing as the major teaching strategy…	Statement of the balance between teacher's guidance and students' participation; Analogy of traveling; Analogy of swim training; Questioning as the major teaching strategy…	Analogy of family party; Analogy of basketball game; Group discussion as the major teaching strategy; Strategies for grouping students…

and after 1960s, such as the arguments that theories are the result of creative work, the scientific method does not exist, and scientific interpretation depend on their prior knowledge and the prevailing research paradigm.

In this study, a prominent controversy among Chinese science teacher educators was whether the former or the latter group of NOS elements should be emphasized in their instruction. Fourteen out of twenty four educators chose to focus their NOS instruction on the classical. As explicitly stated by an integrated science teacher educator,

> In the Western world, the views on science can be classified into two periods. This first is before 1970. This is the classical views on nature of science, 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 views considered that observation cannot reflect the objective world, so the scientific theories aren't objective. Instead, they are just the visions that scientists construct in their heads. They are the contemporary or post-modernist views of science… I'll focus on teaching those classical views of science in my teaching (STE3 SI p. 4).[5]

At the same time, the other eight educators chose to focus their NOS teaching on the contemporary elements. For example, a biology teacher educator (STE15) also separated NOS views into two groups, labeled as "the traditional and the contemporary" (STE15 GI p. 2).[6] Those elements suggested in his NOS teaching were:

- Scientific enquiry activities are based on observation, but observation is not science itself.
- Observation is different from inference. There is not a continuous process from the observation to inference.
- Scientific laws and theories are two forms of scientific knowledge. The law is the result of deducing the observed data while the theory is the result of construction.
- The cognitive activities in the scientific enquiry are influenced by the scientists' experience and person background.
- Science is influenced by the social and cultural factors.
- Scientific knowledge is tentative.

As for the other two (STE1, 20), there seemed no distinct difference between the numbers of classical and contemporary NOS elements included by them in their NOS instruction. In other words, a number of both classical and contemporary NOS elements were included by them, so they were somewhat mixed.

It should be noted that the use of the traditional-versus-contemporary label to tag the NOS elements may imply an evaluative stance that the latter ones are inherently better than the former ones, which is not the intention of this study. In order to avoid such an evaluative instance in the wording, we decided to adopt the classical-versus-contemporary label, which just indicates that two kinds of ideas about science originated in relatively different periods of the history of human' understandings about science.

5.2 Value of Teaching NOS

The second dimension of Chinese science teacher educators' conceptions of teaching NOS that emerged from the data was the value of teaching NOS, i.e. educators' views of why it was important to teach NOS to preservice science teachers. Nine educators saw values that are more related to or within the scope of science teachers' day-to-day teaching, which is labelled as NOS value within science teaching. As generally asserted by a physics teacher

[5] "STE3" means that this educator is the 3rd Chinese science teacher educator in the present study. "SI" means that this extract is from the scenario-based. "p. 4" means that this extract is in 4th page of the transcripts of scenario-based.

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

educator, science teachers are “required to have a sufficient understanding about science itself, which is a fundamental basis for their future science teaching” (STE2 GI p. 6).

More specifically, it was also believed that teaching NOS to science teachers can stimulate them to “enrich their science teaching by incorporating the nature of science into their science teaching, which in turn will make their science classroom more colorful” (STE23 GI pp. 2–3). In other words, the content to be taught in school science is enriched. The enriched content in school science is further related to increasing teachers’ interest in science teaching. “The traditional science teaching is just focusing on transmitting scientific knowledge and preparing for the examination, which makes science teaching very boring” (STE9 GI p. 3). However, if science teachers know that NOS contents, which are more colorful and enlightening, can be reflected in science teaching, “they’ll find the richness of science teaching…they’ll no longer consider science teaching as tedious work…and will be more interested in science teaching” (STE8 SI p. 4) .

Chinese science classroom has been long criticized for being dominated by the transmissive teaching methods and lack of students’ participation (Gao 1998; Wei and Thomas 2005). As a biology teacher educator stated, “if science teachers know more about nature of science, they will care about the historical development of the scientific knowledge, and let students experience the process of scientific inquiry”, through which “the traditional science teaching methods can be transformed” (STE15 GI p. 5).

In addition to recognizing the values of teaching NOS within science teaching, fifteen educators saw further values of teaching NOS that are beyond science teaching per se. This latter category can be classified into three aspects. The first is enhancing individual well being in daily life and work-related matter. It was believed that discriminating pseudoscience in individual’s daily life “needs scientific or rational way of thinking, and such way of thinking is in turn embedded in those classic NOS elements”, and so “if people were taught of these elements, they would realize and internalize the scientific or rational way of thinking, which in turn would help them to discriminate pseudoscience in their daily life” (STE12 GI p. 4). Besides, when people know more about NOS, “they will know better the nature of such knowledge …they’ll in turn make better use of such knowledge in their work, which will help them work more effectively” (STE5 GI p. 4).

The second aspect of the values beyond science teaching is enlightening Chinese traditional culture. Scientism was considered by educators as “a negative aspect of Chinese traditional culture and needing innovation” (STE6 GI p. 6). Educators believed that “once NOS were popularly taught in China, people will know the limitations of science, so the scientism in Chinese culture might be expected to change to a certain extent” (STE4 GI p. 8). The ambition of overturning authoritarian submission in Chinese culture was also emphasized. Actually, teaching NOS is at the same time enriching general epistemological knowledge. It was hoped that “if people’s epistemological knowledge is strengthened in China, they will be skeptical or critical of other’s arguments” (STE8 GI p. 6), and thus the authoritarian submission in Chinese traditional culture might be conquered. Superstition was deeply rooted in Chinese feudal society and still very popular nowadays in China (Zhao and Lin 2007). Therefore, a biology teacher educator suggested reflecting the scientific worldviews and rationality through teaching about science. “Only when such scientific worldviews and rationality are popularized in China can the superstition be eliminated” (STE13 GI p. 3).

Some science educators explicitly talked about the value of teaching NOS from the perspective of promoting national development, i.e. the third aspect of the values beyond science teaching. It is believed that if people learn more about NOS, they will be more possible “to question and criticize the existing scientific knowledge”. And with such questioning and criticizing, "they can be more creative in their future scientific work, which in turn contributes to the scientific development of China" (STE14 GI p. 5).

5.3 Incorporation of NOS Instruction in Courses

Different kinds of preference were found among educators on the way of arranging their NOS instruction in their courses of training preservice science teachers. Twelve educators tended to have NOS instruction infused into the teaching of various course components, which made NOS instruction as an infused theme in their courses. The others tended to have a separated NOS module in their courses, though NOS might also be touched upon in other course components. Thus, NOS instruction was a separated theme in their courses.

Two types of experience can be used to develop NOS understanding, i.e. the first-hand experience of the process of scientific investigation by doing hands-on activities and the second-hand experience of such process through learning history of science (Nott and Wellington 1998). In fact, these two kinds of experience can also be used to teach other components in science teacher educators' courses. Therefore, sometimes NOS instruction can be infused by educators into their teaching of these components. Table 4 illustrates four kinds of such components stated by the educators in this study, as well as their corresponding courses and learning experience used.

When NOS instruction is infused into the teaching of other components, the priority of arranging teaching activities is actually given to other content. The following is the example of a chemistry teacher educator's arrangement in his course of History of Chemistry.

> I'll first illustrate the chronicle development of Chemistry…At the same time, I'll also ask the students to discuss the development of some specific themes in chemistry. The periodic table of chemical elements is an example. I'll ask the students to find relevant materials to find what research work had been done on chemical element before Mendeleev's periodic table of chemical elements, what was the social background, what motivated Mendeleev to do such research, how he did such research, what controversies appeared after this table was published, and what made people to accept such a table…I'll ask student to talk about them in the lessons. After their discussion on those issues, students can also be guided to further think about scientific spirits… the scientific worldviews… and logic methods in the scientific investigation in those contents of history of science (STE19 GI p. 7).

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

Table 4 Components used by educators to infuse NOS instruction in this study

Component used by educators to infused NOS instruction	Inquiry based science teaching	History of science	Science subject content	School science textbook analysis
Course	Science curriculum and instruction Science laboratory in school	History of science	Fundamental science	Science curriculum and instruction
Experience used	Hands-on activity	Scientific history	Scientific history	Scientific history

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

Unlike those educators whose NOS instruction was just embedded into the teaching of other contents, another kind of educators planed to teaching NOS mainly through a separate unit in their courses organized under the theme of NOS. The following is a biology teacher educator's description of his arrangement.

> My course of School Biology Curriculum and Instruction can be divided into four parts. The first is the basic theories of biology education … The second part is the practice oriented content…The third part is other theories that are not so closely related to teaching practice, like assessment in biology education and biology teachers' professional development. The last section is mock biology teaching…The nature of science is mainly taught in a separated section in the first part (STE13 GI p. 4).

Although as stated by this educator, he included NOS into the discussion of other following issues in his courses, including the design of science textbook, scientific teaching strategy, assessment, and so on, the priority of arranging teaching activities was given to NOS instruction when he taught NOS in the early part of his course. Thus, when considering his design of his course as a whole, NOS instruction was a separated theme.

5.4 Learning of NOS

Educators had two different kinds of understanding about learning of NOS. One kind of educators (fourteen) considered NOS learning as a process of change from the students' previous understanding of NOS to the targeted understanding of NOS. It is believed that "although the students may not have explicitly thought about questions like what is the nature of science…they'd have actually developed their understanding about science in their past experience of learning science" (STE14 GI p. 2). Thus, "the process of their learning of NOS should be one that changes from their previous understanding to the new one, rather than just the accumulation of the new NOS understanding" (STE5 GI p. 7). Corresponding to such understanding, educators asked students to respond to some questions on NOS at the starting stage of their NOS teaching so as to reveal their preconception of NOS.

> I'll let student teachers speak out their prior understanding about science…I'll ask them to complete a sentence: science is ——. I encouraged the students to feel free to fill in anything in his mind about science in the blank. It can be a noun, a verb, or an adjective…It can be a word, expression or a long sentence…This question is to let the student know their own understanding (STE5 GI p. 6).

Activities were also designed at the end of NOS teaching to prompt students to reflect on the difference between their NOS understanding before and after NOS teaching. "I'll ask them to write an essay to analyze how they perceive science before the lessons, what is their understanding now, what is the difference between their previous and present, and what are the lessons they can get from their learning" (STE8 SI p. 1).

The other ten educators considered NOS learning as a process of accumulation in which students acquired or received new information about NOS. As they thought, "students haven't thought about the nature of science before…They have no understanding in this aspect" (STE18 SI p. 1). "Nobody has told the students about the nature of science before.

Their minds are blank" (STE4 SI p. 2). Therefore, they started their NOS instruction with activities introducing their targeted NOS content to the students.

> Students' discussion on NOS should wait until they have gained a certain level of understanding of NOS… At the starting point of my course, I'll give a brief introduction to the NOS content to be taught…After then, I'll discuss such content bit by bit with the students (STE4 GI p. 9).

When the students were taught of the targeted NOS content at the beginning of the lessons of teaching NOS, it would be rather difficult for them to retrieve afterward their previous understanding of NOS, which in turn made it less possible for them to experience the change from their previous NOS understanding to the targeted one.

5.5 Role of the Teacher

Three variations have been found in the educators' conceptions of role of the teacher in the process of teaching NOS to preservice science teachers. Eight educators perceived the role of teacher in the process of teaching NOS as transmitter. They viewed the process of teaching NOS to be dominated by the teacher and that the students were rather passive receivers in such process. Two metaphors reflecting such conception were found. "When teaching NOS… most of the time…I am *feeding* and students are *digest*ing" (STE21 SI p. 5). "In the classroom (of teaching NOS), students should *follow* the teacher *tightly*"(STE24 GI p. 7).

When the verbs *feed* and *digest* were used to illustrate respectively the teacher and students' activities in the process of teaching NOS, it was actually likening the process of teaching NOS to the one of feeding. As we know, during the feeding process, the feeder needs to choose the food to feed, seek for it, cook it, and finally feed the cooked food spoon by spoon. At the same time, what the fed one needs is to digest as much as they can. It is clear that the process of feeding is dominated the feeder and the role of the fed one is rather passive.

The metaphor used by STE24 might be more obscure. Here, the phrase *follow tightly* was used to illustrate the students' activity in the process of teaching NOS. The verb follow means that one goes after another, which can be found in many activities, like marching, collective hiking, driving and even flying. In all these activities stated above, the leader determines where to go and at the same time what the successor needs to do is just to go after tightly the route of the leader. It is clear that the process of all these activities is dominated by the leader, and at the same time the successor is passive.

Lecturing was the major teaching strategy adopted by this group of educators. "I haven't thought about the specific teaching methods (when teaching the nature of science)…Lecturing is the major method I use…It is very common in higher education" (STE24 GI p. 6). When lecturing is adopted, what is happening in the teaching process is rather similar to the process of feeding. Teacher is responsible to choose what is to be taught, seek the teaching materials to support the teaching contents, reorganize the teaching material to make it clear and logical, and present with clarity to the students. The major responsibility of students is to receive and understand what have been presented by their teacher. The process of teaching is clearly dominated by teacher.

Other nine science teacher educators perceived the role of teacher in the process of teaching NOS as guider. With regard to this conception, teacher's active guidance and students' active participation are both expected in the process of teaching NOS, which is vividly reflected in the analogy of traveling.

> Teacher is a guide and students are the travelers. During the process of travelling, if the travelers just follow the guide, they will gain much less… The real travelling cannot just depend on the guide. It should depend on the travelers' own feet. In some journey of travelling, the traveler can finish it by themselves with the help of the map… Of course, the journey of learning NOS will not be so simple, just like we may encounter with very complicated landscape during our journey. Sometimes, the hill is so steep. And sometimes, the river is so rough… Without the help of guide, it is impossible for normal traveler to get through them. In such occasions, the teacher will be like the guide to give timely help to the students in need (STE11 SI p. 1).

Travel can be different for different people. In some travels, the whole journey is dominated by the guide, who leads the tourists to visit the scenery along road and gives an excellent introduction of the scenery to the tourists. What they need to do is to just follow the guide and enjoy the guide's colorful introduction. If it is the case, the traveling theory is much similar to the feeding metaphor introduced before. For this educator, the traveling took a rather different picture. For him, more room should be provided to the traveler. Otherwise, this travel was less meaningful. At the same time, the guide also needed to keep eyes on the difficulties of the traveler during the journey, and provided assistance for those travelers in need, so as to ensure everyone can finish the journey. Clearly, the guide's active guidance and travelers' active participation were both reflected in this educator's description of travelling.

Questioning was especially important in this group of educators' design of NOS teaching.

> A lesson without questions is a boring and inefficient lesson…The teaching should proceed with continuous questioning and answering between teacher and students…When teaching the nature of science, I'll prepare a number of questions for the students to promote them to constantly think and discuss in the classroom (STE1 GI p. 7).

Questioning is a kind of teaching strategy that have existed since Socrates' time. When a question is raised to the students, there is a pressure for them to think and respond to the teachers. Based on their responses, teachers can judge whether additional questions are needed, more materials should be provided, students need to further elaborate their answers, or they can directly move on to the next topic of teaching. If they move to the new topic, another group of questions will be further raised. It can be found that the teacher' active guidance and students' active participation can be appropriately actualized by this kind of teaching strategy.

The last kind of understanding in this dimension perceives the role of teacher in the process of teaching NOS as facilitator. As for it, the process of teaching NOS is dominated by students and at the same time teacher' control is rather weak in such process. It was believed that "the students could not only learn from their teacher, but they might also learn from their peers and sometimes what they learned from their peer might be even more than what they learned from the teacher" (STE8 GI p. 4). Therefore, "the group discussion was adopted as the major teaching strategy" (STE10 GI p. 6). During the group discussion, considering that there is commonly a number of groups existing in the classroom, the teacher will be less able to control the specific process of students' activities, which will eventually make the process of NOS teaching process dominated by students.

The conception of role of teacher as facilitator was illustrated by an analogy of family party.

> Teacher should be like a party organizer… The organizer chooses the place and provides the food…When the party starts, the organizer changes into the participant… He/she doesn't need to interrupt others' activities…Everyone can organize activities and find fun by themselves in the party (STE12 GI p. 10).

Parties can vary. For some very formal parties, the activities are carefully planned in advance and the process of the party is strictly guided by the organizer. The party referred by this educator in the above excerpt was clearly not this type. As stated by her, the organizer would turn into a normal participant after the party begins and the participants arrange the activities by themselves. Obviously, the participants in such party were mainly dominated by the participants and the organizer' control was rather weak. Similar views can be also inferred in another analogy of basketball game used by a biology teacher educator.

> Teacher is the coach and students are the players in the basket ball court…When the game begins, the result cannot be controlled by the coach. How the game goes will mainly depend on the athletes…It depends on their ability and the cooperation among them. (STE13 GI p. 4)

6 Discussion

This section will first comment on how our findings relate to the research on conceptions of teaching in general and go on to compare our result with the literature on NOS instruction.

6.1 Comparison with the Research on Conceptions of Teaching in General

The present study reveals a number of dimensions of Chinese science teacher educators' conceptions of teaching NOS to preservice science teachers. While some of these dimensions share much similarity with those reported in the studies of conceptions of teaching in general, some are distinctively different, which is embedded in some unique features of teaching NOS to preservice science teachers.

6.1.1 NOS Content to be Taught

In the literature of conception of teaching in general, the variations on teaching content have been reported.[7] However, it should be noted that the major variations reported were not the one in the specific contents. Rather, the major variations reported in these studies are the relationship between teaching content with teacher, student, textbook, curriculum or examination. For example, the major variation reported in Samuelowicz and Bain (1992)'s study is whether teacher or student is in control of the content of teaching. In addition, there are three major different views suggested in Kember (1997)'s paper, including being defined by the curriculum, being defined by the teacher, and being defined by the students. However, the variation in the specific contents, like variation between pluralism and essentialism, has not been found in such literature.

The emergence of the variation within the specific contents in conception of teaching NOS can be attributed to two factors. First, it is concerned about teaching of a specific topic, NOS, rather than teaching in a very general sense—which is the case for most studies on teaching conception studies. When people think about teaching in general, the context of thinking is commonly detached from the very specific teaching content, hence they seldom get into the specific teaching content. On the contrary, respondents are more likely to relate their thinking to, as introduced in the preceding paragraph, the different factors as the main force influencing their decision on teaching content. Nonetheless, when

[7] See for example Kember (1997), Martin and Balla (1990), Pratt (1992), Prosser et al. (1994), Samuelowicz and Bain (1992).

people think about teaching NOS, a very specific topic, it is necessary for them to get into the specific NOS elements. Under such a situation, it is likely that variation exists regarding the specific NOS teaching content to be taught. At the same time, the different factors that influence the decision on NOS teaching content discussed above (e.g., defined by curriculum, teacher or student) would likely become the contextual elements which can explain such variation.

Of course, when thinking about teaching a specific topic which is less controversial (like force in physics), people's decisions on the specific teaching content will not be too different or diverse in opinions. In other words, the major variation on teaching content in people's conceptions of teaching such a topic would not be differences in the specific content, but was just related to the different factors as the main force influencing the decision on teaching content. However, as we know, NOS is a rather contested topic (Osborne et al. 2003). People's decisions on the teaching content for such a contested topic can be very complicated and diverse. Therefore, the difference in the specific contents (like the one between focusing on classical and contemporary NOS elements introduced above) can be found as an important variation in people's conception of teaching it.

6.1.2 Value of Teaching NOS

Values or goals of teaching can be found as an important dimension in two studies of conceptions of teaching in general (e.g., Gao and Watkins 2001; Lam and Kember 2004). Gao and Watkins' studies (2001), whose subjects were eighteen school physics teachers, identified five different goals of teaching, i.e. conduct guidance, attitude promotion, ability development, exam preparation, and knowledge delivery. In addition, these five goals are further conceptualized into two groups, i.e. moulding and cultivating. Lam and Kember's study (2004) investigated 11 art teachers' conceptions of teaching and found four different values of teaching, i.e. moral development, aesthetic development, intellectual development, and expression and therapy. They also further classified these four values into two categories, i.e. in art and through art.

Although a number of values of NOS have been discussed in the literature, like democratic, cultural, moral, utilitarian, science learning, and science teaching arguments (Driver et al. 1996; McComas 1998), these values of NOS have not been further categorized. The present study suggested a way to further categorize values of NOS, which is similar to what has been done in Gao and Watkins' and Lam and Kember's studies. It is to further conceptualize values of NOS into two groups, within and beyond science teaching. As indicated in Table 3, there are nine out of twenty four educators in the present study whose conceptions of values of NOS were limited within science teaching while the other fifteen went beyond science teaching. Given that there are considerable amount of educators in each group, such categorization might be a viable way to conceptualize the value of teaching NOS.

The major variation reflected in this study is different from those reported in Gao and Watkins' and Lam and Kember's studies. Such differences are anticipated as conceptions of teaching were discussed in different contexts. In the present study, the discussion on conceptions of teaching is located in the context of teaching a very specific content in science teacher training, so it is reasonable to find the variation related to science teaching. On the contrary, the discussion on conceptions of teaching in Lam and Kember's studies was in the context of teaching art, so the variation found was related to art. And the discussion on conceptions of teaching in Gao and Watkins' studies was located in the context of teaching science, so the variation found in such study was related to science learning. Such shifts in the major variations in conceptions of teaching different contents are actually reflecting the content- dependent nature of conceptions.

6.1.3 Incorporation of NOS Instruction in Courses

The variation in the specific ways of arranging instruction in the courses has not been reported in the literature on conceptions of teaching in general (e.g., Kember 1997; Martin and Balla 1990; Prosser et al. 1994). Since the conception of teaching in general is detached from the specific content, it is not necessary to consider, during thinking about teaching in general, the issue of how to handle the relationship between the targeted content with other components in the courses. Therefore, it is natural to find the absence of this variation in the literature on conceptions of teaching in general. Of course, if we think about teaching of a certain content, the experience used to teach which is relatively independent from experience used to teach other components in the courses (like plant in biology), it is also not necessary to consider, during thinking about teaching such content, the issue of how to handle the relationship between the targeted content with other components in the courses. However, in the present study, the focus is on the conception of teaching NOS, which is a very specific content and the experience used to teach which is overlapped with the experience used to teach other components in the courses. As a consequence, it is possible to find the variation in the specific ways of arranging NOS instruction in the courses.

6.1.4 Learning of NOS

The dimension of the process of learning as a process of change versus accumulation has been reported widely by a number of studies into the conceptions of teaching in general.[8] Such finding is echoed in the present study on a specific group of people's (i.e., Chinese science teacher educators) conception of teaching a specific topic (i.e., NOS). Thus, it can be found that the dimension of the process of learning may be a relatively stable dimension of the conception of teaching. Actually, it has been argued for several decades in the field of science education that learning science concepts should be considered as a process of change (e.g., Posner et al. 1982; Yuruk et al. 2003) and a large number of studies has been done on designing and evaluating instructional strategies causing such a process of change and identifying the factors that may influence its effectiveness (Duit and Treagust 2003). Such theory has been already disseminated into the learning of other areas (Samuelowicz and Bain 1992). Although this theory might not be adopted by all the teachers, its wide influence makes the process of learning a popular dimension in conceptions of teaching.

6.1.5 Role of the Teacher

Role of the teacher in the process of teaching is also an ancient topic in education. It has been popularly discussed in the literature of conceptions of teaching in general.[9] In Bartholomew et al.' study (2004) of the practice of teaching NOS, it is differentiated into dispenser of knowledge and facilitator of learning and considered as an important

[8] See for example Christensen et al. (1995), Gao and Watkins (2002), Kember (1997), Martin and Balla (1990), Pratt (1992), Prosser et al. (1994), Samuelowicz and Bain (1992).

[9] See for example Christensen et al. (1995), Dall'Alba (1990), Fox (1983), Gow and Kember (1993), Kember (1997), Martin and Balla (1990), Pratt (1992), Prosser et al. (1994).

dimension of distinguish a teacher's ability to teaching NOS effective. Although there is a minor difference in the number of its variations (some include three while some just include the two) and its names, an overall impression is that this dimension is also, to some extent, consistent across contexts. Of course, there is not a definite answer to what is the best role of teacher in the classroom since it is influenced by a great deal of factors, such as the nature of the content, the ability of students, the pressure of examination, the time available, students' motivation and expectation, teacher's visions of teaching, and etc. Facing such a complicated issue, people may always have rather diversified views no matter what teaching is discussed.

6.2 Comparison with the Literature on NOS Instruction

Although no phenomenographic research of conceptions of teaching NOS can be found until now, some controversies on NOS instruction are well-known in the published papers. Among these controversies, the most prominent ones are between pluralism and essentialism on NOS content, and implicit and explicit approach to teaching NOS. They are related to two dimensions revealed in this study, and so will be the focus of discussion in the following paragraphs.

6.2.1 NOS Content to be Taught

In the literature, the controversy between pluralism and essentialism has been explicitly discussed and considerable examples can be found for each view, and so it may be a prominent one in the West. However, 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 each of these educators. As indicated in the data, the major controversy revealed in this paper is whether focusing on the classical or contemporary NOS elements.

Such a difference may be explained by a prevailing philosophical tradition in China. It is well known that modern Chinese society is deeply influenced by Marxism (Wei 2012; Wan et al. 2012), which was introduced into China in 1917–1920 when October Revolution broke in Russia. The victory of 1949 further made Marxism the dominating ideology of society and the guiding thought of China. Until now, it has been believed in and admired by millions throughout the country and has also become a formal component in the curriculum of Chinese school and university. Marxist basic philosophical standpoints are materialist, realist and empiricist. In other words, it favors the classical views of science. Therefore, when the contemporary NOS views were introduced into Chinese science education, the proponents of Marxism tended to reject and even refute them so as to protect their own worldviews. At the same time, some other avant-garde educators that were more influenced by post-modernism, constructivism or relativism in the West intended to utilize contemporary NOS views to challenge the traditional Marxist worldview. Consequently, the controversy between focusing NOS instruction on the classical or contemporary NOS elements was very prominent among Chinese science teacher educators. On the contrary, if there was not a so prevailing philosophical tradition in China, Chinese educators might be more tolerant of different NOS views, and so they might be in a position to turn their *focal awareness* to the controversy between pluralism and essentialism.

6.2.2 *Incorporation of NOS Instruction in Courses*

The implicit and the explicit approaches have been explicitly discussed in the context of teaching NOS to school students and science teachers. Their difference lies in whether the conceptual descriptions of NOS elements is providing during the process of teaching. Although these two concepts are named as approaches to teaching NOS, which focusing on ways of teaching, they can still imply two different ways of incorporating NOS instruction in course. If the educator adopted the implicit approaches to teaching NOS, his incorporation of NOS instruction in course is actually as an implicit theme. At the same time, when the educator adopted the explicit approaches to teaching NOS, his incorporation of NOS instruction in course is actually as an explicit theme. In other words, there are two layers of meanings for the implicit-versus-explicit categorization. The first is related to the ways of teaching and the second is related to the incorporation of NOS instruction in courses. In this study, the controversy between implicit and explicit approaches seems not prominent among Chinese science teacher educators' conceptions since none of them adopted the implicit approach or incorporation of NOS instruction as an implicit theme, which may be partly explained by the influence of Vygotskian theory in China.

"Psychological tools" is a typical term and key concept in Lev Vygotsky's work (Kozulin and Presseisenm 1995), which refers to symbolic systems consisting of signs, symbols, maps, charts, models, pictures and, above all, language (Vygotsky 1986). These symbolic systems are called tools because Vygotskian theory holds that they are inventions in the long history of human development and high-level thought must be mediated by them. Since they are inventions through a long period in the history, they cannot be easily generated. It is hence believed that psychological tools should be communicated by teachers rather than discovered by learners themselves. When explaining why the implicit approach was not adopted, some educators explicitly mentioned the concept of psychological tools. As they stated, "NOS elements are the theorized understandings about science" (STE13 SI p. 8). These understandings should be conceptualized through *psychological tools,* which are invented through a very long history of the academic studies about science (STE5 SI p. 4). Hence, "it was impossible for students to generate these *psychological tool*s simply through the experience of scientific inquiry and learning history of science" (STE10 SI p. 5).

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

The appearance of the variation of Chinese science teacher educators' views of arranging NOS instruction in their courses in this study should be explained in terms of the fact that China is just at the starting stage of formally introducing NOS in science education. Actually, the terminology *NOS* has just begun to appear in China in last 10 years. Among Chinese science curriculum documents published recently, only one, i.e. Integrated

Science Curriculum Standards (7–9 years)[10] (MOE 2012b), intentionally discusses this topic. It is argued in its first chapter, "the curriculum is designed on the basis of the contemporary views of nature of science, and aims to develop the students' understandings of nature of science" (p. 2). After then, it uses a session to illustrate what are its NOS views. On the contrary, when NOS appears in others curriculum documents (MOE 2012a, c), it is just touched on. For example, when Chemistry Curriculum Standards (7–9 years) illustrates the values of doing scientific inquiry, it says that "through scientific inquiry, students learn the scientific knowledge, gain the scientific skills, experience the scientific process, and understand the nature of science" (p. 8), but no further elaboration on NOS can be found afterwards. Since NOS is not a prominent topic in most of curriculum documents, and as introduced before, does not appear as a separated section in most of the textbooks for training Chinese science teachers, when teaching such a topic, Chinese science teacher educators need to base on their own considerations to make decisions on how to incorporate NOS instruction in their courses. Thus different arrangements can be found among them.

7 Conclusions and Implications

Among the five dimensions of Chinese science teacher educators' conceptions of teaching NOS to preservice science teachers, considerable differences have been identified between three of them (i.e. NOS content to be taught, values of teaching NOS and incorporation of NOS instruction in courses) and the findings reported in the studies of conceptions of teaching in general. As discussed before, such shifts are embedded in some unique features of teaching NOS to preservice science teachers. Besides, within the dimensions of NOS content to be taught and incorporation of NOS instruction in courses, findings in this study reveal some variations that are to some extent different from what is reflected in the literature of NOS instruction. These data may be an annotation of the argument that conceptions are context dependent (e.g., Gao and Watkins 2001; Marton 1981; Samuelowicz and Bain 1992). They also imply that teaching NOS is more complicated than teaching normal content since more sophisticated decisions should be made by teachers themselves during the process of teaching it.

Given the complexity of teaching NOS, professional supports should be provided to teachers or educators for their NOS instruction. In addition to developing their understanding of NOS, more efforts should be made to (1) prompt the educators or teachers to reflect on their own views of teaching NOS and exchange their views with colleagues, (2) enhance their intention and self-efficacy of teaching NOS, and (3) then provide opportunities for developing their pedagogical content knowledge of teaching NOS in authentic teaching contexts. The five dimensions reported in this paper can constitute a valuable framework for the first effort, i.e. reflection and exchange of views of teaching NOS.

Intention of doing something is closely related the perception of the values of such action. A good number of specific values of teaching NOS have been reported in this paper. Those within science education include enriching content to be taught in school science, transforming traditional science teaching methods, increasing interest in teaching science, and constituting a foundation of school science teaching. At the same time, the values beyond science teaching are enhancing individual well-being in daily life and work, enlightening Chinese traditional culture through mitigating scientism, authoritarian

[10] Integrated Science Curriculum Standards (7–9 years) is for the Grade1–3 students in secondary schools.

submission and superstition, as well as promoting national development. These values are not just directly imported from the Western world. Instead, they are from the mouths of practicing Chinese science teacher educators and interpreted by them with consideration of the social and cultural contexts of China. Therefore, these contents can be a useful resource for enriching Chinese teachers or educators' perceptions of the values of teaching NOS and then enhancing their intention of teaching NOS. Given that some of these values may also be able to apply to the areas outside China, they can also be used as the reference for strengthening the intention of teaching NOS of teachers in these areas.

As stated by Tobin and Tippins (1996), metaphors and analogies hold the appeal "as ways of beginning conversations about teaching and learning science and make it easier to be reflective on and in practice" (p. 728). As described in the findings, some analogies were used by Chinese science teacher educators to describe their practice of teaching NOS, including travelling, family party and basketball game. They are rather vivid and insightful. These analogies may be used as valuable tools to facilitate the change of some science teacher educators or science teachers' practice of teaching NOS. It is argued in the discussion section that conception of the role of teacher is less contextual. In other words, it may be consistent across different contexts of teaching. Hence, the analogies introduced above can also used in the modules or programs of training teachers of other content or subjects.

Identification of the component dimensions of a conception is a crucial step in conception studies. Without the key dimensions of a specific conception, it is rather difficult to reveal the internal structure of such a conception. The dimensions revealed in this study can be the basis to probe the conceptions of teaching NOS of other groups of subjects (like school teachers' conceptions of teaching NOS) or in other contexts (like teaching NOS to in-service teacher). The specific content included in these dimensions can provide some clues to analyzing the data and discussing the findings in these studies.

Chinese science teacher educators have dramatically different cultural, social and political background that is different from their Western counterparts. The present study has tried to compare some aspects of Chinese teacher educators' conceptions of teaching NOS to preservice science teachers with those that can be inferred in the Western literature. The author bears in mind that there are two limitations of inferring Western science teacher educator' conceptions of teaching NOS based on the published NOS literature. Firstly, Western science teacher educators who published papers on teaching NOS are just a small portion of the whole group. Secondly, the full picture of a specific educator's conception of teaching NOS might not be completely presented in one paper. Given the existence of such limitations, additional research is needed to probe Western science teacher educators' conceptions of teaching NOS.

As introduced in the methodology section, the first author did not force the interviewees to talk about the questions that are explicitly related to the specific dimensions of conceptions of teaching NOS. The interview questions just focused on their experience of teaching NOS, such as "how do you start your NOS lessons", "what are your major teacher and learning activities", "what teacher materials have you used", and "what are the assignments in your NOS lessons". The data available in the study thus is limited for analyzing the internal relationships among the dimensions of conceptions of teaching NOS. More in-depth and focused studies are needed to probe such internal structure. In addition, conceptions of teaching NOS are just one of the factors that influence NOS teaching, which may bear relationships with other factors. Further study can be conducted to further probe those external relationships between the five dimensions and other constructs.

The subjects in the present study only represented a specific group of science teacher educators from the economically developed areas of Mainland China. It is still unknown whether this model of conceptions of teaching NOS presented in the current study can be applied to the educators in other parts of China, e.g. those teaching in developing areas or to prospective teachers from minority groups. Further studies can include more educators in other areas to test if the model can be generalized to other areas in China, in particular, those regions inhabited mainly by ethnic minority groups whose cultural traditions are quite different.

Appendix: Scenario D[11]

A. Group NOS papers in terms of a number of themes (like the logic and methods of science, products and tools in science, visions of reality and the role of observation in science, and etc).
B. Divide students into several small groups.
C. Assign each group to read and write a report on one theme in one section.
D. Ask several groups to present their reports in the class.
E. Organize classroom discussions on the basis of students' presentations.

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[11] Scenario D was designed on the basis of the paper by McComas (1998).

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