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COMPARATIVE RESEARCH ON THE UNDERSTANDINGS OF NATURE OF SCIENCE AND SCIENTIFIC INQUIRY BETWEEN SCIENCE TEACHERS FROM SHANGHAI AND CHICAGO

Jingying Wang,
Ying Zhao

Abstract. *Nature of science is considered to be an important component of scientific literacy, and understanding the nature of science is advocated as an important goal of science education. Scientific inquiry is regarded as the core of curriculum reform, which has become the consensus of the international K-12 science education, as well as a scientific direction for which educators have been striving over the last century. To compare the views of nature of science and scientific inquiry of teachers between China and United States, 90 high school science teachers from Shanghai and Chicago are chosen to do open-ended questionnaires and interviews. By conducting the sequential mixed method and using the empirical investigations of VNOS-D and VOSI-S, their different understandings mainly perform in the specific aspects of nature of science and scientific inquiry, cognitive stages, types and relationships etc. Overall, the level of American teachers' views of nature of science and science inquiry are better than Chinese. Finally, some suggestions on Chinese science teachers' education are proposed.*

Key words: *epistemological belief in science, nature of science, scientific inquiry.*

Jingying Wang, Ying Zhao
Capital Normal University, People's Republic of China

Introduction

The construct "nature of science" (NOS) and "scientific inquiry" (SI) are eternal topics in the domain of international science education, and at a general level, understanding the NOS and SI is often defended as being a critical component of scientific literacy (Lederman, 2007). Epistemological belief in science refers to the characteristics of scientific knowledge and perceptions of knowledge or development process (Elder, 2002), which belongs to a personal scientific philosophy belief. Epistemological belief in science is developed through the prism of history (Kalman, 2009). With the dialectical evolution of philosophy of science, and blending the view of history, sociology and psychology, the modern epistemological belief in science, focuses on the social and cultural aspects of scientific knowledge, distinctive with traditional logical positivism's point of view, and states the process of the real scientific research and the value in the perspective of sociology (Abd-El-Khalick & Lederman, 2000). Teacher's epistemological belief in science mainly includes the understandings of NOS and SI.

NOS typically refers to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development (Lederman, 1992). NOS not only enjoys a high status in scientific theories, but also has an important influence on the development of science and the real life. The role of NOS is mainly manifested in the following issues: To promote the learning of science content, help to understand science, develop students' interests in science, strengthen scientific decision-making, and help to impart scientific knowledge (McComas, Clough & Almazroa, 1998). NOS is a scientific judgment criterion, and the basis of the judgment about whether scientific development is reasonable or credible and the scale of distinction between science and pseudoscience. It affects people's views of science directly, to guide people's scientific activities and daily behaviors. It

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is an important component of scientific literacy. Most recently, NOS has been advocated as a critical educational outcome by various science education reform documents worldwide (Lederman, 2007).

NOS refers to the characteristics of scientific knowledge and the development of relevant values and beliefs, while SI refers to the characteristics of the development process of scientific knowledge (Lederman, 2006). The interpretation of contemporary philosophy of science on characteristics of scientific knowledge' development argues that scientific knowledge is temporary, contemporary significance, and changing to the situation, and they regard science as one of the processes of human to pursue knowledge (Abd-El-Khalick & Lederman, 2000). Science and other actions in thoughts are equivalent to explore the world of human activities such as economic, society, culture, religious, and has the interactive relationship between each other. With the progress of the science education standard in the United States, the international K-12 science education research gradually suggests that the process of development of scientific knowledge will help students to understand and generate scientific knowledge, which means to improve students' understanding of NOS would benefit to SI, and situational and procedural meaning of SI has pushed forward the study on epistemological belief in science. Since the 1970s, China has begun to introduce inquiry teaching and regard it as the critical goals of the eighth K-12 curriculum reform from 2001. With the development of international science education reform, the connotation of SI has evolved, resulting in great change of the value orientation of science education, as well as the whole paradigm of science education. SI is not only the pursuit of science education in China, but also an inevitable development direction. Today's dynamic scientific philosophy believes that science is an endless process of exploration, and SI means to establish an important method and the process of scientific concepts, rules, principles, theories, as well as its own situational and procedural dynamic characteristics. During science teaching, teachers not only need to ask students for learning scientific knowledge, but also have a duty to develop students' basic skills and thinking methods during the process of the scientific knowledge (Cavas, 2012). As an implementer of inquiry teaching, science teachers' views of NOS and SI could directly affect their classroom teaching and students' learning.

Literature Review

NOS has been advocated as an important goal for students studying science for more than 100 years (Central Association of Science and Mathematics Teachers, 1907). The research on the views of NOS is mainly divided into four issues: Teachers and students' understandings of NOS and its test with improvement methods; Curriculum research and development, application and evaluation to improve students' understandings of NOS; Method to improve teachers' understanding and their teaching; (4) The relationship among teachers' understandings of NOS, classroom teaching, and students' understandings of NOS (Lederman, 2007). Considering the longevity of objectives related to teachers' conceptions of NOS, the first assessment was developed by Anderson in 1950. From 1960s-1980s, many researchers used survey questionnaires of NOS, interviews and other methods in their study. The results of the initial research on teachers' understanding about the NOS shows science teachers do not possess adequate conceptions of NOS, irrespective of the instrument used to assess understandings (e.g. Behnke, 1961; Miller, 1963; Schmidt, 1967; Billeh & Hasan, 1975; Blakely, 1987).

Since investigation and study results of science teachers' understanding about the NOS are quite worried, American researchers have dedicated to the research on "how to promote teachers' understandings of NOS". With the intermediary media application such as the curriculum design, teachers have better understandings of NOS (Palmquist, 1993). In general, these studies have used two similar ways to the teaching strategies, one is the implicit method, which is teaching the NOS by "process-skill", science content and the way of "learning by doing" to promote teachers' learning. The researchers use this method to take advantage of the teaching on scientific process skills or inquiry activity or certain learning environment. Another kind of method is the explicit one which is the reflective activity to promote teachers' understandings of NOS and introduce NOS with an explicit way. It also provides an opportunity for self-examination when they participate in scientific activities or learning content, to help teachers clearly express their understandings of NOS (Lederman, 1992; King, 1991). The difficulties they encountered in the teaching practice are as follows: firstly, the insufficiency or imbalance of science teachers' understandings of NOS. The knowledge about NOS depends on personal experience of science research and requires knowledge background of philosophy of science, the history of science and sociology, which shows high demands on teachers (Lederman, 1992); Secondly, teachers have no ideas on how to use courses to achieve specific objectives. What they need is not only the end of the course, but also the map to get there, which is the guidance of teaching practice (Matthews, 1998); Thirdly, the shortage of curriculum resources, such as supporting teaching materials. Even if the corresponding view existed in the content of teaching material, it is still incomplete or even incorrect (McComas et al., 1998). After more than 50 years of research related to assessing and improving teachers' conceptions of NOS, a generalization can be justified: techniques to improve teachers' conceptions have met with some success when they have included either historical aspects of scientific knowledge or direct, explicit attention to NOS.

The history of the assessment of NOS mirrors the changes that have occurred in both psychometrics and educational research design over the past few decades (Lederman, 2007). The first formal assessments, beginning in the early 1960s (Cooley & Klopfer, 1962), emphasize quantitative approaches. Within the context of the development of various instruments, some open-ended questions are involved in the construction and validation of items, and the representative research comes from Lederman (1990). He refers to the fact that the NOS is epistemology, a way to get knowledge, or senses of worth and beliefs that consistent with the development of scientific knowledge. There is an acceptable level of generality regarding NOS that is accessible to K-12 students and relevant to their daily lives that can be found in the writings of the comments of Elby and Hammer (2001) and Rudolph (2003). Moreover, at this level, little disagreement exists among philosophers, historians, and science educators. Among the characteristics of scientific knowledge corresponding to this level of generality are the analysis framework of NOS in seven aspects: scientific knowledge is tentative (subject to change), empirically based (based on and/or derived from observations of the natural world), and subjective (involves personal background, biases, and/or is theory-laden); necessarily involves human inference, imagination, and creativity (involves the invention of explanations); and is socially and culturally embedded. Two additional important aspects are the distinction between observations and inferences, and the functions of and relationships between scientific theories and laws (Lederman, 2007). Scientific inquiry is systematic orientation in problem solving that scientists are seeking, and its analysis framework covers eight aspects: Scientific investigations all begin with a question, but do not necessarily test a hypothesis; No single set and sequence of steps followed in all scientific investigations; Inquiry procedures are guided by the question asked; All scientists performing the same procedures may not give the same results; Inquiry procedures can influence the results; Research conclusions must be consistent with the data collected; Data is different from evidence, and evidence is the data which supports a particular inference; Explanations are developed from a combination of collected data and what is already known; An investigation involving the manipulation of variables so that a hypothesis can be tested and causal relationships can be determined (Lederman et al., 2006). Although scientific inquiry is deeply connected with scientific process, scientific inquiry is not only the development of process skills, which also includes observation, inference, classification, speculation, measure, questioning, interpretation and data analysis, etc. (Wang, Guo, & Jou, 2015). Traditional scientific process is included in scientific inquiry, but also includes the fusion of the process and its interaction with scientific knowledge, scientific and rational, and critical thinking, which leads to the production and development of scientific knowledge.

In fact, science is something exotic in China, the idea of the NOS and SI also comes from the western countries, especially from the United States. After approximately 50 years of research related to students' and teachers' views of NOS, what follows is just a few of the critical lines of research that need to be pursued (Lederman, 2007), primary importance of which is the research for the teaching of NOS across cultures. Although much research on individuals' worldviews has been pursued (e.g. Cobern, 2000), such research has rarely been directly and systematically related to views on NOS or SI. Views of NOS and SI may be a subset of one's worldview or at least affected by one's worldview. Teachers' understandings of NOS and SI directly affect their scientific teaching and cognitive development of personal epistemology.

So far no direct comparative research on views of NOS and SI held by science teachers from China and United States has been conducted, an cross-national study aiming to identify the differences of science teachers' views of NOS and SI are quite important.

Research Methodology

General Characteristics of Research

What happens when there is a clash between one's cultural views and the views expressed in western-influenced depictions of NOS and SI? To answer this question, a sequential mixed method is conducted to investigate the differences and cognitive stages of views of NOS and SI held by science teachers from Shanghai and Chicago, as well as the correlation and cultural differences between two kinds of scientific understanding. Standardized paper-and-pencil assessment is composed of multiple-choice questions in the form of closed-ended items, which

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could conclude the understanding of specific aspects of NOS from the existed questions to improve their teaching strategy. If a researcher wants to know more about participants' cognitive types of NOS or SI, such as cognitive types, stages and relationships, standardized tools with multiple choice questions will have some limitations. Supplementary survey tools with open-ended questionnaires and follow-up interview should be needed. Based on the scoring guide for participants' views of NOS, open-ended questionnaires (VNOS-D, View of Nature of Science, the version D and VOSI-S, View of Scientific Inquiry, version S) and follow-up interview are conducted to collect data. These two instruments are designed to be used in conjunction with follow-up interviews, and each of the seven and five open-ended questions focuses on different aspects of NOS and SI. Although VNOS and VOSI have been widely used with excellent reliability and validity (Lederman, 2007), it takes a long time to conduct the sampling process, questionnaires distribution and response, interview, data collection and coding, data analysis and mining in Shanghai and Chicago from Oct. 2012 to Dec.2014.

Sample Selection

Based on the principle of typical sampling of participants' selection, Chinese teachers are chosen in Shanghai, American teachers in Chicago, as well as 45 high school teachers of each city equally selected. The sampling process takes the two critical factors (cities and schools) into consideration. It is common that imbalances of educational resources exist in the same city, as well as in different cities among developed countries and developing countries. Therefore, two central cities, Shanghai and Chicago are selected as appropriate samples for comparison. Shanghai is the business center and one of the three largest cities in China as well, while Chicago is the second commercial center and the third metropolis after New York and Los Angeles in United States. The second factor for consideration is locations of selected schools. In China, schools closer to the city center usually have better qualities than those located in remote rural areas, which is different in the United States. With the principle of convenience, basic characteristic like sampling city, school type, grade and other aspect are kept the same. 5 high schools are chosen in Shanghai and Chicago respectively, with 4-5 science teachers in one school selected in both demonstrative and average schools distributed in rural and urban areas.

Instrument and Procedures

Open-ended questionnaires of VNOS-D and VOSI-S and follow-up interview are used in this study. VNOS-D has seven questions based on the theory of NOS proposed by Lederman, involving five aspects of tentative, observation and inference, subjective, tentativeness and empirically based which is easier to be accepted by teachers and students in K-12 science curriculum. Two additional abstract aspects are not included which are socially and culturally embedded and the functions of and relationships between scientific theories and laws. VOSI is composed of five problem-solving questions based on the theory of knowledge about scientific development process from Lederman, and mainly used for the survey of scientific process how scientists develop the scientific knowledge, i.e. "understanding of scientific inquiry", with nine aspects of scientific inquiry. The process of open-ended questionnaires and interview includes following stages: collecting, time and quality control, checking in Shanghai and Chicago with sampling and interview on the scene and internet to explore teachers' views of NOS and SI. In the meantime, the effectiveness of questionnaires and interview are reviewed to decide whether to make additional in-depth interviews with typical teachers by means of on line, telephone or face to face.

Data Analysis

The collection and assessment of questionnaires are conducted in Shanghai and Chicago respectively, and the author is responsible for collecting and evaluating the data of questionnaires and interview. Researchers who participate in translation and assessment of questionnaires are two Ph.D. students from United States majoring in science education, named K and J, two Ph.D. students from China majoring in physics and chemistry education, named T and H, an education editor S, and two of Chinese science teachers, named A and Z. With the assistance of another Chinese Dr. J in Chicago, the author firstly translates VNOS-D and VOSI-S from English into Chinese, and then J translates them from Chinese into English. After that, the editor S from the Educational Press would review Chinese version and ask two high school science teachers A and Z to read, and then make the corresponding adjustment, which aims at making the understandable text for Chinese teachers and avoiding the influence of cultural differences.

Generally speaking, qualitative data is collected by open-ended questionnaires and interview to conduct qualitative analysis, however, the hierarchical coding method is used in the quantitative processing and analysis of the open-ended questionnaire, which could change the qualitative data into quantitative ones. Therefore, both quantitative and qualitative methods have been used for the analysis of open-ended questionnaires and interview. Coding methods of VNOS and VOSI are learned from scoring guide developed by Lederman. Each question of the questionnaire has a scoring standard guide to one aspect of NOS and SI, which is divided into four grades. The assessment levels from low to high are unclear, naive, traditional, informed, with respects to the evaluation of assignment from 0 to 3 (Lederman, Lederman, Kim, & Ko, 2006). For example, Description of "Subjectivity" score based on analysis of teachers' responses in VNOS: unclear-Unintelligible responses or no evidence, Naive-Student cites only opinion or bias as sources, Transitional-Seeming contradiction(s) or only one of the two listed criteria from "informed" described below, Informed-participant cites both of the following: Scientists viewing the same data come up with different conclusions, and scientists come to these different conclusions because they have different prior experiences, background, education, etc. Since teachers' views of NOS and SI could change over time by both implicate and explicate teaching approach, many investigations attempted to change teachers' conceptions from an alternative perspective. Shifts in viewpoints are most likely gradual and certain aspects of NOS may be more easily altered than others. There are several transitional phases between such levels like scored 1.5-2 or 2.5-3, which means teachers' understandings about the NOS and SI are coming closer to the advanced stage, so these aspects of NOS and SI may be more easily altered to the advanced ones than others. Based on the assessment instructions and standards as well as the interview result, each three assessors from both China and United States reach a census on assessment scoring (includes author and two doctoral K and J in the United States and two doctoral T and H in China) as the final results of evaluation.

Results of Research

Results of Science Teachers' Views of NOS and SI

Paired sample T tests are used to compare and analyze whether there is a significant difference on the understandings of NOS between science teachers from Shanghai and Chicago. Table 1 represents the statistic result of the score of five aspects on science teachers' understandings of NOS, and the mean value represents the average score of teachers in every aspect. Teachers from Chicago score lower in aspect of N_3 (Subjectivity), but higher than teachers from Shanghai in the other four aspects. According to the paired sample T test (p <.05), there are significant differences in aspects of N_1 (Creativity), N_2 (Observation and Inference), N_4 (Tentativeness). Among the three aspects mentioned above, N_1 and N_2 have significant difference, and differences in N_2 are the most significant ones.

Table 1. Results of VNOS between the teachers from Shanghai and Chicago.

No.	Items	Average of Shanghai	Average of Chicago	*p*
N1	Creativity	2.08	2.48	.000
N2	Observation and inference	1.68	2.35	.000
N3	Subjectivity	2.28	2.11	.260
N4	Tentativeness	2.08	2.25	.029
N5	Empirically Based	2.75	2.84	.320

As shown in Figure 1, one aspect of Chinese teachers' understandings of NOS is between the stage of traditional and informed, which is N_5 (Empirically Based). Three aspects are in the traditional stage, including N_3 (Subjectivity), N_1 (Creativity) and N_4 (Tentativeness). One aspect is in the transitional stage from naive to traditional, which is N_2 (Observation and Inference). Teachers in Chicago also have an aspect of N_5 (Empirically Based) in the transitional stage from traditional to informed, which is the same as teachers in Shanghai, and the other four aspects are all in the traditional stage. In addition to the aspects of "Observation and Inference", "Creativity" and "Tentativeness", the other aspects of NOS don't have significant difference.

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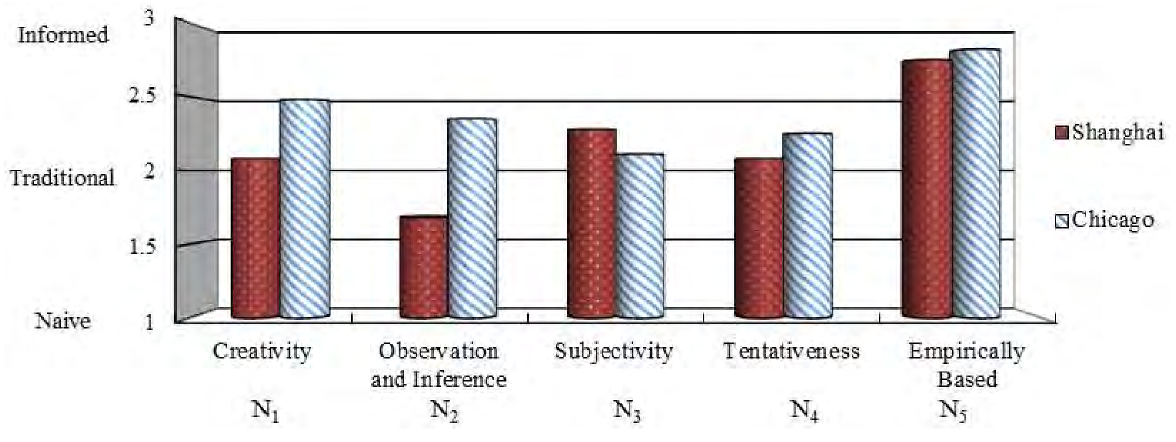

Figure 1: **VNOS results of teachers from Shanghai and Chicago.**

There are differences in three aspects of N_1 (Creative), N_2 (Observation and Inference), N_4 (Tentativeness) in VNOS. The majority of the Chinese teachers think creativity exists in one or two steps in scientific research, but not in all of them, while most American teachers think creativity exists in all of the process of scientific inquiry. Evaluation of "Observation and Inference" mainly comes from the question of "whether there is certainty in the weather forecasting". Most Chinese teachers think the weatherman is sure of the type of weather through computer modeling, while most American teachers think the weatherman is not very sure of the weather model, they are just guessing. From the difference of "Observation and Inference" aspect, we may know that Chinese teachers have paid attention to the creativity and tentativeness in NOS, but in practical problems, like the one mentioned above, they tend to emphasize more technical ability and accuracy, which is also found in the interview. Most American teachers think the weather forecasters' guess is not accurate but creative and temporary.

Table 2 summaries the statistical result on the average score of nine aspects of Chinese and American science teachers' views of SI. Chinese teachers' average scores are much lower than American. Except S_2 (Multiple Methods), the remained aspects have significant difference, including S_6 (Conclusions Consistent with Data), S_7 (Data ≠ Evidence) and S_9 (Views of Experiment), and S_7 has the greatest difference. Generally speaking, Chinese teachers don't understand what is data, what is the evidence and they can't distinguish between inquiry and experiment.

Table 2. **Results of VOSI between the teachers from Shanghai and Chicago.**

No.	Items	Average of Shanghai	Average of Chicago	p
S1	Begins with a Question	2.12	2.46	.030
S2	Multiple Methods	1.81	1.88	.712
S3	Inquiry Procedure Guided	2.01	2.35	.022
S4	Same Procedure ≠ Same Results	2.30	2.62	.021
S5	Inquiry process Influence the Result	2.25	2.58	.015
S6	Conclusions Consistent with Data	2.02	2.57	.000
S7	Data ≠ Evidence	1.61	2.38	.000
S8	Criteria for Scientific Explanations	2.05	2.30	.028
S9	Views of Experiment	1.55	2.12	.000

As shown in the figure 2, there are six aspects of views of SI held by Chinese teachers lie in the traditional stage (the average scores are 2-2.5), which are S_1 (Begins with a Question), S_3 (Inquiry Procedure Guided), S_4 (Same Procedure ≠ Same Results), S_5 (Inquiry process Influence the Result), S_6 (Conclusions Consistent with Data) and S_8 (Criteria for Scientific Explanations). Three aspects are in the transitional stage between naive and traditional (the average scores are 1.5-2), which are S_2 (Multiple Methods), S_7 (Data ≠ Evidence), S_9 (differences between inquiry and experiment), and S_7 and S_9 scores are the lowest with 1.61 and 1.55 respectively. Comparatively, American teachers have three aspects in the transitional stage from traditional to informed (the average scores are 2.5-3), which are S_4 (Same Procedure ≠ Same Results), S_5 (Inquiry process Influence the Result), S_6 (Conclusions Consistent with Data). There are five aspects in the traditional stage held by American teachers, which are S_1 (Begins with a Question), S_3 (Inquiry Procedure Guided), S_7 (Data ≠ Evidence), S_8 (Criteria for Scientific Explanations), S_9 (Views of Experiment). There is one aspect in the transitional stage between naive and traditional, which is S_2 (Multiple Methods). In conclusion, Chinese teachers have six aspects in the traditional stage, three in the naive stage, while American teachers have three aspects in the transitional stage between traditional and informed, five in the traditional stage, and one in the naive stage.

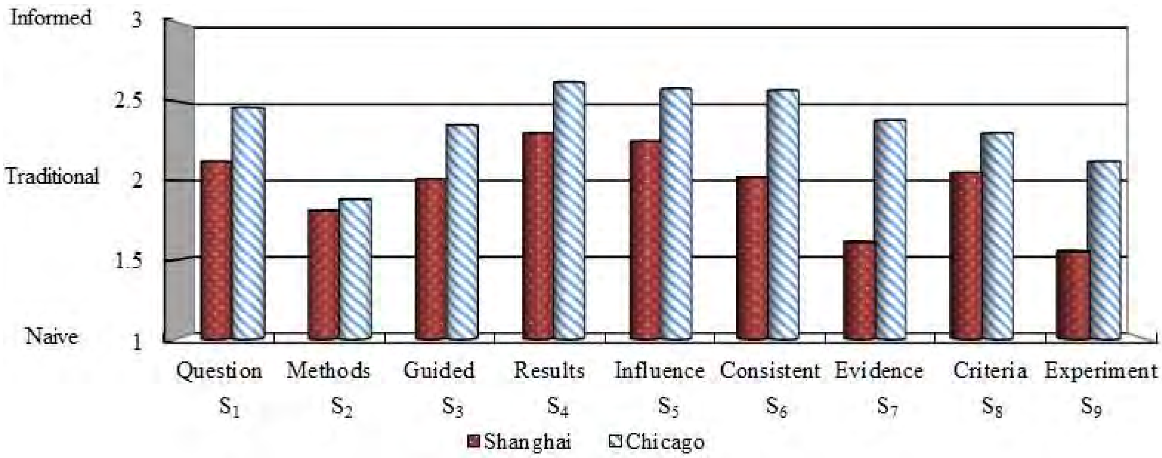

Figure 2: Comparisons between Shanghai and Chicago teachers' views of scientific inquiry.

The aspect which does not have significant difference is "Multiple Methods". As this question is directly asked in the questionnaire, further discussion is arranged with relevant teachers after they complete the questionnaire. This aspect also gets the lowest scores in both Chinese and American science teachers, and it is in the transitional stage from naive to traditional. According to the individual scoring statistics, it shows that majority of Chinese teachers are in the naive or traditional stage, while only half of them are in the informed stage with no one in the stage of unclear. American teachers, however, almost are distributed in the informed, traditional and naive stage. Further study on teachers' understandings of scientific method has been conducted with additional interviews. Teachers are asked to give examples of research methods during the interview. This is the 4th question in VOSI, which is expressed as follows: Do you think that scientific investigations can follow more than one method? If so, describe two investigations that follow different methods. Explain how the methods differ and how they can still be considered scientific. If not, explain how and why there is only one method for scientific investigations. The responses guide indicates: This is a direct question about views of "scientific method." If the respondent thinks there is only one scientific method, then they usually describe it as an experimental approach with hypotheses, variables, and controls. Responses may also suggest a single scientific method, but the description of that method may be broad such as: asking questions, making a procedure, collecting data, analyzing data, and making conclusions. Their explanation of why this method is the only method is very important for understanding their position on "scientific method." Interview follow up should ask for clarification through examples. Various examples reveal the fact that their understandings of scientific method in properties and categories are different. Chinese teachers provide two typical examples when they talk about the multiple scientific methods: "induction and deduction", "theory and experiment or reasoning and experiment". Generally speaking, Chinese teachers' examples are almost specific scientific method with strong operability, considered from the perspective of "doing". They don't have a clear understanding of experimental methods or distinguish between the experiment and other scientific methods such as measurement (specific method used in subject problem solving). Chinese teachers' understanding of scientific method is generalized without in-depth understanding and distinguishing between experiment and other methods. American teachers also provide two typical examples: "Observation and Experiment", "Describe and Control the Experiment". American teachers focus on the nature of the experimental methods, such as controlling

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variable. They believe experiments couldn't be done without control and they regard "control" as a main difference compared with other scientific methods. American teachers' understanding of experiment is based on the essence of the experiment not just at the level of "doing".

Eight aspects have statistically significant differences in VOSI, which are S_1 (Begins with a Question), S_3 (Inquiry Procedure Guided), S_4 (Same Procedure ≠ Same Results), S_5 (Inquiry process Influence the Result), S_6 (Conclusions Consistent with Data), S_7 (Data ≠ Evidence), S_8 (Criteria for Scientific Explanations) and S_9 (Views of Experiment). While S_6 (Conclusions Consistent with Data), S_7 (Data ≠ Evidence) and S_9 (Views of Experiment) are the three aspects with the greatest significant differences. Further analysis of the questionnaire shows that Chinese teachers don't understand what is data, what is evidence, and they cannot distinguish between inquiry and experiment.

The aspect of S_9 (Views of Experiment) is mainly evaluated based on the third question in VOSI. Most of the Chinese teachers think the descriptive research of bird's beak is not science, or experiment. Teachers' answers of the differences between inquiry and experiment are divided into four types, which are "science, experiment", "science, non-experiment", "non-science, experiment" and "non-science, non-experiment". Some teachers have a reasonable understanding of "what is experiment and inquiry", while the other teachers also come to the same conclusion, however, their understandings are not adequate. So teachers with the answer of "science and the experiment" are divided into two categories: informed and traditional stages. The teachers with the answer of "science, experiment" and "not science, experiment" are only aware of one aspect of the problem, so they are in the naive stage. Teachers with the answer of "not science, experiment" have no correct understanding, so they are put into unclear stage and they confuse about the relationship between inquiry and experiment. Most Chinese teachers are in the traditional stage, and they think that the study of birds' beak is a scientific study rather than an experiment. Their understanding of the scientific method, however, is not informed. Only one Chinese teacher is in the informed stage, 23 in the traditional stage. Majority of the American teachers are in the informed stage, with the number of 21, and 11 are in the traditional stage.

Stages of Science Teachers' Views of NOS and SI

To understand the stage of 45 Chinese teachers' views of NOS, the cognitive stage of each teacher is drawn based on the statistical data (The degree of the NOS is calculated by the average scores of the nine aspects), and listed in ascending order. American teachers' views of NOS degree are also listed in ascending order, and then a comparative line graph is made, as shown in Figure 3. The average levels of teachers are above the traditional level. 75% of Chinese teachers are in the traditional to the primary part of informed stage (2-2.5). American teachers in the traditional to the advanced part of informed stage (2.5-3) are slightly more than primary part, which are 50% and 40% respectively. In a word, Chinese teachers' views of NOS are basically in the traditional stage, while American teachers' are in the transitional stage between traditional and informed.

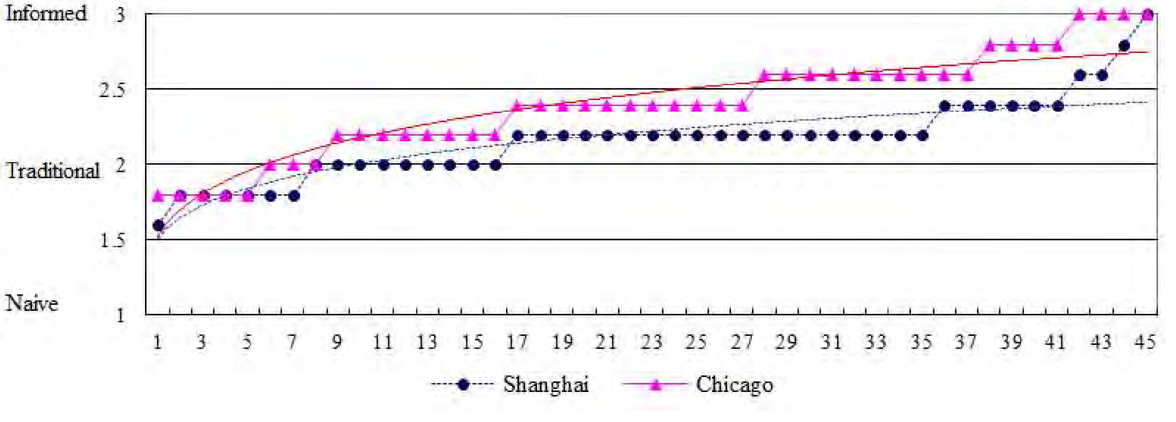

Figure 3: Stage distributions of NOS between Shanghai and Chicago science teachers.

Same methods are used to analyze views of SI between science teachers from Shanghai and Chicago. Figure 4 shows each teacher's cognitive stage of understandings of SI. More than one third (35%) of 45 Chinese science teachers' cognitive stage of understandings of SI are in the traditional stage (1-2), 60% between traditional and informed, but all of them are below the middle level of the stage, which is the traditional stage (2-2.5). As for American science teachers, nearly one fifth (18%) are below the traditional stage, while there are nearly half (47%) of the teachers in the advanced part of the stage between traditional and informed (2.5-3). Therefore, Chinese teachers' understandings of SI are mostly in the naive and traditional stage and traditional to the primary part of informed stage, which means the traditional stage. Half of the American teachers, however, are in the traditional and advanced part of the informed stage. Most of them are in the traditional stage, which is the transitional stage between traditional and informed.

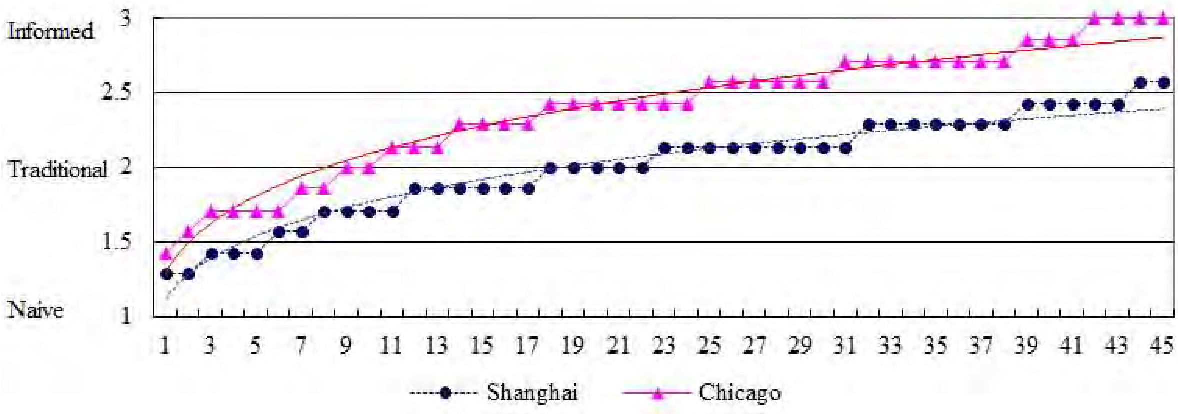

Figure 4: **Stage distributions of the SI between Shanghai and Chicago science teachers.**

Correlation Analysis of Two Kinds of Scientific Understanding

Since the data is hierarchical structure, correlation analysis of the hierarchical variable is conducted, based on the method of nonparametric test, with the Spearman and Kendall's tau_b rank correlation coefficient to measure the linear correlation between variables. The correlation analysis of rank variable is mainly used to deal with the ordinal variable, and the size of value of ordinal variable can represent a certain order of relations (grade, orientation or size, etc.) of the observed objects, also based on the "quality" factor of the variables. The evaluation values of the two kinds of scientific understanding are: 0-unclear, 1-naive, 2-traditional, 3-informed, and the value from small to large represent the cognitive level. Tested by SPSS19.0 (Table 3), the Spearman and Kendall s tau_b rank hierarchical coefficient are significantly correlated at the level of 0.01 between science teachers from Shanghai and Chicago, which means science teachers in both of the countries have a correlation in the understandings of NOS and SI.

Table 3. **Correlations of science teachers' views of NOS and SI.**

Correlations of NOS&SI		Shanghai	Chicago
Kendall's tau_b	Correlation Coefficient	.329**	.311**
	Sig. (2-tailed)	.005	.006
Spearman	Correlation Coefficient	.416**	.428**
	Sig. (2-tailed)	.006	.004

*** The correlation is significant at the 0.01 level (two tailed tests).*

Eview 6.0, software to analyze and forecast Econometrics, is used to analyze whether there is a causal relationship between the variables with Granger causality. Generally speaking, if the P value is less than 0.1, it could reject the original hypothesis (of course, the higher of the absolute value of F and the smaller of P value, the better is the result). As shown in table 4, the value of P is 0.02862, less than 0.1, with the rejection of hypothesis "Shanghai teachers' understanding of NOS is not the cause of SI". It could be concluded that the understanding of NOS leads to

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SI. While P value in the first row is more than 0.1, and the original hypothesis can't be refused. For data of Shanghai, the understanding of NOS is the cause of the change of SI, i.e., Shanghai teachers' understanding of NOS is in the leading position, and exerts impact on their understanding of SI. For the Chicago teachers, often choosing the lagging period of 2 (Table 5), can't determine the relationship, while choosing the lagging period of 3 (Table 6), Chicago teachers' understanding of SI influence their understanding of NOS. A causal relationship does exist in the two kinds of epistemological understanding held by teachers from Chicago, but it is a long-term effect, needing a long period of incubation. There are other factors that cause the interaction of these two kinds of understanding, which is why no significant correlations exist in the lagging period of 2. The result of quantitative analysis is more explicit, however, Shanghai teachers' understanding of NOS influences their understating of SI, and the interaction of these two kinds of understanding of Chicago teachers has a certain lagging period, and their understanding of SI mainly influences NOS.

Table 4. Grainger causality test of NOS and SI from Shanghai (lag phase 2).

Null Hypothesis	Obs	F-Statistic	Probability
Shanghai-SI does not Granger Cause Shanghai-NOS	43	0.95826	0.38268
Shanghai -NOS does not Granger Cause Shanghai-SI		3.86912	0.02862

The optimal lag order number is 2, significant level is .05

Table 5. Grainger causality test of NOS and SI from Chicago (lag phase 2).

Null Hypothesis	Obs	F-Statistic	Probability
Chicago-SI does not Granger Cause Chicago-NOS	43	4.35256	0.01898
Chicago-NOS does not Granger Cause Chicago-SI		4.38162	0.01889

Table 6. Grainger causality test of NOS and SI from Chicago (lag phase 3).

Null Hypothesis	Obs	F-Statistic	Probability
Chicago-SI does not Granger Cause Chicago-NOS	42	3.01012	0.04299
Chicago-NOS does not Granger Cause Chicago-SI		1.99811	0.13622

Discussion

Some differences on science teachers' understandings of NOS and SI can be found through the empirical study, especially in the specific aspects and cognitive stage of NOS and SI. Main conclusions are summarized as follows: There are three out of five aspects of NOS have significant difference between science teachers from Shanghai and Chicago. Chinese teachers get higher score than American teachers only in the aspect of Subjective, and perform lower than American in the rest four aspects of Observation and Inference, Creativity, Tentativeness and Empirically Based. Most of the science teachers from Chicago are in the stage of informed, while teachers from Shanghai are basically in the traditional stage. As pointed out by Lederman (1992), science teachers' understanding of NOS is insufficiency or imbalance, which is also shown in this cross-national study. There are eight out of nine aspects on the understandings of SI have significant difference between science teachers from Shanghai and Chicago. The cognitive levels of Chinese teachers are all lower than American teachers. The aspects are listed in the differences from high to low in the order of S_7 (Data ≠ Evidence), S_9 (Views of Experiment), S_6 (Conclusions Consistent with Data), S_3 (Inquiry Procedure Guided), S_5 (Inquiry process Influence the Result), S_4 (Same Procedure ≠ Same Results), S_1 (Begins with a question) and S_8 (Criteria for Scientific Explanations). American science teachers' understandings of SI are in the transitional stage between traditional to informed, however, most Chinese teachers are in the traditional stage. In a word, the understanding levels of SI of Chinese science teachers are half stage lower than American. Chinese science teachers should appropriately increase the contemporary learning of NOS with implicit way like science history or explicit way like scientific activities, leading the improvement of teachers' understanding of SI (Ragnhild, Jan, Glenn, & Lars, 2013). Training needs practice and reflection with "do inquiry", so that they could construct context in activities, experience and self-narration, internalize informed understanding of SI to improve their inquiry teaching.

In general, There is correlation between teachers' understandings of NOS and SI, and Chinese teachers' understanding of NOS plays an important role on their understanding of SI. The interaction of two kinds of understandings of American teachers has a lagging period, and their understanding of scientific inquiry mainly influences the NOS in a certain period of time. It seems that American science teachers pay more attention to do inquiry rather than theoretical summary. A lot of cultural elements are reflected upon the traditional education model in China. Western culture innately includes objectivity and an inquisitive nature. Scientific inquiry has flourished for more than a century in science courses taught in Western schools (Bybee & DeBoer, 1993). There are many differences between scientific culture and the Chinese Confucian culture (Morris, & Peng, 1994) which has led to differences in the understandings of NOS and SI between Chinese and Western teachers.

Conclusions

Differences exist in the understandings of NOS and SI held by science teachers from Shanghai and Chicago represented in specific aspects, cognitive stage, characteristics, types and relationships and so on. When Chinese try to have a dialogue with American about the NOS and SI, it is not only beyond the separation of space, but also the meaning is quite different in cross-national study. Compared with teachers from Shanghai and Chicago, there is an obvious gap between their understandings of NOS and SI. Chinese science teachers are affected by thoughts of logic positivism philosophy, who always regard scientific cognitive process as a copying process, and science is a real reflection of object. They tend to focus on "what is knowledge" and "what's the use of knowledge". Without considering the background of science learning experience and teaching practice, teachers might have imbalanced understanding of scientific knowledge. Science education in United States emphasizes teachers' understandings of NOS and SI for many years and achieves excellent results. And there are lots of reasons that Chinese science teachers' understanding of SI does not cause their understanding of NOS, such as little experience in doing inquiry, culture of Confucian and so on, which are originated from Chinese inherent cultural traditions. The purpose of improving teachers' understanding of NOS is to realize the teaching of inquiry and NOS. Subsequent research may utilize large scale quantitative surveys to compare and identify the statistical differences between understandings of NOS and SI expressed by American teachers and Chinese teachers as well as the reasons behind these differences. Further cross-national study could also be conducted for the types of understandings of NOS and SI, and how these understandings affect classroom teaching in different countries.

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Jingying Wang
(Corresponding author)
Ph.D., Associate Professor, Physics Department, Capital Normal University, No. 105, North Xisanhuan Rd., Haidian District, 100048 Beijing, People's Republic of China.
Email: wangjingying8018@126.com

Ying Zhao
M.A., Physics Department, Capital Normal University, No. 105, North Xisanhuan Rd., Haidian District, 100048 Beijing, People's Republic of China.
E-mail: betty-zhaoying@163.com