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Exploration of the variety of teachers' VNOS in China: Is the "step-over development" approach effective?

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Abstract

To improve the effectiveness of science teacher training, with regard to the impact of Chinese culture on teachers' views on the nature of science (VNOS), a nationwide survey of primary science teachers was performed in China in 2013. The primary findings showed that the participants could be classified into four groups through cluster analysis according to their characteristics of classic VNOS and modern VNOS among the groups: the Ambiguous group (AG), Post-modernist group (PG), Classic group (CG) and Modern group (MG). Despite slight uncertainty between the CG and MG, the scores of VNOS knowledge application in both daily life and classroom teaching increased largely from the AG, PG, and CG to the MG, and the differences in these scores among the four groups were statistically significant. These findings seem to imply that the post-modernist stage occurs prior to the classic stage in certain Chinese teachers' VNOS development, which notably contrasts with the historical processes of both science and science teacher training practices in developed countries. Moreover, the AG and PG had the longest training times among the four groups, which might indicate that science teacher training programmes in China were ineffective for these teachers. Unlike in Western countries, Chinese traditional culture lacks basic elements of scientific concepts. The society has not experienced the entire process of the development of science. Thus, Chinese teacher training programmes should pay attention to the progression from the classic VNOS to the modern VNOS and should be cautious of the "step-over development" approach.

Keywords: Classic and modern VNOS, Nature of science, Chinese culture, Science teacher training

Introduction

Public scientific literacy has been widely acknowledged to be one of the most important indicators of the international competitiveness of a country; therefore, governments and social organizations in many countries have issued various policies to improve the quality of science education at all levels. As a rapid developing country, China has also made significant investments in science education, including science teacher training, in past decades by adopting teacher training theories and programmes from developed countries, assuming that "step-over development" was desirable. The Ministry of Education of China initiated the National Teacher Training Project (NTTP) in 2010, and it invests $89.6 million every year to provide professional development opportunities for teachers

(Mu 2013). Several in-service teacher training bases for science education have been established across the country, aiming to improve teachers' professional knowledge and ability. However, the teachers' scientific literacy in terms of their understanding and application of the nature of science (NOS) has improved very little according to a follow-up survey of the past 10 years. Ironically, this unsatisfactory improvement was not statistically correlated with the training time that the teachers experienced (Zhang et al. 2016; Zhang et al. 2013). Unlike in the Western world, in China, little is known about how to organize NOS training, which should be situated in the country's unique social, cultural and historical context.

The NOS is typically known as the epistemology and sociology of science, science as a way of knowing, or the values and beliefs embedded in scientific knowledge and its development (Lederman 1992). The NOS not only affects people's views of science directly, but it also guides people's scientific activities and daily behaviours (Wang and Zhao 2016). As a critical component of scientific literacy, the NOS has become one of the core educational objectives in school curriculum standards and teacher training programmes in many countries (Lederman 2014). Consequently, teacher's views on the nature of science (VNOS) have been paid much attention by researchers for more than half a century in Western countries (see Anderson 1950; Behnke 1961; Aflalo 2014). However, many previous studies have revealed that teachers' VNOS were quite confusing, even after participating in training programmes, so researchers have explored the methods used to promote teachers' understanding of NOS. After nearly 60 years of exploration, a resolution has been reached: either in explicit, reflective approach or using the history of science could be effective in teaching the NOS (Wang and Zhao 2016; Pavez et al. 2016; Bilican et al. 2015).

In China, however, the terminology of the NOS has just begun to appear in the last 15 years (Wan and Wong 2013). Although explicit discussion on the NOS has emerged in recent Chinese academic journals, there is neither elaborate guidance in most official documents and standards on how to teach NOS nor specific units in most textbooks for training. In fact, the NOS is simply mentioned as a slogan in the NTTP standard for science teachers without any specifications, stated thus: "to understand the concept, value and application of the NOS" (National Teacher Training Project (NTTP) 2012). As a result, Chinese science teacher educators are free to design their own NOS instruction. Most of them, in training courses explicitly or implicitly, tend to introduce contemporary or even post-modern VNOS, neglecting the universality and objectivity of science because it seems more advanced and cutting-edge and congruent with the general policy of "step-over development" for the whole country (Cai and Chen 2012; Wei and Huang 2008; Shi and Liang 2008).

Moreover, the complicated conceptions of the NOS generated in the West would exert a special impact on educational practices in developing countries (Wan 2014). It has been argued that the post-modernist VNOS, interrelated with Chinese traditional culture and the ideas of anti-science and technology, has exerted significantly negative effects on science education in China (Zhang and Yu 2004) and even in Western countries (Osborne 1996). This study aims to further explore this issue empirically and to identify possible solutions for effective teacher training through quantitative assessment of the teachers' VNOS and their connections to the behaviours of the teachers.

Literature review

History of science and VNOS

The NOS changes with the development of science and the society that embodies it. Before the sixteenth century, the natural world was often interpreted using religion and theology. Ancient people's views about the NOS were naive and ambiguous, and they are generally referred to "ambiguous VNOS" in the following text. VNOS featured intuition and guesswork until the late sixteenth century, when Newton introduced his classical system of mechanics. The "classic VNOS", as it is called in this study, was largely in favour of empiricism, mechanical materialism and positivist epistemology, believing in the objectivity of scientific observation, the uniformity of the scientific method, the truth of scientific theory and the disinterestedness of scientists. The "classic VNOS" has also been called the "traditional VNOS" in the literature (e.g. Yuan 2006). However, the rapid development of science in the nineteenth century exerted a negative influence on society. Together with cutting-edge scientific theories, such as the principles of quantum mechanics, coming into existence, the "modern VNOS", as it is called in this paper, or the "contemporary VNOS", as it is called by some other researchers (see Wan et al., 2013a), emerged in science education after the 1960s and grew significant in the 1980s. At the same time, another school of VNOS emerged, and it is defined in this study as the "post-modernist VNOS",[1] which thoroughly denies the classic VNOS and excessively focuses on the subjective and uncertain aspects of science. This type of view on the nature of science is quite extreme, featuring relativistic and anti-rational worldviews. It is very different from science in almost every way (Good and Shymansky 2001).

It is true that precise definitions of classic science, as well as the modern science, in the communities of the philosophy of science and science education are disputed and varied. Nevertheless, there is broad consensus regarding the cognitive development of human beings that classic science preceded modern science. Ibrahim A. Halloun (2007) has proposed three categories of realistic views on nature of science, namely, the naive scientific realism (NR), the classic scientific realism (CR) and the modern one (MR). The viability of CR or MR as he deemed has been well established by a concerned scientific community within well-defined scopes and limits of approximation and precision, and the two dimensions complement one another in specific respects. And he further announced that "My own natural paradigmatic profile is currently dominated more by classical scientific realism (CR) than by modern scientific realism (MR) because my professional experience has so far been concerned more with CR than with MR." This study, therefore, conducts a special investigation of the classic VNOS of participants in China where science did not originate, and draws comparisons between classic VNOS and modern VNOS.

Classic VNOS versus modern VNOS

In current education practice, there is a great deal of discussion about defining science for public school teachers, their students, and the general public from two sides: one is prone to the classical deterministic worldview, and the other tends to favour the modern in-deterministic conceptualization of science (Abd-El-Khalick and Lederman 2000). Someone who holds classic views about the nature of science sees nature as real, existing independently of humans (Good and Shymansky 2001), emphasizes the importance of evidence and believes that the nature of knowledge is provable and confirmable. Matthews (2004) offered a classic positivist view of the nature of science that consisted of at least the following core commitments.

1. Science seeks the truth; it endeavours to find out how the physical, social and personal worlds work and are constituted.
2. Ultimately, empirical testing and evidence are determinative for scientific truth claims.
3. Statements that, in principle, are non-empirical (theological and traditionally metaphysical) are nevertheless meaningful but are neither true nor false.
4. Science is unified, and although there are different methods employed across the natural sciences and social sciences, there is a unified family of methodology involved in all science.
5. The methodology of science is rational.
6. Science is universal: there are no "local" sciences; the truths of science are equally true across cultures.
7. Science methodologically assumes a naturalistic (but not materialist) worldview.
8. A naturalistic worldview is the only true one; transcendental, metaphysical and orthodox religious worldviews are mistaken.
9. Science is part of the Enlightenment tradition; this tradition has had positive benefits for the world and needs to be defended and extended.

However, people who hold modern views about the nature of science emphasize a relative view on the nature of knowledge, opposing "absolute truth" and believing that scientific knowledge is tentative. They emphasize humankind's active role in the process of interpretation of events and objects. McComas et al. (2002) extracted a consensus modern view of the nature of science from eight international science standards and documents, as follows.

1. Scientific knowledge, while durable, has a tentative character.
2. Scientific knowledge relies heavily, but not entirely, on observation, experimental evidence, rational arguments, and scepticism.
3. There is no one way to do science (therefore, there is no universal step-by-step scientific method).
4. Science is an attempt to explain natural phenomena.
5. Laws and theories serve different roles in science; therefore, students should note that theories do not become laws, even with additional evidence.
6. People from all cultures contribute to science.
7. New knowledge must be reported clearly and openly.
8. Scientists require accurate record keeping, peer review and replicability.
9. Observations are theory laden.
10. Scientists are creative.
11. The history of science reveals both an evolutionary and revolutionary character.
12. Science is part of social and cultural traditions.
13. Science and technology impact each other.
14. Scientific ideas are affected by their social and historical milieus.

In fact, the classic VNOS and modern VNOS have not received same courtesy over last three decades, partly because positivistic philosophy has encountered hardship in the Western world. The situation was described by M. Matthews (2004) as follows: "It is an understatement to say that Positivism is unpopular in progressive science education circles. Indeed 'positivist' has become a term of extreme scholarly abuse, it is almost the worst thing that can be said about a philosopher or social scientist. Once some position is identified as 'positivist', then it can be dismissed; such identification is basically the end of any argument. It is difficult to think of any term in the educational lexicon so laden with negative connotations as 'positivism'. 'Positivist' is to education, what 'terrorist' is to geo-politics." Mathews further examined and elaborated on two educational papers by Philipp Frank and Herbert Feigl, two famous logical positivists, and concluded that a number of the philosophical and educational 'principles' of these foundational positivists are of value to educators in facing the worldwide drift from the natural sciences in schools and universities, as well as an increasingly anti-science student lobby in universities and society. A similar argument came from Osborne in his paper entitled "Beyond Constructivism". Another conclusion obtained by Matthews (2004) was that "There has been a clear failure by science educators to identity foundational positivism and separate it from tabloid or vulgar positivism." Further, Matthews argued that science educators owe a duty to the scientific tradition and to society to be more adequately informed about the history and philosophy of the discipline that they are preparing teachers to teach. More specifically the inaccurate, mistaken, cheap throw-away lines that pass as arguments against positivism (and frequently against the Enlightenment tradition that positivism defends) do not do justice to anyone, much less to trainee science teachers who are increasingly required to convey something to their own students about the nature of science.

The situation is different in China, where science was imported from the West only a century ago. Chinese schoolteachers had not experienced the history of classic science, which pervaded the period of industrialization, before they were required to teach school science. They did not experience periods, such as the Renaissance and the Enlightenment. There did not experience such things as Galileo's observations, which were so objective that they could dismiss the subjective views of theology. In fact, the traditional Chinese philosophy has paid more attention to the order of human connections and emotion rather than the Nature and logic. This absence of classical conceptions, such as the observation, objectivity and consistency or unity of science, has had negative influences on Chinese science teachers, especially when they skip into the post-modern stage (Zhang and He 2012; Zhang and Wan 2017).

Elements of NOS for science learners

Although the definition of the NOS remains controversial, many science educators have come to a consensus on certain aspects of the NOS, which should be possessed by science teachers and learners. N. G. Lederman (1999, 2014), the famous American expert in science education, proposed seven aspects of the NOS for teaching: observations and inferences; the tentativeness of scientific knowledge; subjectivity and objectivity in science, creativity and rationality in science; social and cultural embeddedness in science; scientific theories and laws, and scientific methods. J. F. Osborne, a famous British expert in science education, and his colleagues (2003) proposed a different schema of NOS topics by conducting a Delphi study in the UK: science and certainty; scientific methods and critical testing; creativity; historical development of scientific knowledge; science and questioning; diversity of scientific thinking; analysis and interpretation; hypothesis and prediction; and cooperation and collaboration. Both the American and British schemes include classic and modern elements of the NOS, while their emphases seem different. The British conception seems to pay more attention to the classic aspects than the American conception. For example, as reported by Osborne et al. (2003), two scientists who participated in the study emphasized specifically the classic concepts of science for elementary science education, and they considered the certainty of scientific knowledge to be an important component of pupils' learning; scientific knowledge taught in schools should be well established and beyond a reasonable doubt. In addition, Friedrichsen et al. (2006) believed that it was not appropriate to teach the tentativeness of scientific knowledge in elementary classroom settings because it can cause students to question the trustworthiness of the content that they learn.

Teachers' VNOS and the practice of inquiry teaching

Inquiry learning has been regarded as one of the common critical goals of science education in many countries' curriculum standards for K-12. Therefore, many studies have investigated the relationships between teachers' NOS and their practices of inquiry teaching. Moscovici (1999) argued that science teachers' views about the NOS greatly influence their willingness and ability to bring inquiry learning to students. The level of teachers' NOS can also influence the style and quality of science inquiry that teachers implement in science classrooms. A better understanding of NOS concepts assists teachers in developing greater appreciation of inquiry activities, which are less structured and more student oriented and open ended (Atar and Gallard 2011).

It is a popular practice for Chinese science teachers to set a time limit for students to complete scientific inquiry activities or to allow them to compete with each other. Some science teachers even treat scientific inquiry like drama, encouraging students to perform according to a prepared script. Group inquiry work for pupils is always assigned by a team leader, who controls the process and even the results of the inquiry, which is the opposite of the democratic atmosphere proposed by J. Dewey (Zhang 2003). In general, adequate understanding of NOS concepts is a necessary condition for science teachers to successfully implement inquiry learning in science classes. This study, therefore, by correlating Chinese teachers' VNOS with their teaching behaviours, seeks to prove the validity of the assessment of the characteristics of Chinese teachers' VNOS and to further investigate their development processes in understanding NOS.

Cultural impact on teachers' VNOS around the world

Since possessing adequate understanding of NOS is quite important, many researchers have conducted cross-cultural investigations of teachers' VNOS in different countries around the world. Significant disparities in teachers' VNOS have been found among countries and districts, indicating some social-cultural impacts. Wang (2010) conducted an investigation and reported that the VNOS of American science teachers was in the transition stage from the classic to modern. Ding (1999) also found that Taiwanese primary school science teachers' views about the NOS were between the traditional and modern views. Similarly, Chai et al. (2012) reported that Taiwanese science teachers were more relativistic than those in Mainland China. More research reported that the views on the NOS of science teachers in Mainland China were traditional and naïve (Liang 2005; Wang 2010; Wan 2014). Iqbal et al. (2009) found that the views of majority of Pakistani science teachers fell into the 'traditional domain', which is comparable to the "classic" type in this study. In summary, in contrast to the developed countries and districts, it is difficult to find an advanced viewpoint about the NOS reported in poor countries and areas.

However, some research has indicated the complexity of VNOS in non-Western, developing countries, which cannot be simply described as dualistic, traditional or advanced. Vietnamese students showed high scores on scientific uncertainty, while the compulsory philosophy in Vietnam is Marxism-Leninism, which contradicts the tentativeness of scientific knowledge (Thao-Do and Yuenyong 2015). The majority of Bangladeshi school science teachers held "uninformed conceptions" of the nature of science (Sarkar and Gomes 2010); i.e., they might believe in the myths of the scientific method and experimentation, while their viewpoints might be self-contradicting and inconsistent. An odd and inconsistent phenomenon was also observed among Taiwanese graduate students: "These students express different epistemological views on different dimensions. They hold moderate positions while discussing epistemological issues, but they adopt a firmly logical positivist views to address the issues relative to their research work." (Chang 1995).

Liang et al. (2008) built a quantitative instrument to assess preservice teachers' views about the nature of scientific knowledge development in terms of six aspects, based on Lederman's scheme as above. They later (2009) conducted an international collaborative investigation using the above instrument. It was found that Chinese teachers possessed higher scores on five of the six Likert sub-scales than their American counterparts, except for the most traditional one: "observation and inference". Weakness in foundational science concepts of science teachers has also been found by many Chinese researchers (Wan 2014; Zhang 2003).

Corresponding to the finding above that Chinese science teachers possessed higher scores in modern VNOS than their American counterparts, the targets of science teacher training programmes in China have tended to equip teachers with modern NOS conceptions, rather than the classic conception (Wei and Huang 2008; Shi and Liang 2008). There have been certain expectations that the most advanced modern values associated with the nature of science, derived from the Western, developed countries, would also benefit Chinese science education.

However, some determinants of this expectation becoming real have been neglected because the cultural backgrounds of learners affect their learning processes in science (Morrison et al. 2008) as found in various non-Western countries (Ogunniyi et al. 1995). In fact, many researchers have found that VNOS of students and teachers seems to be closely related to the culture contexts from which they come (Slay 2000; Peng and Knowles 2003; Wan et al., 2013b). Therefore, it has been advocated that focusing on cultural context is an important prerequisite for science teaching since science is a sub-culture of Western culture (Aikenhead 1996; Gaskell 2003). In particular, some scholars have suggested that the constructivist pedagogies originating from Western countries should be examined for their cultural appropriateness when they are used for science education in non-Western settings (Baker and Taylor 1995).

In recent years, the complicated relationship between Chinese traditional culture and the VNOS of the people has attracted the attention of many researchers. Ma (2009) found that Chinese people's understanding of the nature of science intertwines with their native belief system. She warned that, when introducing the modern VNOS into Chinese science classrooms, educators should consider whether it can be taught in the same manner in Chinese contexts. In particular, the traditional worldviews derived from Confucianism might have an impact on Chinese students' VNOS (Slay 2000). Based on in-depth interviews of 30 pre-service science teachers in China, Wan (2014) found that the pattern of VNOS of Chinese science teachers and students, as deeply rooted in Confucianism, could be recognized as an alternative conceptual framework to that of Westerners: many of them understand scientific concepts and theories largely using an accommodating tool within an inter-personal context; they had little appreciation of scientific objectivity, for they showed more interest in human relationships rather than exploring natural laws; and their perceived scientific communication and collaboration were similar to those of official meetings. Consequently, some Chinese scholars have argued that Chinese science education programmes should not adopt the "step-over" approach. Instead, they should follow the evolutionary rule by emphasizing the classic science concepts and beliefs before introducing modern ideas because modern science itself evolved and did not originated from Chinese culture (Zhang and He 2012). Thus, it has been said that the most urgent task for Chinese researchers is to create "a true, relevant, and affordable science curriculum for Chinese children" (Wei 2008). However, these arguments have not been supported by sufficient empirical evidence.

Therefore, considering the complexity of the Chinese teacher's VNOS caused by the unique culture, this study designs an instrument with separate scales for the classic and modern VNOS to answer the following questions: (1) What are the characteristics of Chinese science teachers' VNOS in terms of the structure of the classic and the modern views? (2) What factors are closely related to these characteristics, especially the effectiveness of teacher training programs? (3) How are these characteristics associated with teachers' performance?

Methods

Participants

A total of 2005 Chinese primary school science teachers were examined in a survey for this study in 2013. They were invited to complete questionnaires while they assembled for a local meeting about science education or professional training in 21 provinces and autonomous regions of China. The return rate of valid questionnaires reported by the local authority was almost 100%. In terms of the population, the total number of science teachers in primary schools in China was 173,505 in 2011, according to the Web site of CERNET (Chinese Educational Research Network).[2]

The prominent characteristics of the socio-demographic information of the teachers are their degree structure and the specialization structure, as presented in Table 1. Approximately two thirds of them have Bachelor's degree or above, and only approximately one fifth (21.5%) of them are graduates with STEM majors.

Table 1 Basic information about the participants

Variables	Demographics	n	Percentage
Gender	Male	701	35.4%
	Female	1282	64.6%
Age	< 20	35	1.7%
	21–30	498	24.8%
	31–40	832	41.5%
	41–50	528	26.3%
	> 50	112	5.6%
Training time	≤ 400 h	243	20.9%
	> 400 h	920	79.1%
Degree or certificate	High school	79	4.0%
	Junior college	642	32.2%
	Bachelor's degree	1229	61.7%
	Master's degree	41	2.1%
Title[a]	Senior teacher in middle school	91	4.8%
	Senior teacher in primary school	1041	55.0%
	First-grade teacher in primary school	677	35.7%
	Second-grade teacher in primary school	85	4.5%
Specialization of education	Arts and Humanities	553	28.0%
	Social Sciences	736	37.2%
	Natural Sciences, Mathematics, Computer Science, and Engineering	425	21.5%
	Others	262	13.3%

[a]The top rank is "senior teacher in middle school", although the teachers work in primary schools. The ranks from "senior teacher in middle school" to "second-grade teacher in primary school" appear in decreasing order

Instruments

The content of the questionnaires used in this survey had four parts.

Part one was about the demographic information of the participants, including gender, age, undergraduate education major, degree, training time for science education, and the title of the rank system for the teaching profession in China.

Part two was about the ability to apply knowledge of the NOS in daily life, which is a latent variable in this study. Instead of explicitly asking teachers for self-evaluations, all of the items in this part were presented in a situated format with single choices to improve validity, reflecting the difference between science and superstition, the consistency of scientific knowledge, the concept of evidence, and the concept of experimental control, which reflect basic and crucial concepts of scientific literacy.

For example, the question on experimental control was articulated as follows:

If the curative effect of a type of new drug for treating hypertension is doubted, which type of approach among the following will scientists adopt for further research?

[1] *Investigate the opinions of patients and then perform statistical analysis*
[2] *Conduct a questionnaire investigation of patients and doctors and then perform statistical and comparative analyses of data sets*
[3] *Judge the practical curative effects of the new drug with the latest theory of medicine*

[4]*Divide the patients into two groups: one group takes the new drug, and the other group takes the old drug; then, conduct comparative analysis*
[5]*I have no idea.*

Answering [4] is the only correct answer. The four questions of this part are entirely on this sub-scale, so the maximum score on this part is four, and the minimum score is zero.

Part three was about VNOS, which consists both the classic and modern VNOS sub-scales. Representative items of each dimension are shown in Table 2. The classic VNOS was critical in this study for increasing the validity of the measurements for the Chinese case, addressing the inconsistent phenomena mentioned above (Liang et al. 2009). With regard to the characteristics of Chinese teachers' VNOS according to previous findings, as stated above, four dimensions were used in this scale: the importance of observation; the unity of science; the objectivity of science; and communication and collaboration in science. The classic scale consists of 18 items on three-point Likert scale, which is a revised version of the questionnaire for an earlier national survey performed in 2003 (Zhang et al. 2016). The Cronbach's α was 0.48, which is slightly less than a normal psychological measurement. However,

Table 2 Descriptions and representative items of each dimension in the VNOS scale

Sub-scale	Dimension	Descriptions	Representative items
Classic VNOS	Importance of observation	Observation is a basic scientific method, which plays an important role in scientific exploration.	Detailed and thorough data analysis can offset the lack of an observation step in an enquiry (reverse scoring).
	Unity of science	Science is unified, there is a unified family of methodology involved in science.	If the history could be re-run, scientific knowledge might not be as it stands now (reverse scoring).
	Objectivity of science	Science seeks the objective truth.	As science continues to develop, scientific exploration will become increasingly closer to the truth.
	Communication and collaboration in science	Communication and collaboration is beneficial to scientists for keeping unbiased and creative.	To ensure that their findings are correct, scientists communicate with each other regularly.
Modern VNOS	Observations and inferences	Scientific knowledge development involves a combination of observations and inferences.	Scientists might offer different interpretations based on the same observations.
	Tentativeness	Scientific knowledge is tentative and subject to change.	Scientific theories could be completely replaced by new theories in light of new evidence.
	Scientific theories and law	Scientific theories and laws are functionally different types of scientific knowledge.	Scientific laws are theories that have been proved (reverse scoring).
	Social and cultural embeddedness	Scientific knowledge is socially and culturally embedded.	Scientific research is not influenced by society and culture because scientists are trained to conduct pure, unbiased studies (reverse scoring).
	Creativity and Imagination	Scientific knowledge development involves human imagination and creativity.	Scientists use their imagination and creativity when they collect data.
	Scientific methods	Scientific knowledge development involves the use of diverse scientific methods.	Scientists use different types of methods to conduct scientific investigations.

this phenomenon is quite common in the measurement of scientific literacy (Kim and Nehm 2011), especially in non-Western countries. For example, a study in Vietnam found that a Western assessment tool became less effective in an Eastern context because of the different epistemology and philosophy (Thao-Do and Yuenyong 2015). In this study, the unsatisfactory reliability might also have been caused by individuals' confused ideas about the nature of science. In addition, since the real utility of the data in this study is to investigate the performance of teachers in groups with large sample sizes, rather than to assess individual teachers, the internal consistency coefficient does not matter (Fosnacht and Gonyea 2012).

The modern VNOS scale with 23 items is a five-point Likert scale adapted from Liang et al. (2008), which has demonstrated satisfactory validity and reliability. This scale is based on Lederman's interview framework containing six dimensions: observations and inferences; tentativeness; scientific theories and laws; social and cultural embeddedness; creativity and imagination; and scientific methods. The Cronbach's α for our sample is 0.71, which is higher than in the study by Liang et al. (2009).

In addition, with regard to the validity of these scales, we consulted with three distinguished scientists at Nanjing University for a consensus (Two of them are academicians in physics and the other is an oceanographer trained in the UK with a Ph.D.).

Part four concerns the ability of teachers to apply VNOS in classroom teaching focusing on their attitudes towards and actions regarding the implementing of inquiry learning, which is also treated as a latent variable including five items. Considering social acquiescence responses, which prominently appear in East Asian countries (Smith 2004), the items in this sub-scale implicitly reveal whether teachers have applied inquiry learning in their classroom teaching processes, instead of explicitly asking them for self-evaluations. For example, "Do you set a time limit for children to complete activities/hands-on learning?" The four choices for answers are "always; often; very rare; and never", scored from 1 at the lowest to the 4 at the highest.

Data analysis

After the primary descriptive statistics of participants' VNOS, cluster analysis was used to group teachers with similar VNOS into one cluster. Based on the features of different VNOS mentioned in the literature review, teachers could be attached to a cluster based on their performance on both the classic and modern VNOS scales. However, the classic VNOS scale has 3 points, while the modern has 5. To integrate them into the same analysis, Z-score normalization[3] was applied. Since the data set of this survey was very large, K-means clustering was chosen, with the number of clusters assigned in advance. In the subsequent step, the chi-square test, as well as the contingency coefficient, was used to analyse the differences in the teachers' socio-demographic characteristics among the groups. Finally, MANOVA was conducted to reveal group disparities in their abilities to apply the knowledge of the NOS in daily life and in classroom teaching. For this purpose, ANOVA was performed as the first step to test the group differences, and then Tukey's HSD was used for post hoc comparisons of the particular variables among the groups.

Results

Descriptive statistics of teachers' VNOS

Descriptive statistics was performed to demonstrate the teachers' VNOS for each NOS dimension (see Table 3).

The data in Table 3 show that the disparities among the dimensions in modern VNOS are obviously larger than those in classic VNOS, and the teachers' scores for classic VNOS were slightly higher than those for modern VNOS. However, the basic dimensions concerned with observation (importance of observation; observations and inferences) in both the classic and modern scales remained quite low. In addition, the dimension of understanding scientific communication and collaboration had the lowest score in the classic VNOS (2.25). Contradictions were also significant; e.g., while they had the highest score in the dimension of "tentativeness" (4.06), they possessed the lowest score in that of "scientific theories and law" (2.76).

Characteristics of Chinese teachers' VNOS: Group diversity

To determine the characteristics of Chinese teachers' VNOS, the cluster analysis technique was used. A four-cluster result was then obtained using the scores for both the classic and modern views on the NOS with 1507 valid samples (Fig. 1). The first group showed comparatively lower scores on both the classic and the modern VNOS scales. Therefore, it was labelled the Ambiguous VNOS Group (shortened to AG, $n = 338$, 22.4% of the total 1507). The second group scored the lowest on the classic VNOS scale, but it scored above average on the modern VNOS scale. Without the foundation of classic science concepts, high scores on the modern VNOS scale were assumed to be unreliable. Based on a previous study, as presented in the literature review, it could be inferred that teachers in this group were significantly influenced by the post-modernist VNOS denying classic science conceptions, which is thus labelled the Post-modernist VNOS Group (shortened as PG, $n = 282$, 18.7% of the total). The third group was characterized by the highest scores on the classic VNOS scale and below average scores on the modern VNOS scale, so it was subsequently called the Classic VNOS Group (shortened as CG, $n = 382$, 25.3% of the total). Different from these three groups, the fourth group possessed above average scores on both the classic and

Table 3 Descriptive analysis of teachers' VNOS on each dimension

Sub-scale	Dimension	Mean(percent[a])	SD
Classic VNOS	Importance of observation	2.33 (77.67%)	0.37
	Unity of science	2.40 (80.00%)	0.39
	Objectivity of science	2.44 (81.33%)	0.49
	Communication and collaboration in science	2.25 (75.00%)	0.47
Modern VNOS	Observations and inferences	3.31 (66.20%)	0.76
	Tentativeness	4.06 (81.20%)	0.85
	Scientific theories and law	2.76 (55.20%)	0.63
	Social and cultural embeddedness	3.42 (68.40%)	0.74
	Creativity and Imagination	3.27 (65.40%)	0.97
	Scientific methods	3.79 (75.80%)	0.75

[a]Since the classic and modern scales are different in scoring methods (3 points and 5 points), conversion was performed to obtain a unified centesimal system

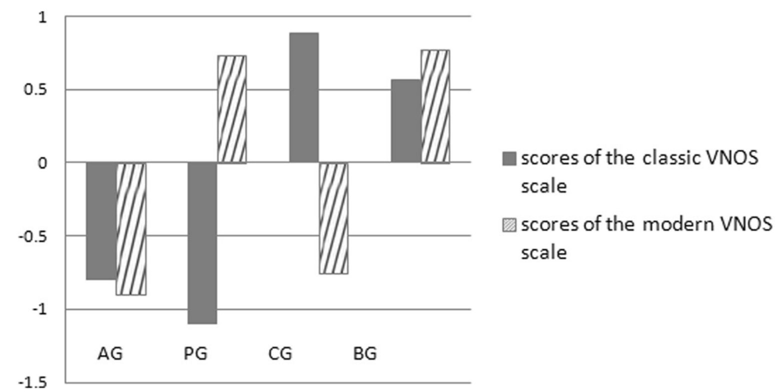

Fig. 1 Four groups of teachers in terms of both the classic and modern VNOS

modern VNOS scales, so it was labelled the Modern VNOS Group (shortened as MG, $n = 505$, 33.5% of the total), indicating the most advanced level of VNOS. Teachers in this group largely not only viewed scientific knowledge as based on observations of the natural world, but they also criticized and reflected on the limitations of scientific conduct to improve it; e.g., they may believe that science aims to be objective and precise, but subjectivity in science is difficult to avoid. This type of VNOS is certainly beneficial to the healthier development of science and science education, rather than completely de-constructing it as post-modernists would.

Relationships between socio-demographic factors and group diversity

No significant differences were found in gender, age, degree or certificate of education or educational specialization amongst the four groups according to the Chi-square test. However, there were significant differences in training time ($X^2 = 10.57$, $p < 0.01$; $C = 0.11$, $p < 0.01$) and the title ranks of the four groups ($X^2 = 16.94$, $p < 0.05$; $C = 0.11$, $p < 0.05$), for which Figs. 2 and 3 show more detailed information about cluster composition.

In particular, the teachers in the MG represented the greatest proportion (32.3%) who participated in more than 400 h of training (Fig. 2). Unexpectedly, the teachers in the CG

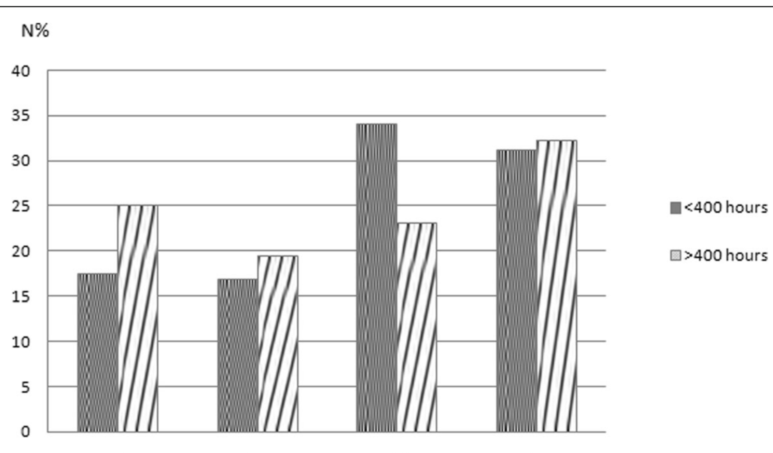

Fig. 2 Training time differences in cluster composition of the four groups

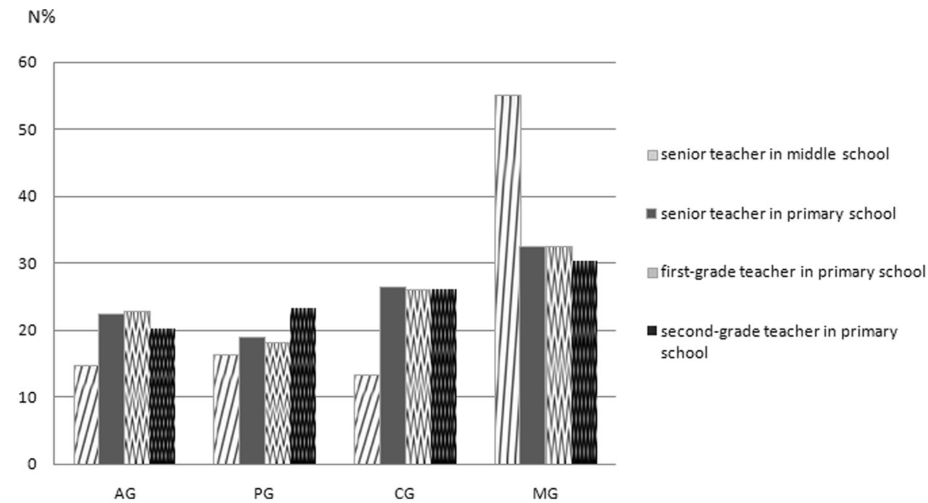

Fig. 3 Teacher's title differences in cluster composition

represented the largest proportion (34.1%) who participated in less than 400 h of training, with only 23.1% of them trained for more than 400 h. In contrast, the AG constituted 25.1% of teachers trained for more than 400 h, while only 17.6% had less than 400 h. Similarly, 19.5% of teachers in the PG had been trained for more than 400 h, while 17% of teachers trained for less than 400 h. In addition, the T-test proved that the classic VNOS score decreased with the increase in training time ($T = 2.859$, $p = 0.004$), while the modern VNOS score increased with the increase in training time ($T = -2.182$, $p = 0.029$) (Zhang et al. 2013).

In terms of the title rank, more teachers in the MG had the "senior teacher in middle school" title, which was the highest rank, than all of the other groups (Fig. 3). Strangely enough, the CG, instead of the AG or PG, possessed the lowest proportion of the teachers with the highest rank.

Group diversity in teachers' performance and training time

The differences among the four groups in terms of teachers' ability to apply knowledge of the NOS in daily life and in classroom teaching were analysed by means of MANOVA. The disparity in training time was also analysed. The values of training time were recoded and simplified (1 indicates that the training hours (T) are less than 100 h; 2 indicates $100\ h \le T < 200\ h$; 3 indicates $200\ h \le T < 300\ h$; and the pattern continues.) These three variables can also be used to prove the external validity of cluster analysis, as below. The results are displayed in Table 4.

Table 4 NOS knowledge application ability and training time for each group

Variables			AG		PG		CG		MG	
	F	Sig	Mean	SD	Mean	SD	Mean	SD	Mean	SD
The ability to apply VNOS in daily life	14.138	< .001	2.76	1.22	3.06	1.17	3.04	1.16	3.27	1.00
The ability to apply VNOS in teaching	5.036	0.002	10.82	2.03	10.61	2.04	11.21	2.14	10.78	2.15
Training time	3.74	0.011	6.86	2.75	6.65	2.91	5.93	3.34	6.50	3.00

The results of post hoc comparison analysis of VNOS implementation in daily life revealed that teachers in the MG scored the highest in this ability (Mean = 3.27) with statistical significance, with scores higher than in the AG (Mean = 2.76, $p < 0.001$), CG (Mean = 3.04, $p < 0.05$) and PG (Mean = 3.06, $p < 0.10$). Consistently, the scores for this type of ability in the AG were significantly lower (Mean = 2.76) than those in the PG (Mean = 3.06, $p < 0.01$), CG (Mean = 3.04, $p < 0.01$) and MG (Mean = 3.27, $p < 0.001$). The difference between the PG and CG was insignificant, however (t = 2.26; $p > 0.05$). In terms of the ability to apply VNOS in teaching, there were similar significant group differences as well. Moreover, the group of teachers possessing the highest scores in the ability to apply VNOS in teaching were the CG (Mean = 11.21), instead of the MG, and these scores were significantly higher than those of the PG (Mean = 10.61, $p < 0.01$), MG (Mean = 10.78, $p < 0.05$) and AG (Mean = 10.82, $p < 0.10$), although it was the group possessing the smallest proportion of teachers with the highest rank of professional title, as shown in Fig. 3. In short, the scores of NOS knowledge application in both daily life and classroom teaching increased or stayed the same from the AG, PG, and CG to the MG successively, and the differences between the groups were statistically significant.

Discussion

The purposes of this study were to investigate the current situation of Chinese science teachers' understanding of the NOS and to diagnose the possible influencing factors to improve the pertinence and effectiveness of training programmes for them.

The situation of Chinese teachers' VNOS seems to improve according to the scores for VNOS in the classic conceptions, compared with the findings of previous research (Zhang 2003). While the scores of modern VNOS were a little bit lower than those of Liang et al. (2009). The sample of this study was nine times larger than that of Liang et al. (2009), including teachers from less developed areas in China. Thus, the score of this study might be more representative, showing the level of the whole nation. Besides, the participants scored higher in the tentativeness aspect and lower in the theory and law aspect, which was similar to the findings of Liang et al. (2009). However, the basic dimensions concerned with observation, in the context of either classic or modern, remained problematic. Contradictions also appeared in their concepts of the nature of science.

To detect the different situation of the integration of the classic and modern VNOS in various combinations, the cluster analysis technique was applied, and four different groups of Chinese science teachers' VNOS were identified. The Ambiguous Group consisted of 22.4% of the total participants, the Post-modernist Group consisted of 18.7%, the Classic Group consisted of 25.3%, and the Modern Group consisted of 33.5%.

Possible developmental connections among the four groups were explored preliminarily by their associations with the socio-demographic variables and the variables of "the ability to implement VNOS in daily life" and "the ability to implement VNOS in classroom teaching". In terms of the socio-demographic variables, significant differences existed only in "training time" and "title rank of teaching profession", rather than as conventionally expected in "educational degree" or "specialization". Astonishingly, the variables of training time and title rank exerted a negative influence on teachers' VNOS development. More precisely, the AG and PG experienced more training time than the other two groups, although the MG on average had been trained for longer than the CG. In addition, it was the CG, rather than the AG or PG, that possessed the lowest proportion of teachers with the highest rank or professional title, indicating a discouraging promotion policy for teachers in the CG, who performed the best in classroom teaching among the four groups. Although there have been many cases of unfairness in the Chinese teacher promotion system, there has not been a systematic approach to this issue.

In terms of the ability to apply knowledge of the NOS in teaching, it was the CG, rather than the MG, that performed the best, with statistical significance. Researchers have found that the influence of teachers' NOS conceptions on teaching practice can vary from one VNOS to another. Some NOS conceptions are reflected more explicitly in teaching than others. For example, a teacher who has a better understanding of the empirical nature of scientific knowledge might place greater emphasis on asking students to base their explanations on scientific evidence (Atar and Gallard 2011). This study supports these findings to some extent. In terms of the ability to apply VNOS in daily life, the MG had the best performance, while the AG performed the worst among the four groups despite the differences between the congenial CG and PG being insignificant statistically ($p > 0.05$). In general, except for a little uncertainty concerned with the comparison between the CG and MG, the scores for NOS knowledge application in both daily life and classroom teaching increased or remained unchanged from the AG, PG, and CG to the MG, and the differences between the groups were statistically significant.

As inferences, the findings first demonstrated the patterns of Chinese teachers' development of VNOS as follows.

In terms of the ability for NOS knowledge application in daily life:

$$\mathrm{AG} \le \mathrm{PG} \le \mathrm{CG} \le \mathrm{MG} \tag{1}$$

In terms of the ability for NOS knowledge application in classroom teaching:

$$\mathrm{AG} \le \mathrm{PG} \le \mathrm{MG} \le \mathrm{CG} \tag{2}$$

Second, the findings also demonstrated the following pattern of teachers' participation time in their in-service training:

$$\mathrm{AG} \ge \mathrm{PG} \ge \mathrm{MG} \ge \mathrm{CG} \tag{3}$$

The patterns above show that the AG and PG performed worse than the other two groups, although they were trained longer than the other two. On the one hand, it could be inferred from the longer training time that the AG and PG are indeed "disadvantaged groups", which required more training and improvement. On the other hand, it might be inferred that the training made no sense or even had a negative influence on these teachers' VNOS.

The bad performance of the PG also proved that high scores on the modern VNOS scale might be illusory for many teachers in the Chinese context, which could be justified by their contradictory conceptions of the NOS shown above. More fundamentally, Chinese teachers did not experience real, traditional scientific inquiry at all during their normal university undergraduate study (Zhang and He 2012) or in-service training programmes. They also did not experience scientific communication with classmates or colleagues to formulate a theory based on observations or argue using reasoning and logical consequences in a democratic atmosphere. Scientific knowledge was always infused in them by their teachers when they were students. Therefore, the pictures of modern science in the minds of Chinese and western teachers are essentially different. When a Chinese teacher criticizes the objectivity aspect of science, it might not mean that his/her understanding is the same as that of a western teacher. The attempts of the anti-science post-modernists first emerged in Western countries to remedy the negative influence of rapid economic development stimulated by science and technology through reflection on science. However, the motivations of the anti-science group in China are either blindness or narrow-minded nationalistic defences against imported modern science or even post-modernism gained from traditional Chinese philosophy, which emphasizes human orders over natural laws. Thus, if Chinese teachers have not obtained sound basic science concepts by conducting genuine scientific inquiry, they could not have any real understanding of modern science, although they might earn high scores in assessments.

Thus, the development patterns of Chinese science teachers' understanding of the NOS, as indicated by the findings of this study, could be described as double-modes, as shown in Fig. 4. Most of them are in Mode A, and at least 18.7% of them are in Mode B. Mode A is a normal development process that conforms to the history of science and the history of science teacher training in developed countries. Mode B contains an outlier in the trend, which could be a consequence of the integrated impact of western modern and post-modern ideas and Chinese traditions. The imported radical post-modernism which completely denies objectivity is more likely to have resonance in Chinese traditional culture, which exaggerating the subjectivity and asserting "anything goes" (Liu et al. 2009). Therefore, for teachers possessing Chinese post-modern VNOS in the sense of Mode B, it is necessary to remedy the course of classic nature of science for them to get back on a normal track, avoiding of relativism, irrationalism and even anti-scientism.

However, we must indicate that scholars have controversial ideas on the definition of post-modernist VNOS due to its complexity, which range from the mild to the harsh. Post-modernism, in this study, refers to the extremely radical one completely denying objectivity of scientific observation and inductive reasoning. The interpretation of our findings as above is not only based on our inferences, but also on the previous literatures which include those of Chinese cognition on science. For example, R. Nisbett (2005) conducted systematic study of Chinese cognitive character and found that Chinese people in general have different cognitive styles from westerners in the field of science in that they do not regard nature as objectivity that exists independently, which

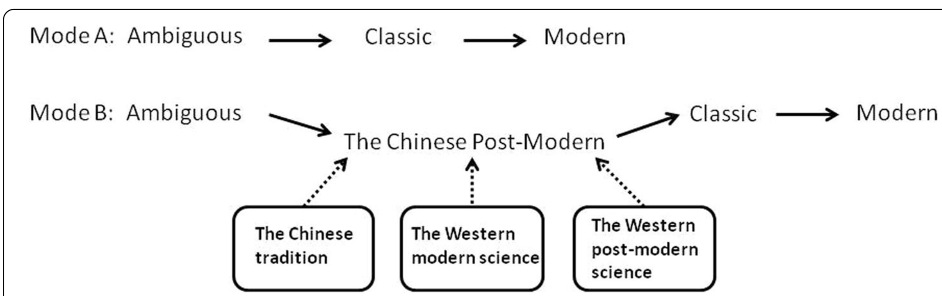

Fig. 4 Development patterns of Chinese science teachers' VNOS

is more likely to have resonance in western radical post-modernism rather than modernism. Chinese post-modern VNOS features in relativism, irrationalism and even anti-scientism in form of Chinese rhetoric, so it might be inappropriate to name "post-modernism" as in the western world; we could call it "radical constructivism". But considering that this paper not only refers to styles of students' cognition and teachers' teaching methods, but also relates to the development process of various views on nature of science, we temporarily still choose to call it "post-modernist VNOS".In fact, while classic concepts such as "observation" and "objectivity" to define the NOS to teachers or students are used in the USA, it is certainly problematic, and the bad consequences could damage the democratic tradition in the USA. In contrast, if they are used in China, it is different because they are more suitable to the needs (not wants) of Chinese teachers. In contrast, if Chinese teachers ignore the basic concepts of science and skip over to post-modern ones, the consequences could cause the society retreating into a foolish, irrational, savage stage. Just as Good and Shymansky (2001) proclaimed, "novices do not and should not be expected to grasp the complexities before they understand what sets science apart from other ways of knowing; that is, it essentially rational, progressive, universal nature."

The above inferences are also based on the theory of educational recapitulation originating from the theory of recapitulation in life science, which holds that, as individuals' cognition develops, individuals repeat the evolutionary history of the human race (Armitage 2007), although the nature of the changes in the development process might be interpreted differently (see Haaften 2007). With regard to the pedagogical significance of the recapitulation approach, the child should trace and follow the progress of humankind's evolutionary history. In other words, a lower level of the educational stage should be the prerequisite for entry to a higher stage without skipping or reversal (Zhang and Foskett 1998). Therefore, Frank and Feigl, as well as Matthews (1994), argued that the history and philosophy of science should be part of the curriculum for all science teachers, which would be more suitable for Chinese teachers. Indeed, history is the best tool to understand a concept that has developed within it.

In the field of science education, some empirical research has indicated that an individual's learning process of the concepts in science is parallel to the history of science (DiSessa 1982; McCloskey 1983; White 1983). This idea can also be supported by the logical similarity between the genetic epistemology of Jean Piaget and the theory of scientific revolutions of Thomas Kuhn (Fig. 5). Thus, J. Dewey once argued that even the basic knowledge that modern man took for granted needed to be discovered and recognized for the first time (see Fallace 2012).

Chinese teachers training programmes should be in accordance with the successive order of the history of science and the history of science teacher training practices, and the content of the programme should start with the classic conception and then progress to the modern version. In short, a "step by step" mode could be more effective.

Another rationale for not including the most advanced content, which yielded post-industrialized society, is that the Chinese teachers are living in a pre-industrialized society. It is important to equip in-service teachers with VNOS coinciding with their level of understanding. Without the foundation of classic science concepts and beliefs, too much emphasis on post-modernist ideas can possibly lead to radical deconstructive ideas. Therefore, the classic VNOS ought to be regarded as a developing VNOS, rather

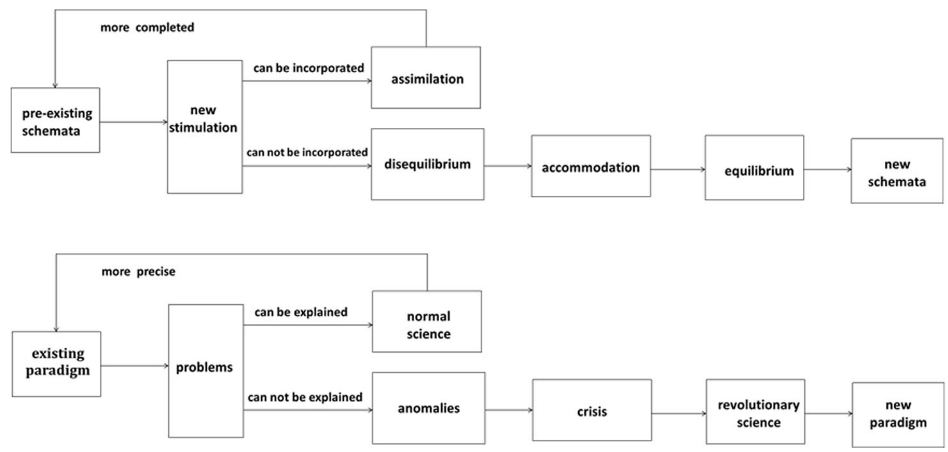

Fig. 5 Comparison of the patterns of the theories of J. Piaget and T. Kuhn (Shi 2006)

than an outdated one. Whether a teacher has adequate views about nature of science should not be judged only by their scores on modern VNOS scales without considering their classic concept level. Simply saying that scientific knowledge is tentative or subjective without any defining conditions is not the consensus idea of the majority of the scientific community. This type of saying expresses little about the nature of scientific knowledge specifically, but rather about the nature of cognition in general (Dijk 2013).

Conclusions

Chinese science teachers in primary schools belong to different groups according to their scores on classic VNOS and modern VNOS scales. The best performers in daily life and classroom teaching are teachers from the MG and CG, rather than those with post-modern conceptions of the nature of science.

There could be two modes of development pattern of teachers' VNOS. One mode is consistent with the history of NOS, similar to that in Western countries; the other contains the outlier "Chinese post-modern VNOS" before the solid classic VNOS has been established, resulting from "step-over development". Consequently, it is suggested that Chinese science education, including teacher training, places greater emphasis on the classical nature of science, such as the importance of observation and the objectivity of data collection, before incorporating any modernist perspectives into the curriculum, given the special Chinese idealistic and metaphysical tradition, from which modern science did not originate, and the late-developmental nature of the society. A balance should be cautiously maintained in China between introducing the advanced American model of science teachers' professional development theory and practice and the classic conceptions of science as an objective and truth-searching endeavour.

Another obvious suggestion derived from this study would be to update the uniform training programmes for teacher training to fit their characteristics regarding views on the NOS. For the approximately 40% of teachers in the Ambiguous Group and Post-modernist Group who lack the classic concepts and beliefs of science, training programmes should start from the very beginning of the development course of modern science, i.e., the classic concepts, because if trainees are exposed to too many of the concepts of dialectical relativism without a solid foundation in objectivist conceptions, they can easily slip into the radical post-modernist VNOS.

Moreover, the issues concerned with the Post-modernist group in this research might also be meaningful to developed countries in addressing the problem of "the global nature" of pervasive misconceptions about the nature of science among citizens and teachers (Miller et al. 2006).

One obvious limitation of this research is the lack of samples from the West for comparison. Future research should compare the four groups of teachers' VNOS in China with their counterparts in Western countries to validate their levels of VNOS so that the relationships of VNOS with social background and other abilities could be clearer. Another limitation was the instruments, i.e., scales should have included more items to improve their validity and reliability and some interviews should have been done for complement with the questionnaire survey approach.

Endnotes

[1]Scholars have controversial ideas on the definition of post-modernist VNOS due to its complexity. The post-modernist VNOS in this study refers to the extremely radical one.

[2]http://www.edu.cn/jcjy_9453/ Retrived in 2014,8,8.

[3]Z-score normalization is also called zero-mean normalization. The values of variable X are normalized using the mean and standard deviation of X. A new variable X* is obtained using the following formula:$X^* = (X-\mu)/\ \sigma$where μ is the mean of X, and σ is the standard deviation of X.

Abbreviations

AG: Ambiguous VNOS Group; CG: Classic VNOS Group; MG: Modern VNOS Group; NOS: Nature of science; NTTP: National Teacher Training Project; PG: Post-modernist VNOS Group; VNOS: Views on nature of science

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Availability of data and materials

The data used in this study is part of the dataset that we got in 2013. We agree to share our data to someone who needs it and submit our data to your journal.

Authors' contributions

The first two authors, QL and HZ, have made substantial contributions to the idea of this study and drafted the manuscript. The third author, BW, has provided advice on the entire research study. All of the three authors approved the final manuscript.

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Competing interests
The authors declare that they have no competing interests to report.

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