ECNU Review of Education
2022, Vol. 5(3) 520–536

DOI: 10.1177/2096531120966782
journals.sagepub.com/home/roe

Exploring Pre-service Science Teachers' Perspectives on the Nature of Science: A Comparative Study Between China and Canada

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Highlights

- The Nature of Science (NOS) is an important component of scientific literacy. Science teachers' Views of the Nature of Science (VNOS) directly affect their teaching behaviors. Therefore, it is of great significance to explore science teachers' VNOS and find ways of improvement.
- This study was designed to comparatively investigate preservice science teachers' VNOS between China and Canada. The study employed a survey design to explore how Chinese and Canadian preservice science teachers understood the seven different aspects of NOS.

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- Data showed that preservice science teachers in China and Canada both hold a modern view about science education. The level of Chinese and Canadian participants' understanding of NOS was above the relatively naive level. Chinese teachers had better macro-understanding toward science education, but their micro-mastery was insufficient. The Canadian participants had a better understanding of the NOS than their Chinese counterparts.
- The study suggested that there is a need to reconstruct the preservice science teacher education curriculum in China and promote the transformation in the science teacher educational system.

Keywords

Culture, Nature of Science, preservice science teachers, teacher education

Date received: 19 July 2020; revised: 30 August 2020; accepted: 22 September 2020

Introduction

Understanding of the Nature of Science (NOS) is a core component of scientific literacy. Liang (2005) indicated that the eternal goal of international science education is to cultivate students' scientific literacy. Canada is recognized worldwide for its outstanding quality of education. In 2015, the Programme for Internatioal Student Assessment (PISA) reported that Canada's science education level is at the top of the world (OECD, 2015). This has something to do with Canada's ways of governing. Canada is a typical country of decentralization, and it has impacts on its own educational system. Each province formulates education policy independently and promulgates curriculum standards. Ontario, as Canada's political and economic center, has become a model of curriculum reform among all Canadian provinces because of its first-class level of education (Yao & Guo, 2013). In Ontario, the reform documents cover almost all grades from elementary to high school. The Grades 1–8 science and technology curriculum was revised in 2007, and the Grades 11 and 12 science curriculum was revised in 2008. Such revisions are for improving scientific literacy as the ultimate goal in science education. The revisions also emphasize NOS and Science, Technology, Society and Environment (STSE) (Zhao, 2015). Similarly, China went through educational reform commencing to prepare students for the 21st century. In this reform, it formulated the science curriculum standards for primary schools and the Grades 7–9 science curriculum standards in 2001. Such reforms aim at fostering students' understanding toward scientific literacy, scientific knowledge, scientific inquiry, and the NOS, and more importantly, cultivating students' scientific attitudes and values. However, China's reform in science curriculum started relatively late. To arrive at the level of the science education that other developed countries have reached, joint efforts from the Chinese education departments, schools, and teachers are needed. Science teachers'

Views of the Nature of Science (VNOS) is an intermediary variable affecting the science literacy education, and it also directly affects teachers' teaching behaviors (Wan & Wei, 2017a). Therefore, it is meaningful to improve the science teachers' level of understanding of NOS as it is important in cultivating students' scientific literacy and promoting reform in science curriculum.

Literature has reported a number of studies in China that investigated teachers' VNOS, but there is a lack of cross-cultural comparative studies around this topic (Cobern, 2010; Wang, 2010). Liang et al. (2009) reported that Chinese science teachers had a different understanding of NOS compared with the American and Turkish teachers, but the reasons behind such differences had not yet been explored. To advance the relevant literature, our study was designed to comparatively investigate Chinese and Canadian preservice science teachers' VNOS. The study was conducted between one comprehensive university located in southern Ontario Canada and one large university located in southwest of China. These two universities were key players of a major partnership project of Reciprocal Learning in Teacher Education and School Education between Canada and China funded by the Social Science and Humanities Research Council of Canada.

Research questions and methods

Referring to Yuan (2006), this study classifies NOS into two categories from the perspective of scientific philosophy: traditional NOS and modern NOS. The traditional NOS is based on rationalism, with an emphasis on experience, evidence, and induction. It holds a view that knowledge is scientific, absolute, and objective. The modern NOS is based on constructivism, with an emphasis on the subjectivity, constructiveness, and temporariness of scientific knowledge, and it negates the absolute truth of scientific knowledge. Teachers who hold the modern view of NOS are more likely to organize the teaching content with constructive thinking, which helps students to deeply understand the NOS and from which cultivates students' scientific literacy (Luo, 2019). This study used a survey design to collect both quantitative and qualitative data. The researcher compared and analyzed two sets of quantitative and qualitative data and examined the consistency between the two sets of data to ensure the reliability and validity of the study. This research was designed to find out answers to two research questions:

1. How well do preservice science teachers in China and Canada understand NOS?
2. What are the differences between Chinese and Canadian preservice science teachers in regards to their understanding of NOS?

Study instrument

Abd-El-Khalick et al. (1998) defined seven aspects of NOS, including the tentativeness of scientific knowledge (it can be changed), observations and experiments basis, theoretical load (affected by the scientists' personal background, experience, and prejudice), creativity and imagination (including the creation of interpretation), social–cultural embeddedness, the difference between observation and inference, and the function and relationship of scientific theories and laws (Yan, 2009). To measure NOS, Ling Liang developed the scale of Views about the Nature of Scientific Knowledge, which is often used by Chinese scholars (Chen, 2006). The scale consists of close-ended questions and some corresponding open-ended questions. This study was designed to collect a combination of the quantitative and qualitative data to gain a comprehensive understanding of the preservice science teachers' VNOS. Past studies reported in the literature only used close-ended scale as the research tool. The open question was underutilized (Huang & Nie, 2019; Shi, 2018). These researchers believe that this is because open-ended questions are disconnected with the specific situation. Therefore, the researchers of this study combined Lederman et al.'s (2002) VNOS-C and Khalick's VNOS-HS open-ended questionnaires and revised the open-ended questions to let the research participants express their thoughts about the NOS under a specific situation. This is how the research tool was finally formed, and it is called *The Pre-service Science Teacher's Nature of Science Understanding Questionnaire*. The questionnaire consists of two parts: basic information questions and scale questions. There are four basic information questions regarding the study participants' gender, grade, major, and whether they have enrolled in courses about the history of science, philosophy of science, or sociology of science. The scale questions consists of seven topics. Each topic consists of a number of positive or negative statements regarding the NOS (5-point Likert-type scale) and an open-ended question. There are 52 close-ended questions in total. The order of positive and negative questions is randomly arranged. The validity of this research tool has been checked by many experts from two participating universities. The 5-point Likert-type scale uses a 5-level scoring system. Participants can respond with a maximum of 5 points, a minimum of 1 point, and a null response is 0 point.

The questionnaire was distributed to Chinese participants in Chinese and to Canadian participants in English. Participants were given enough time to finish the questionnaire without a preset time limitation. The accuracy of the translation of the questionnaire was cross-checked by a group of scholars. A two-way process of translation technique was used to ensure the accuracy of translation: from Chinese to English and then from English back to Chinese. Any inaccuracy of translation was caught for change in this process. The process led to the final wording of both Chinese and English versions of the questionnaire.

Participants

In China, students can become elementary or high school teachers after completing a four-year undergraduate degree. It is different in Canada. Students who have an undergraduate degree need to study an additional two-year diploma in teaching before they are able to become a registered teacher. On a voluntary basis, a total of 70 Year 3 and Year 4 students from the Chinese university participated in this study. Their majors were, respectively, chemistry, geography, biology, and physics. In the Canadian university, a total of 26 preservice teachers participated in this study. They were both Year 1 and Year 2 students from the postgraduate teacher education program. Their majors were, respectively, in chemistry, biology, physics, and math. A total of 96 questionnaires were distributed to all participants, and 89 valid questionnaires were collected. The return rate was 92.7%. Among Chinese participants, 12 (19%) were male and 52 (51%) were female. Canadian participants had a very different gender distribution with 14 (56%) male teachers and 11 (44%) female teachers.

Results

There were two parts in the analysis. The first part was quantitative statistics for the close-ended questions, and the second part was qualitative analysis for the answers from the open-ended questions. Both quantitative and qualitative data were later combined to draw conclusions. This research was designed based on Lederman's definition of NOS and the differences in the traditional NOS and the modern NOS. A coding framework of qualitative data analysis was developed according to Park et al.'s (2014) grounded theory. There are seven topics in this framework, which are detailed in Table 1.

Quantitative results

The quantitative data analysis first looked at individual scores on the measurement. Each participant received a percentage of correct scores over the total scores. According to Lederman et al.'s evaluation criteria (2002), preservice teachers' understanding of NOS can be divided into five levels, namely naive level (participants who obtained 60 out of 100 points below), relatively naive level (60 to 70 points), general level (70 to 80 points), relatively ideal level (80 to 90 points), and ideal level (90 to 100 points). The distribution of percentage scores for each level is illustrated in Figure 1. The percentages of Chinese participants who landed on each level were 6.25, 43.75, 50, 0, and 0, while the percentages for Canada participants were 0, 32, 64, 4, and 0. It is worth noting that 6.25% of the Chinese participants were placed at the naive level, while at the relatively naive level and the general level, the percentages were 43.75 and 50, respectively. No one reached the relatively ideal and ideal levels. In speaking of the Canadian participants, the percentage for the relatively naive level was 32 and the general level was 64. There were 4% participants placed at the relatively ideal level. There was no Canadian participant at the naive and ideal levels. It is clear that participants' understanding of NOS was basically clustered around the relatively naive and the general levels, be they from China or Canada. However, a higher percentage of Canadian participants landed on the general level than Chinese participants.

Table 1. Coding framework.

Topic	Type	Explanation
Tentativeness	Traditional	Don't change. Evidence supports knowledge; scientific knowledge is based on experiments
	Modern	Change. New discoveries, new explanations, and scientific knowledge can be wrong
Based on experimentation and evidence	Traditional	Yes. Directly obtained from observation and experimentation
	Modern	No. Inferenced from observation and experimentation
Theoretical load	Traditional	Lack of data; lack of direct observation; data similarity
	Modern	Scientists' personal preferences; scientists' background and knowledge
Creativity and imagination	Traditional	Don't use. Interference on the study of objective facts
	Modern	Use. Science needs innovation; data are insufficient and need explanation
Social–cultural embeddedness	Traditional	No. Science is the same all over the world; science in history is always the same
	Modern	Yes. Science is influenced by social values; scientists are the product of their culture
Observation and inference	Traditional	Science must be based on direct observation
	Modern	Science needs evidence; inference is the interpretation of the observed phenomena
Scientific theories and laws	Traditional	Theories and laws are transformable; theories contain laws; laws have been approved
	Modern	Theories explain laws; laws confirm theories

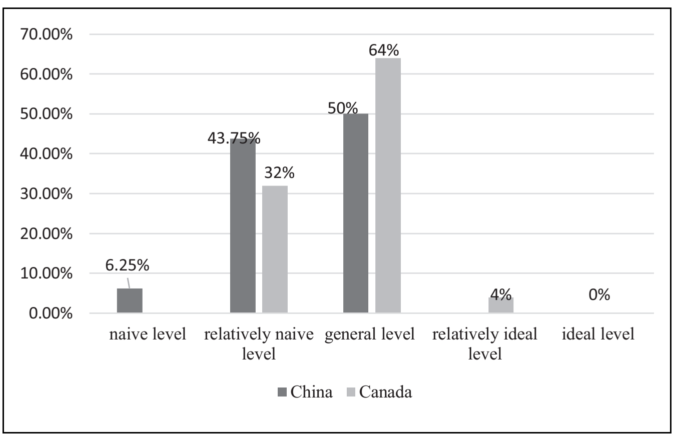

Figure 1. The stage distribution of the NOS.
Note. NOS = Nature of Science.

Table 2. Scores of preservice science teachers in China and Canada.

No.	Topics	Average, China	Average, Canada	*T*-test, *p*-value	Relationship of average
N1	Tentativeness	3.51	3.41	.323	China > Canada
N2	Based on experience and evidence	3.67	3.75	.593	China < Canada
N3	Theoretical load	3.03	3.29	.012*	China < Canada
N4	Creativity and imagination	3.64	3.76	.438	China < Canada
N5	Social–cultural embeddedness	3.62	3.95	.016*	China < Canada
N6	Observation and inference	3.72	4.14	.001**	China < Canada
N7	Scientific theories and laws	2.94	2.99	.572	China < Canada

Note. * statistically significant at 0.05 level; ** statistically significant at 0.01 level.

The averages of participants' scores on each topic were then analyzed. Table 2 presents the Chinese and Canadian preservice teachers' responses for the seven topics. Chinese participants got a higher average value on the topic of N1 (Tentativeness) than Canadian participants, but lower averages for the rest of six topics (N2 to N7). The overall average value of the Chinese participants' VNOS was 3.45, and the Canadian participants' score was 3.61. Further inferential analysis showed that there were significant differences ($p < .05$) between Chinese and Canadian participants on the topics N3 (theoretical load), N5 (social–cultural embeddedness), and N6 (observation and inference). Among them, N6 (observation and inference) had the greatest difference, followed by N3 (theoretical load) and N5 (social–cultural embeddedness). It is reasonable to conclude that Canadian participants had a better understanding of NOS than Chinese participants.

Qualitative results

Participants' responses to the open-ended questions of the survey were coded for analysis. Four scholars were involved in an independent coding process and led to 91% consistency in coding results.

Tentativeness. Although scientific knowledge is relatively reliable and can be tested with time, it is not absolutely correct or certain. An open-ended question around the topic of tentativeness was "Will the scientific knowledge that the preservice teachers currently learning change in the future? Please explain and give examples." Through analyzing participants' writing responses to this question, we got insights into their perspectives about the tentativeness of science. Table 3 summarizes their perspectives and explanations to this topic. Most of Chinese and Canadian participants shared the same view. They understood that scientific knowledge would change with constant development of

Table 3. Qualitative responses on the topic of tentativeness.

Type	Explanation	China (%)	Canada (%)
Modern/Change	With the development of technology, new evidence can be found	33	50
	New interpretations for existing data, natural phenomena, or changes in people's thinking	22	18
	Improved scientific theories leads to changes in scientific knowledge	5	10
	Unreasonable answers	5	4
	Other (substance change or multiple reasons)	26	11
Traditional/Don't change	The theory supported by experience and evidence is unchangeable	5	7
	Unreasonable answer	2	0
No answer		2	0

science and technology or the new interpretations for the original evidence. They also realized that mistakes were unavoidable in scientific knowledge, but these mistakes could be corrected and that would lead to changes in scientific knowledge. This is modern understanding about the NOS. In the meantime, several Chinese and Canadian teachers hold a traditional view that scientific knowledge is unchangeable. They believed that scientific knowledge was accumulated on the grounds of experience and evidence. Scientific knowledge would become even accurate and will not have too many changes when the time goes by.

Data analysis demonstrated that the answers of the open-ended question were consistent with the findings from the quantitative data. Most of Canada and China participants hold a modern view. When they were required to give some examples in supporting their answers, the Canadian participants were more likely to mention about the atomic model, while the Chinese participants often talked about the use and disuse theory, the theory of evolution, the geocentric theory, and the Heliocentric theory. Although all the examples that had been given were different, the Chinese and Canadian participants both showed an accurate understanding about the tentativeness topic and they could give appropriate examples to explain their perspectives. This showed that they had a deep level of understanding of the tentativeness of science.

Science is based on experimentation and evidence. It is a common belief that science is based upon observation and experiment. However, this belief only tells one part of the story. Science also requires imagination and reasoning. The open-ended survey question for this topic was "Are the atomic models described in the textbook a true and accurate representation of the atomic structure? How did scientists get to know these atomic structures?" The participants' responses are summarized in Table 4. A majority of Chinese and Canadian participants had a modern view

Table 4. Qualitative responses to the topic of experimentation and evidence.

Type	Explanation	China (%)	Canada (%)
Modern/Yes	Acquiring scientific knowledge through existing observation, experiment, and inference	32	23
	Acquiring scientific knowledge through direct observation or experimentation	14	46
	Other (calculation, measurement of physical properties, motion trajectory)	20	8
Traditional/No	Acquiring scientific knowledge through direct observation or experimentation	5	18
Other		14	4
Have no idea		9	1
No response		6	0

on this topic. They believed that the atomic models are not equal to the real structure of atoms. Scientists use these models to describe what it looks like inside an atom. A few participants hold a traditional view as they believed that the model was the real structure of atoms. They explained that the atomic structure can be seen by using an electron microscopy.

Many participants emphasized that atomic models were only built based on direct observation or experimentation. However, there were 31% of Chinese participants and 23% of Canadian participants responding that scientists also made inference on top of the observation and experimentation data. Some participants even realized that other experimental results could be used as the indirect evidence in the development of atomic models. For example, a Canadian participant indicated that "the Geiger–Marsden experiment does not directly describe the atomic structure, but it indirectly proves the correctness of the Thomson atomic model." When responding to the question about how they learned about the atomic model, the Chinese participants revealed that they learned the basic steps of scientific inquiry from textbooks. Those basic steps include: "asking questions, making hypotheses, experimental verification and drawing conclusions." The participants' responses showed that the Chinese participants were likely to believe what was written on the textbooks as they adore authority, consequently, they do not digest those theories. When it comes to the open-ended questions, there were 65% of Chinese participants and 77% of Canadian participants holding a modern view about NOS. This result was consistent with quantitative data. In short, most Chinese and Canadian participants were aware of the importance of evidence in science. The Canadian teachers had a deeper understanding toward this topic.

Table 5. Qualitative responses to the topic of theoretical load.

Type	Explanation	China (%)	Canada (%)
Modern	Personal preferences/background and knowledge	74	66
Traditional	Unclear/insufficient data	19	31
Other	It's very difficult to study the universe, and we can't observe it directly	3	3
No answer		4	0

Theoretical load. Scientists' work is influenced by scientific theories, their academic beliefs, possessed knowledge, their scientific training, experience, and expectations. The qualitative survey questions for this topic were "Why do astronomers draw different conclusions from the same set of data (expanding vs. contacting universe)? Are you aware of any other disputes among scientists? Please provide examples and explain." Participants' responses are summarized into three categories in Table 5. There were 73% of Chinese participants and 66% of Canadian participants holding a modern view of NOS. They believe that some scientists draw conclusions based on their personal background, their level of knowledge, and their personal preferences. Scientists are human beings, and they prefer to conduct research using methods that they are familiar with. The traditional view that some participants hold was "unclear data lead to different conclusions." In other words, the lack of sufficient evidence leads to speculation. Under such circumstance, scientists' prior knowledge affects how they interpret data. This finding is consistent with a past study, which found that both high school students and scientists believed that scientists had different explanations due to the lack of sufficient data (Wong & Hodson, 2009).

Analysis about the answers to the open-ended questions and quantitative data showed that most of the Chinese and Canadian participants hold a modern view about NOS. The quantitative data showed that the Canadian participants' understanding about NOS was significantly better than their Chinese counterparts. According to the statistics from the open-ended question, 28% of Canadian participants could provide examples. Those examples include the evolution and creationism theories, the atomic model, and so on. However, there were 22% of Chinese teachers providing such examples: the reasons that caused the dinosaurs' extinction, the plate tectonic theory, and the Cambrian explosion.

Creativity and imagination. Science is based on evidence, but the generation of scientific knowledge also needs imagination and creativity. The open-ended question designed for this topic was "Will scientists use their creativity and imagination at different stages of research, namely asking questions, proposing conjecture, and hypothesis, making research plans and designing experiments, conducting experiments and collecting data, analyzing and interpreting data, and reporting result?"

Table 6. Qualitative responses to the topic of creativity and imagination.

Type	Explanation	China (%)	Canada (%)
Modern/Use	The development of science requires innovation	34	68
	Insufficient data/inconsistent with scientific knowledge, explainable with creativity and imagination	31	16
	Other (no further explanation)	28	12
Traditional/ Don't use	Interference on the study of objective facts	0	4
No answer		7	0

Participants were required to give explanations by giving examples. Their responses are summarized in Table 6. Analysis showed that their answers to the open-ended question were consistent with the results from the quantitative data. More than 93% of participants believed that scientists use creativity and imagination in their work, which means that participants from both sides hold a modern view about this aspect of NOS. Most participants believed that the stages of making research plans, designing experiments, and analyzing and interpreting data require creativity and imagination. The examples participants provided included the Mendel experiment of pea hybridization (in the research planning and design stage), the proposal of the benzene ring in the periodic table (in the data analysis and interpretation stage). Some participants even believed that creativity and imagination can be used at every stage of the scientific experiments. Results showed that the Canadian and Chinese participants both had a profound understanding about this topic as no significant difference was shown.

Social–cultural embeddedness. Science mutually interacts with society and culture. As a human endeavor, science is practiced under a large cultural background. The people themselves who are engaged in this endeavor are products of this culture. The open-ended question on this topic was "Will scientific research be influenced by society and culture? Please explain why." Most participants believed that society and culture had an impact on scientific research. There were significant differences between Chinese and Canadian teachers about their answers to the close-ended questions. In their responses to the open-ended question, different types of examples were given by participants from China and Canada, which reflected that Canadian and Chinese participants may have different concerns. Their responses are summarized in Table 7. A total of 48% of Chinese participants mentioned that some external pressures, which come from China's society and culture, stress the need for scientists to work for social interests. Most of the Canadian participants mentioned the economic limitations in scientific research and the role that the scientists take as members in

Table 7. Qualitative responses to the topic of social–cultural embeddedness.

Type	Explanation	China (%)	Canada (%)
Modern/Yes	Society, culture, and politics require scientists to work for the benefit of society, or scientists should be motivated by social demands	48	20
	Social/economic support for research affects science	6	20
	Scientists are members of society, so they cannot avoid being influenced by society (through education and way of thinking)	11	28
	Science has been playing a role in social development	5	0
Traditional/No	Scientific knowledge and research involve nature, so scientific truth is not influenced by culture or politics	5	20
Answer was unreasonable		14	8
No answer		11	4

Canadian society. The Chinese and Canadian participants' different views may be rooted in how important the two different counties view the relationship between science curriculum and science and society. Canada released *The K-12 Common Framework of Scientific Educational Goals* in 1997 aiming at improving Canadians' scientific literacy through STSE education. In other words, the importance of STSE education was clearly highlighted in science education (Zhou, 2002). In the latest updated *China's Junior High School Science Curriculum Standard* (2017 edition), a goal was clearly set in this version that students' STSE abilities need to be cultivated (Liu, 2017). For the first time, STSE education was highlighted, and "Environment" was added in this science curriculum standard. All changes were made based on its 2001 and 2011 editions. Comparing the two science curriculum frameworks/standards, we can tell how importantly the two countries, respectively, view science education. It influences preservice science teachers from both sides to form a different understanding toward NOS. Other international studies also revealed that every government's science education policy reflects science teachers' and students' understanding about science (Cobern, 2010). In other words, to improve preservice teachers' fundamental understanding about NOS, STSE education is necessarily needed to be emphasized in governments' science education policy. In addition, all schools need to implement educational activities designed based on the concept of STSE education. Such designs should cover areas from educational goals, curriculum settings, content knowledge, and implementation to evaluation in STSE education.

Observation and inferencing. Observation is the description of how natural phenomena directly affects human senses. Inference is the description about the phenomena, which cannot be sensed directly.

Table 8. Qualitative responses to the topic of observation and inference.

Type	Explanation	China (%)	Canada (%)
Modern	Scientific inferencing is the explanation of the observed phenomena	61	76
	Science requires evidence (direct and indirect observation)	16	16
Traditional	Science must be based on direct observation	9	4
Other		7	4
No answer		7	0

For the differences between scientific observation and inferencing, participants' answers and explanations are summarized in Table 8. Sixty-one percent of Chinese participants and 76% of Canadian participants were able to distinguish observation and inferencing. They thought that scientific inferencing is how a phenomenon is interpreted. Observation is the description about some natural phenomenon, which directly impact human senses or the extension of these senses. Inferencing is the description about the phenomena that cannot directly impact human senses. From the analysis of the Chinese participants' answers, it was found that they paid more attention to observation than inferencing. The participants' answers to the open-ended question and the quantitative data also revealed that most Canadian and Chinese teachers hold a modern view about NOS, and the Canadian participants' understanding of NOS was better than their Chinese counterparts.

Scientific theories and laws. Law is a narrative statement about the relationship between visible phenomena. Theory is the inferential explanation about the observed phenomena or the law of the phenomena. Participants reported five types of explanations about the difference and connection between theory and law, which are summarized in Table 9. The majority of Chinese and Canadian participants hold a traditional view about this aspect of NOS. Only 15% of Chinese participants and 23% of Canadian participants hold a modern view. These qualitative results are quite consistent with quantitative data. Among all participants, only one Canadian participant could correctly illustrate the relationship between theory and law by giving an appropriate example. The example this participant gave was the use of the universal gravitation theory to explain the free fall law. The null answer for this topic was relatively high compared to the rest of topics. A possible inference that can be made from this is that the Canadian and Chinese participants lacked understandings toward this topic. This guessing is consistent with the current findings in the existing researches, that is, teachers and students lack a profound understanding about theory and law (Lin, 2011).

Conclusion and implication

Data analysis reveals that there were some differences between Chinese and Canadian participants in regards to their understanding of NOS. Chinese participants scored higher than their Canadian

Table 9. Qualitative responses to the topic of theories and laws.

Type	Explanation	China (%)	Canada (%)
Modern	Scientific theories are used to explain laws	14	19
	Scientific laws confirm the validity of scientific theories	2	4
Traditional	Scientific theories can be transformed into laws supported by valid evidence	15	8
	Scientific theories contain laws, or laws are more important than theories	13	19
	Scientific laws have been proven; scientific theories have not been fully proven	11	12
Other		25	31
No answer		20	7

counterparts on the tentativeness of scientific knowledge but lower for other six topics. Among all seven topics of NOS, significant differences were found in three topics (theoretical load, social–cultural embeddedness, and observation and inference), with Canadian participants outperforming Chinese participants.

The level of Chinese and Canadian participants' understanding of NOS was above the relatively naive level. The Chinese teachers' view about NOS was mainly distributed at the relatively naive and general levels, while Canadian teachers' understanding level was placed at the general level.

Chinese and Canadian participants generally hold a modern view about NOS. Through qualitative data analysis, significant differences were found between participants from the two countries. Chinese teachers showed a better macro-understanding than micro-understanding. They were more likely to rely on what was written on textbooks, in other words, they believed in authority. Whenever they encountered a point of view that they have never learned from the textbooks, they could not give examples to support that view. In contrast, some Canadian participants could explain that view by giving concrete examples.

In short, this study suggests that Canadian participants had overall better understanding of NOS than Chinese participants. Such difference might have something to do with relevant teacher education policy, curriculum, and pedagogy. Considering the differences of teacher education in China and Canada, we propose the following suggestions for changes.

NOS emphasis in teacher education curriculum

Firstly, we should value the importance of NOS education. The core connotations in the history of science (H), philosophy of science (P), and sociology of science (S) are the understanding of NOS. Thus, the HPS perspective should be added in science teacher education. To view NOS from the perspective of HPS reflects a value concept system, which includes scientific thought, scientific belief, scientific spirit, scientific aesthetics, and scientific ethics (Wu, 2011). This study showed that preservice science teachers in China lack understanding about HPS, and the teacher education curriculum lacks the content knowledge about NOS. Therefore, it is necessary to add courses designed from the HPS perspective and implement the NOS education in preservice science teacher training. This is important to improve the scientific literacy for Chinese preservice science teachers.

Secondly, to be more in line with the trend of development in international science education, it is necessary to add courses related to STSE, STEM, and STEAM in science education. Teacher education in China should incorporate STSE education, which integrates science education with social development, social production, social life, and environment (Li, 2013). In speaking of STEM education, it is an interdisciplinary program that includes science, technology, engineering, and mathematics, which emphasizes the integration of multi-subjects (Yu & Hu, 2015). On the top of STEM program, art is added and made a STEAM program, which is believed the most updated comprehensive education model. Preservice teachers' understanding of the NOS is a dynamic process of development. Basic education and higher education both have impacts on how teachers view NOS. Therefore, the reform in science education curriculum should be running from elementary schools all the way to colleges or universities. To set up elective courses related to STSE, STEM, and STEAM programs in postsecondary institutions will help preservice science teachers to improve their understanding of NOS.

Transformation in teacher education

Solid foundation in scientific knowledge and teaching abilities are important factors that affect science teachers' understanding of NOS. Science teachers in China mainly received their training in teacher colleges with a major in teaching. Such teacher training adopts a 4-year mixed model with a blending of scientific knowledge, educational theories, and teaching skills. This design has been criticized as it pays too much attention to teaching skills but focuses less on scientific knowledge. It becomes the major reason why science teachers lack a solid academic background in all science disciplines. Teacher education in Canada is different from China. Canada closed its teacher colleges in the 1950s and 1960s, instead, they set up Faculty of Education in universities to provide teacher training. They do so because the comprehensive universities have strong training abilities and academic specialties, which enable them to provide teacher education. Wan and Wei (2017b) indicated that in developed countries, 4 + 2 is the major mode to train science teachers. This training mode is similar with one of the Chinese teacher training pathways where postgraduate students take a full-time Master of Education (MEd) program. They can become teachers upon completion of this program. However, the numbers of enrollment in these MEd programs are low in comparison with the numbers in teacher colleges. Teacher education in China is still in a need to come up with a solution to boost future teachers' academic background while keeping the strength in teaching skill training. It might be worthwhile to explore the possibility of moving teacher education from traditional teacher colleges to comprehensive universities.

Contributorship

This paper was developed based on a reciprocal learning project in science teacher education between Canada and China. The project was supervised by George Zhou and Yuanrong Li. Guihua Zhang and Sonia Wai-Ying Ho were graduate assistants to the project. Guihua Zhang drafted the paper. The rest of the authors participated in reviewing and finalizing the paper.

Declaration of conflicting interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: We gratefully acknowledge the Social Sciences and Humanities Research Council of Canada (SSHRC) for its financial support of Canada-China partnership grant program on reciprocal learning in teacher education and school education (No. 895-2012-1011).

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