Conceptions of Nature of Science of Pre-service Teachers: Implications for Science Teacher Preparation Programme

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Nature of science (NOS) has undergone a drastic change from mechanistic, objectivistic and deterministic world view to viewing nature, people and their relationships in a holistic manner (Prigogine and Stengers 1984). Science teachers as well as science students are expected to be aware of the holistic nature of science. Science teacher preparation programmes are expected to apprise pre-service science teachers with an adequate understanding of NOS. This study shows that most of the science pre-service teachers had uninformed conceptions of NOS. Therefore, this study emphasizes the role of teacher preparation programmes in equipping pre-service science teachers with an adequate understanding of science and nature of science before they embark on a journey of a regular science teacher.

Keywords: Nature of Science, Science teacher preparation, Pre-service teachers

Introduction

Science can arguably be defined as having at least three aspects: body of knowledge, process/method, and a way of constructing reality, that is, nature of science (NOS), that distinguishes it from other disciplines or ways of knowing. These three aspects are different although an overlap between these three aspects is unavoidable like the knowledge of science has been derived through a myriad of science processes, the nature of these processes is a direct function of the way science proceeds to construct reality, and the status of the knowledge is a direct result of both the processes and epistemological commitments of science. But when we try to distinguish science from other endeavours, it is the "nature of science" (i.e., the values and assumptions inherent to the knowledge and its development) that clearly establishes science as different from other academic endeavours (e.g., political science, art, history, religion). Science teachers are not only given the responsibility to teach science content with a focus on inquiry based approach but are also expected to nurture an understanding of the NOS. This paper explores the understanding of NOS by pre-service science teachers and provides valuable feedback to pre-service science teacher education programmes regarding imparting instruction related to NOS.

Research Question

The research question that guided this study is: What are pre-service science teachers' conceptions of NOS, particularly scientific knowledge, scientific method, scientists' work, and scientific enterprise? The answer to this question is significant because through multiple lenses NOS describes how science functions. For science educators the phrase "nature of science" is used to describe the intersection of issues addressed by the philosophy, history, sociology, and psychology of science as they apply to and potentially impact science teaching and learning. As such, the NOS is a fundamental domain for guiding science educators in accurately portraying science to students. Science students need to know not only facts/concepts but also about the processes through which this knowledge is generated. NOS courses in science teacher education (a) can help in enhancing teacher's ability to implement conceptual change models of instruction and (b) can help teachers in understanding the psychology of students' learning (Matthews, 1994).

If the teacher's understanding and philosophy of science is not congruent with the current interpretations of the nature of science,... then the instructional outcomes will not be representative of science (Carey & Strauss, 1968 p. 368). The type of science imparted to students depends upon the teachers' own views of the nature of science (Gill, 1977, p. 4). Hence, bolstering teachers' understanding of NOS is clearly a prerequisite for effective science teaching.

Methods

Instrument: To explore pre-service science teachers' conceptions of the NOS, the researcher of this study utilised an instrument entitled the *Myths of Science Questionnaire* (MOSQ) developed by Khajornsak Buaraphan & Sunun Sung-ong, University of Bangkok, 2009. The MOSQ consists of 14 items and addresses four aspects of NOS: (1) scientific knowledge (6 items–Items 1, 2, 3, 4, 8, 9); (2) scientific method (3 items–Items 5, 6, 7); (3) scientists' work (2 items–Items 10, 11); and (4) scientific enterprise (3 items–Items 12, 13, 14). The creation of the MOSQ items was largely inspired by McComas's (1998) article entitled "The Principal Elements of the Nature of Science: Dispelling the Myths". MOSQ respondents are required to select which of three responses, i.e., agree, uncertain, or disagree; best fits their opinion of the item statement and to provide an additional written response to support their selection. Multiple responses for an item were not allowed.

Individual Interviews: To obtain more information on conceptions of nature of science, participants were individually interviewed.

Data Collection

The data were collected during the culmination of the 2009-2010 academic sessions. The respondents were 34 pre-service science teachers in a one year teacher preparation programme conducted at Army Institute of Education, Delhi Cantt. (affiliated to I.P. University). The researcher administered the MOSQ and collected it back from the teachers who were all army dependants. A majority of the teachers (85%) were female, and taught chemistry as well as biology during their school life experience. On the basis of their educational background teachers could be categorised as general science graduates (50%), chemistry postgraduates (22%) and biology postgraduates (28%).

Data Analysis

The frequency of each response (i.e., agree, uncertain, and disagree) was counted, and percentages calculated. In some items the agree response is an informed conception and in others it is an uninformed conception. The same is true for disagree responses also. However, "*one's view of the NOS is a complex web of ideas that loses meaning when reduced to simple numbers*" (Palmquist & Finley, 1997, p. 601). Therefore, the written arguments supporting each response were categorised and their frequencies calculated for each category.

A majority of pre-service science teachers (76%) held the contemporary view about hypotheses and theories. They disagreed with the statement "*hypotheses are developed to become theories only*". Of written responses, 68% argued that hypotheses are developed into theories if proved under all circumstances and 32% of written responses additionally argued that hypotheses may also be formulated to understand thinking, concepts as well as to get solutions of daily life problems. However, only 12% of pre-service science teachers were uncertain about hypotheses and theories, while only four of them explicitly expressed an informed conception. Nearly one eighth of pre-service science teachers (12%) were uncertain about theories and laws. In addition, 59% of respondents expressed the traditional view that scientific theories are less secure than laws, out of which 53% are of the opinion that "*theories can be modified/improved with new research, but laws are always fixed*" but 6% pre-service teachers wrote that theories are made on the basis of laws. A major explanation supporting the uninformed view (15%) was that, "*theories are less credible than laws because theories can be changed, but laws are fixed, they cannot be changed*". Two pre-service teachers (6%) from uninformed view group felt that even theories are as secure as laws and three pre-service teachers (9%) had an altogether different opinion that "*laws might have loopholes while scientific theories have concrete base, which is also proven*".

Item No.	Statement	Response	No. of Respon dents (Percentage)
1.	Hypotheses are developed to become theories only.	Agree	4 (12%)
		Uncertain	4 (12%)
		Disagree	26 (76%)
2.	Scientific theories are less secure than laws.	Agree	20 (59%)
		Uncertain	4 (12%)
		Disagree	10 (29%)
3.	Scientific theories can be developed to become laws.	Agree	28 (82%)
		Uncertain	4 (12%)
		Disagree	2 (6%)
4.	Scientific knowledge cannot be changed.	Agree	5 (15%)
		Uncertain	5 (15%)
		Disagree	24 (71%)
8.	Accumulation of evidence makes scientific knowledge more stable.	Agree	29 (85%)
		Uncertain	–
		Disagree	5 (15%)
9.	A scientific model (e.g., the atomic model)expresses a copy of reality.	Agree	23 (68%)
		Uncertain	5 (15%)
		Disagree	6 (18%)

Table 1: Pre-service science teachers' conceptions of the NOS: Scientific knowledge

A very high proportion of pre-service science teachers (82%) believed in "*laws-are-mature-theories-fables*." A majority of the written responses provided support to their view (79%) that "*when the theories have been proved, they can be developed to become laws.*" Nearly one-eighth pre-service teachers (12%) were uncertain about conversion of theories into laws.

Most of the pre-service science teachers (71%), expressed the view about the tentativeness of science. Nearly all of the written responses (68%) raised the discovery of new or more credible evidence as a reason why scientific knowledge can be changed. However, one teacher believed that "*theories can be developed to become laws, thus scientific knowledge is tentative*." This response demonstrates the conjunction of two beliefs–the first one is incorrect, but accidentally leads to another correct one. Five pre-service teachers (15%) were uncertain about the changing nature of scientific knowledge.

Majority of the pre-service teachers (85%) possessed the naïve conception that "accumulation of evidence makes scientific knowledge more stable". The majority of written responses (68%) supporting this naïve view indicated that "*the accumulation of evidence increases the credibility of scientific knowledge*."

Majority of the pre-service teachers (68%) agreed with the statement "*a scientific model expresses a copy of reality*," while six pre-service teachers (18%) disagreed, and five pre-service teachers (15%) were uncertain. Reasoning given by one pre-service teacher supporting the disagree response, was "*the model in fact explains the concept in a 3-D form.*"

Item No.	Statement	Response	No. of Respon dents (Percentage)
5.	The scientific method is a fixed step-by-step process.	Agree	32 (94%)
		Uncertain	1 (3%)
		Disagree	1 (3%)
6.	Science and the scientific method can answer all questions.	Agree	8 (24%)
		Uncertain	3 (9%)
		Disagree	23 (68%)
7.	Scientific knowledge comes from experiments only.	Agree	11 (32%)
		Uncertain	3 (9%)
		Disagree	20 (59%)

Table 2: Pre-service science teachers' conceptions of the NOS:Scientific method

An uninformed conception of the scientific method was reported by 94% of pre-service science teachers. They believed that scientists must follow a fixed step-by-step method to obtain scientific knowledge. Only one respondent was uncertain about whether the stages of the scientific method could be reordered or if any could be removed. Only one pre-service teacher showed informed conception of the scientific method.

Only very few pre-service teachers (9%) were uncertain about whether "science and scientific method can answer all questions, and around 2/3rd (68%) pre-service teachers disagreed with the statement. Of 23 written responses, 8 of them (35%) raised issues (e.g., ghosts, spirits, the devil, black magic, the supernatural, fortune-tellers, etc.) that science cannot explain. Twelve pre-service teachers disagreed with the statement but without assigning any specific reason. Only one pre-service teacher wrote that science and scientists could not find the reason behind death.

The contemporary view that "*scientific knowledge is not originated from experiments only*" was expressed by 59% of teachers. Eleven of the 20 written statements (55%) supported their responses by stating that scientific knowledge can be obtained from observation as well as experiences. Furthermore, 6 of the 20 written responses (30%) indicated that reading, research; survey as well as investigation methods can be used for obtaining scientific knowledge. Thirty two percent pre-service teachers agreed with the statement that scientific knowledge comes from experiments alone.

Item No.	Statement	Response	No. of Respon dents (Percentage)
10.	Scientists do not use creativity and imagination in developing scientific knowledge.	Agree	7 (21%)
		Uncertain	2 (6%)
		Disagree	25 (74%)
11.	Scientists are open-minded without any biases.	Agree	21 (62%)
		Uncertain	4 (12%)
		Disagree	9 (26%)

Table 3: Pre-service science teachers' conceptions of the NOS: Scientists' work

Majority of pre-service science teachers (74%) believed that "*scientists use creativity and imagination in developing scientific knowledge*." The three frequently raised examples were the creativity and imagination involved in creating scientific models like Bohr's atomic model (12%), designing scientific experiments (28%) and formulating hypotheses (16%).

Nearly two thirds of pre-service science teachers (62%) agreed that "*scientists are open-minded without any biases.*" The majority of written responses (67%) stated that being open-minded and unbiased are desirable characteristics of scientists that allow them to succeed in their work. Only 26% of respondents held the contemporary view and argued that some scientists are not open-minded and possess some biases.

Item No.	Statement	Response	No. of Respon dents (Percentage)
12.	Science and technology are identical.	Agree	10 (29%)
		Uncertain	2 (6%)
		Disagree	22 (65%)
13.	Scientific enterprise is an individual enterprise.	Agree	2 (6%)
		Uncertain	6 (18%)
		Disagree	26 (77%)
14.	Society, politics, and culture do not affect the development of scientific knowledge.	Agree	9 (26%)
		Uncertain	3 (9%)
		Disagree	22 (65%)

Table 4: Pre-service science teachers' conceptions of the NOS: Scientific enterprise

Around two third of pre-service science teachers (65%) disagreed with the statement, "*science and technology are identical.*" One third of written responses (36%) expressed the pre-service science teachers' naïve conceptions that "*technology is applied science*". Three patterns of the relationship between science and technology emerged from the responses, i.e., technology originated from science (34%), science and technology complement each other (23%) and science creates technology and technology makes science more logical and understandable (41%).

A majority of pre-service science teachers (77%) disagreed with the item "*scientific enterprise is an individual enterprise*". Nearly all of the written responses (81%) claimed that science is a social activity that involves many persons. About two thirds of pre-service science teachers (65%) believed that society, politics and culture potentially affect the development of scientific knowledge in some ways.

S.No.	Conceptions	No. of Respondents (Percentage)
1.	Science classrooms to be highly interactive, open and good understanding between science teacher and the students	15 (44%)
2.	Science classrooms to be full of well made charts and models, live and preserved specimens so as to relate to topic	10 (29%)
3.	In science teaching students should be closer to the environment (nature), they must develop fondness with nature, and can relate their learning with the world around them	2 (6%)
4.	Science classroom should be full of enthusiasm and students should be curious enough to bombard the questions	3 (9%)
5.	In science teaching students must have the freedom to experience new things and are able to relate their classroom teaching to daily life, and not restricted to text-books	4 (12%)

Table 5: Pre-service science teachers' conceptions regarding good classroom science teaching

During personal interviews, most of the pre-service science teachers (44%) revealed that good science classrooms should be highly interactive, open and with good understanding between science teacher and the students. Only 9% pre-service science teachers were in the favour of enthusiastic classrooms and curious students who are ready to ask questions.

Discussion

Most of the pre-service science teachers in this study, held uninformed conceptions about the roles of hypotheses, theories, and laws, particularly the "*laws-are-mature-theories-fables*" which means they perceive theories as less secure than laws.

The tentativeness or dynamic nature of science is recognised by pre-service science teachers in this study. However, they considered subjectivity or creativity as important factors that make science tentative. Similar findings are reported by Abd-El-Khalick, Bell and Lederman, 1998; Bell, Lederman and Abd-el-Khallick, 2000; Craven, Hand and Prain, 2002; Mellado, 1997; Murcia and Schibeci, 1999; Palmquist and Finley, 1997. Cotham and Smith (1981) used the terms "tentative" and "revisionary" to define the nature of scientific theories. The tentative component of this conception emphasizes the inconclusiveness of all knowledge claims in science. The revisionary component emphasizes the revision of existing scientific knowledge in response to changing theoretical contexts. Scientific progress can be best described as a revisionary process rather than a cumulative process (Brickhouse, 1990). However, a majority of pre-service science teachers in this study, similar to that of Haidar (1999), strongly believed in Baconian induction. They viewed science as cumulative knowledge, i.e., individual pieces of evidence are collected and examined until a law is discovered or a theory is invented. They were not aware of the problem of induction, i.e., "even a preponderance of evidence does not guarantee the production of valid knowledge" (McComas, 1998, p. 58).

Majority of the pre-service science teachers believed that "a scientific model is a copy of reality. Similar findings were reported by Ogunniyi (1982) and Thye and Kwen (2003). The pre-service science teachers in this study were highly uninformed and uncertain about the scientific method. They strongly believed in the universal, step-wise scientific method. The universal scientific method is widely propagated in school science textbooks (Craven et al., 2002; Haidar, 1999; Mellado, 1997; Murcia & Schibeci, 1999; Palmquist & Finley, 1997). Also, the form of cookbook or verification-type laboratory activities, unfortunately, leads student teachers to portray science as a rigid procedural investigation leading to reliable, valid and dependable knowledge (Palmquist & Finley, 1997).

Many pre-service science teachers disagreed with the statement "science and the scientific method can answer all questions". They raised questions about many phenomena that are unexplainable by science e.g., ghosts, spirits, the devil, black magic, the supernatural, fortune-tellers, etc. More than half of pre-service science teachers believed that scientific knowledge is not solely originated from experiments. They frequently brought up observation and other methods of knowledge accumulation like reading, research, survey etc. (Thye & Kwen, 2003). Observations are the meat and potatoes of science. We start a research project with observations made either in the field, the library, or the laboratory. How these observations are collected, classified, interpreted, and used as the basis of theorizing (from a hunch to eureka) is, more or less, what science is about.

Creativity and imagination were highly regarded as important in developing scientific knowledge, in particular to creating scientific models and designing experiments. A minority of pre-service science teachers believed in objectivity in science and also raised it as an important characteristic of scientists, as in (Palmquist & Finley, 1997), in order to be successful in their work.

Majority of the pre-service teachers disagreed with the statement that "science and technology are identical". Pre-service teachers have no clear distinction between science and technology. They consequently, should present a clear distinction between science and technology and advocate the complexity and the interactive nature of the relationship between science and technology. Three patterns of relationships between science and technology emerged in this study, i.e., technology originated from science, science and technology complement each other and science creates technology and technology makes science more logical and understandable. A majority of pre-service science teachers believed in science as a social activity, which is greatly influenced by society, culture and politics (Bell et al., 2000; Haidar, 1999; Mellado, 1997; Murcia & Schibeci, 1999; Rubba & Harkness, 1993; Tairab, 2001). Only a few prospective teachers did not perceive the influences of society, culture and politics on science advancement.

Implications

There are a number of implications of this research study for science teacher preparation programme which include:

Developing well defined links between NOS & the general science teacher: Nature of science receives a shallow coverage in our teacher education curriculum with no links with other topics like different methods of teaching (lecture method, demonstration method, discussion method, project method etc.), science curriculum construction, lesson plan making etc. These different topics in the science teacher education curriculum must be interwoven with nature of science. Nature of science in science teacher education should be formal and as much as an aspect of subject matter. That means that we should provide explicit instruction on nature of science. How do we accomplish that? Teacher educators can help pre-service teachers understand more about nature of science by helping them design lesson plans around science topics or concepts that have changed over time. Such lessons show pre-service teachers that scientific knowledge in and of itself is not static and that with new information, scientific theories can change. In the lesson plan, the instruction must be explicit on how knowledge has changed and why.

Need to undertake laboratory research projects: Opportunities to undertake authentic laboratory research projects must be provided to pre-service teachers in order to improve their understanding of the nature of science. A number of studies have investigated whether a relationship exists between knowledge of science content and an understanding of the nature of science. Behnke, (1961) investigated a group of scientists and a group of secondary science teachers' regarding the nature of science, science and society, the scientist and society, and the teaching of science. More than one half of the teachers and 20% of the scientists incorrectly viewed the content of science as fixed and unchangeable. He found that teachers differed most from the scientists on statements which involve an understanding of the scientific enterprise in some depth. Teachers and scientists disagree most frequently on statements related to the goals and limitations of science.

Role of textbooks vis-a-vis knowledge of NOS: Most of the time, science books are the only instructional materials available for the science teachers. Thomas Kuhn, in *The Structure of Scientific Revolutions* (1970) makes clear that science textbook convey an image of what science is and how it works. He writes that — [m]ore than another single aspect of science, [the textbook] has determined our image of the nature of science and of the role of discovery and invention in its advance. Teacher education programmes must help pre-service science teachers in understanding that science curriculum must venture beyond the instructional materials. Pre-service teachers must be given opportunity to analyze the textbooks and read the language and try to understand its implicit meaning about the scientific knowledge. Pre-service teachers can also be involved in developing modules as well as curricular materials.

Technology plays the role of enhancing the utility of science for students: Technology and science represent uniquely different yet mutually supportive bodies of knowledge and methods of discovery. Science is about knowing. Its major goal is to understand nature and its functioning. Although viewed by some as the source of "truth" and as a body of "facts," it is more appropriate to consider science as a source of models, theories, and processes that attempt to explain not "what is" but "what we know," and as a method for expanding what is currently "known."

Most of the pre-service science teachers, in this study, think that "science and technology are not identical". Pre-service science teachers must be made to understand that there are many ways to solve a problem, and at the same time, they must learn to establish criteria and processes whereby they can choose the "best for now" solution. By gaining experience in the practice of application, we all can learn even more science. Thus, technology plays the role of enhancing the utility of science for students.

Include historical & philosophical assumptions and contexts in science teacher education curriculum: This study reveals that a large number of pre-service science teachers that "knowledge is tentative in nature". These beliefs can be further strengthened if historical and philosophical assumptions and contexts are included in science teacher education curriculum. Like some early philosophical theories can help us understand present day laws & ideologies including a few of the misconceptions that pre-service teachers (and teacher educators) bring to class. For instance, Aristotle believed that forced motion is maintained by force. Buridan's impetus theory developed from Aristotle's notion maintains that the impetus is an intel source of force that maintains the motion. These views contrast with Newton's laws, which suggest that an object in motion tends to stay in motion unless a force acts upon it.

Encourage cooperation among pre-service teacher: This study shows that a large number of pre-service science teachers think that "Scientific enterprise is a social enterprise". The activities of the science are essential to provide solutions for the future, for both individual and society. Science takes a lot from the society in the form of public funds; human resources etc., so it must return it back to the society. Science is a collective enterprise and not an individual one. Keeping in mind the same spirit, the science teacher education curriculum must focus on cooperative work on real problems. Contrived exercises, individual work on verification activities, and most problems in contemporary textbooks do not help students grow as cooperative citizens ready to tackle the societal problems of our time. A community orientation is needed. A focus on problem resolution rather than problem solution is a realistic and a desirable goal.

Evaluation: Science teacher education programme must provide evaluation based on an ability to get and to use information. Nearly all evaluation in older models of science education focused upon definition of terms and concepts and upon verification skills. The student's ability to find and to use information is an important part of the scientific continuum and is basic to the study of science.

Understanding personal theories of pre-service teachers: During individual interviews, personal theories of the pre-service science teachers became clear. Pre-service teachers come to teacher education institutions with naive, incomplete, inconsistent, non-canonical theories that they have developed to make sense of the natural world. As teacher educators, we need to understand the personal theories, of pre-service science teachers. During their school days, they must have experienced educational settings which reinforce the notion that learning means knowing the right answer. Their classroom experiences could be characterized by the use of worksheets, and other product oriented forms of assessment, an emphasis on external forms of motivation such as grades, and other strategies to control their behaviour. They may not have experienced classrooms where they were encouraged to solve their own problems, develop their own questions and search for answers, or use critical analysis and reflection to develop their own ideas about issues. Due to many distortions and reductionisms acquired over a period of time, pre-service teachers lack a correct orientation to science teaching.

Science teachers' views of scientific knowledge vis-a-vis classroom practice: Research in science education has suggested a possible link between teachers' views of scientific knowledge and their classroom practice. Duschl and Wright (1989) found that the science teachers in their study were committed to a hypothetical-deductive view of the scientific method and to teaching the propositional knowledge of the discipline. These teachers gave little consideration to the nature and role of theories in making curricular and instructional decisions. Smith and Anderson (1984) reported that a science teacher who believed that currently accepted scientific theories could be inferred from observation was surprised when her students failed to discover photosynthesis by observing the growth of plants. Lantz and Kass (1987) found that three high school chemistry teachers who used the same chemistry curriculum taught very different lessons about the nature of science, as a result of differences in their understanding of the nature of chemistry.

Well-designed opportunities for teacher learning can produce desired changes in their classroom practices, can enhance their capacity for continued learning and professional growth, and can in turn contribute to improvements in student learning.

Further study of the influence of teachers' beliefs and instructional strategies is needed to determine how teachers' beliefs are translated into pedagogical content knowledge and through it into practices that affect students' scientific understanding and their activity in science.

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