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A comparison of trained and untrained science teachers' views about certain aspects of the nature of science

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Abstract

This paper reports on the results of a simple paper-pen questionnaire study involving certain key aspects of the nature of science. The questionnaire covers, among other things, aspects such as uniqueness of the scientific method, objectivity of scientific data, and immutability of scientific laws. The survey was given out to 80 trainee teachers enrolled in a full-time pre-service post graduate diploma in education (secondary) i.e. PGDE (S) programme while they were doing their curriculum studies at the National Institute of Education (NIE), Singapore. A similar questionnaire was given out to 42 in-service teachers at the beginning of their part time Master in Education (Science Education Specialization) i.e., MEd (Sc Ed) course. The views of these trained or in-service teachers were compared with those of the trainee teachers in this paper.

Keywords: Curriculum and specific curriculum areas - Sciences

Introduction and Background

While the nature of science (NOS) is a topic that is mentioned in science syllabuses from primary through to junior college or pre-university level, it has not given much attention in the enacted curriculum. Even at the initial teacher preparation level the topic has not been given much attention, owing to the perceived need to include many other more “basic” or “needed” topics in an already overcrowded curriculum.

However, it is felt by the authors that an understanding of the NOS is important to teachers as well as to students and should be addressed, if not at the pre-service level, then during in-service training. Hence it is felt there is a need for a simple and efficient method of sampling the NOS views.

By taking a “snap shot” of the NOS views of these two groups of teachers (in-service vis-à-vis pre-service), and through comparing their NOS views, we could derive a “rough idea” on how additional years of science teaching might have impacted the NOS views of teachers.

While there was a previous effort to sample the NOS views of pre-service teachers (Tan & Boo, 2004), it involved a rather long questionnaire (comprising eight rather lengthy questions), an adapted Views of the Nature of Science (VNOS) questionnaire, Form C, which has been validated and developed over two revisions (A and B) by Lederman et al. (2002). In the Tan and Boo (2004) study, the questionnaire was emailed to respondents and no time limit was set for the completion of the questionnaire.

In contrast, in the study reported in this paper, it was thought that a shorter and simpler questionnaire (comprising six questions, see Appendix) that could be administered and completed in about 15 minutes at the beginning of a course, during class time would be advantageous in terms of sampling the "on-the-spot" views of respondents. This simple paper-pen questionnaire concerns certain key aspects of the nature of science such as uniqueness of the scientific method, objectivity of scientific data, and immutability of scientific laws.

What do we mean by the nature of science (NOS)?

In this paper we adopt the meaning of NOS suggested in Lederman (1992), that is, "the values and beliefs inherent to scientific knowledge and its development". While the NOS is not an issue without contentious debate – especially in academic circles - there still exists a significant level of agreement on some of its more basic tenets. These include some of the points highlighted in McComas, Clough, and Almazroa (1998):

- Scientific knowledge, while durable, has a tentative character.
- Scientific knowledge relies heavily, but not entirely, on observation, experimental evidence, rational arguments and skepticism.
- There is no one way to do science (therefore, there is no universal step-by-step scientific method).
- Science is an attempt to explain natural phenomena.
- Laws & theories serve different roles in science, therefore students should note that theories do not become laws even with additional evidence.
- Observations are theory-laden.
- Science is part of social and cultural traditions.
- Scientific ideas are affected by their social & historical milieu.

Study Method

The study instrument comprises six items derived from some of the basic points of agreement on the NOS among science educators, sociologists of science and philosophers of science highlighted in the previous section as well as from the literature (Hodson, 1998; Kimball, 1967; Ledermann 1992, Lederman et al. 2002; McComas, Clough & Almazroa, 1998). All six items are presented so as to require a negative, or disagree, response to be conformant with the informed view of the NOS; a positive, or agree response, is indicative of an ill-informed view of the NOS.

Forty three teachers embarking on a Masters in Education Course and eighty pre-service teachers enrolled in a post-graduate diploma in education course were asked to complete the questionnaire. The pre-service teachers were enrolled in a chemistry curriculum studies module. The average number of years of teaching experience of the in-service group is 6. Each respondent was asked to read a statement pertaining to the NOS and then indicate their agreement or disagreement with the statement, and to provide reasons for their views.

Study Findings

A large percentage (almost 70%) of the pre-service respondents merely indicated whether they agreed or disagreed with each of the statements and did not provide reasons for their views. In

contrast practically all respondents in the in-service group provided reasons for their views, with only a small number (about 10%) not providing reasons for only one or two of the six statements.

The summary results are shown in the Table 1.

Table 1

Comparison of trained and untrained teachers views on certain aspects of NOS

	No of in-service teachers who agreed with the statement (N=42)	**No of pre-service teachers who agreed with the statement (N=80)**	**Difference in %**
	I	**P**	**P-I**
Statement 1. The process of observation is objective.	13 (31%)	37 (46%)	15%
Statement 2. Science involves constructing a body of knowledge by using the Scientific Method.	30 (71%)	64 (80%)	9%
Statement 3. Scientific knowledge is objective, and independent of culture and social context.	20 (48%)	42 (53%)	5%
Statement 4. Theories are made up of proven hypotheses.	27 (64%)	64 (80%)	16%
Statement 5. While a theory may be altered on the basis of new data, a physical law (e.g. Newton's law of gravitation) is permanent	21 (50%)	50 (63%)	13%
Statement 6. Emotions, feelings and values have no part in scientific acts of discovery or creation.	1 (2%)	17 (21%)	19%

The results above show that across all six items, a higher percentage of pre-service teachers agreed with the statements (ie had an ill-informed view of the NOS) compared to in-service teachers. The biggest difference in these percentages occurs with statements 6, 4, 1 and 5 in descending order.

For the in-service group of respondents, at least half of the respondents showed agreement to statement 2 (71%), statement 4 (64%) and statement 5 (50%).

For the pre-service group of respondents, at least half of the respondents showed agreement to the same statements as for the in-service group, viz., statement 2 (80%), statement 4 (80%), statement 5 (63%), plus **s**tatement 3 "Scientific knowledge is objective, and independent of culture and social context" (53%).

Some verbatim responses to each question from each group are provided below. The letter "M" preceding the Arabic numeral denotes a response from the in-service level participant while the letter "P" preceding an Arabic numeral denotes a response from the pre-service participant.

Statement 1. The process of observation is objective. An agreement to the statement would suggest an ill-informed view of the process of observation. The informed view is that observations are theory-laden, hence the process of observation is not objective, but is dependent, among other things, on the theories held by the observer. Hanson (1958) put it this way: what we see is determined by what we know.	
Agree	**Disagree**
M28 "The process is based on a set of rules by which the observer is to follow. Hence, as long as the rules are adhered to, the process will be objective. "	M5 "Whatever that is perceived by the senses is 'clouded' by our experiences."
M41 "Because observation should be something that you won't give any personal thoughts."	M38 "Depends on the training that the observer had received and the cultural and social background. The observer may be biased."
P1 "We must not be subjective while doing observations or bias will happen and affect the results"	P17 "In chemistry there are many examples of the fact that observations are not objective. There are often disagreements among students on the colour of substances (solids, liquids or solutions); and sometimes between students and the teacher/ textbook."
P4 "Observations are objective otherwise cannot explain why science is so successful; also why waste time to conduct practical tests that involve testing observing skills."	P29 "Observation depends on the person's perspective. Eg different people 'see' the same color differently/subjectively."

Statement 2. Science involves constructing a body of knowledge by using the Scientific Method.	
Here the Scientific Method refers to a series of logical steps that are supposed to be involved in the derivation of scientific knowledge (observing, formulating a hypothesis, collecting data and testing of hypothesis and inferring from data whether the hypothesis is to be rejected or supported). An agreement to the statement would suggest an ill-informed view. An informed view would suggest that there is no one single Scientific Method (McComas, Clough & Almazroa, 1998). Instead, various approaches and methods are used in the construction of scientific knowledge including the use of correlation studies, computer modeling, thought experiments as well as controlled experiments (Hodson, 1998).	
Agree	**Disagree**
M25 "Any observations in science must first be understood/reconstructed through replication of scientific concepts already established. This will be subsequently confirmed through experimentation and analysis of results."	M9 "Historical science like paleontology does not employ the scientific method in their construction of knowledge. It is impossible for the discipline to do so. But it is still considered science."
M38 "Science involves constructing knowledge by a series of logical steps and procedures/steps of coming out with new knowledge or verifying the old."	M28 "In some cases the scientific method may not work and other alternative methods could be used to analyse a piece of information and construct the knowledge."
P1 "To prove a hypothesis, the method must be scientific and understandable."	P3 "Science involves the understanding of phenomena around us. It needs not always to be proven using the Scientific Method."
P7 "Rationales and theories are built on results of testing through the scientific method, and these accumulate as a body of scientific knowledge."	P14 "constructing a body of knowledge can be by any means. Using scientific method is just one of the many ways a body of knowledge can be constructed involving science."

Statement 3. Scientific knowledge is objective, and independent of culture and social context. An agreement to the statement would suggest an ill-informed view of scientific knowledge. The informed view is that scientific knowledge is affected by social and cultural context (McComas, Clough & Almazroa, 1998).	
Agree	**Disagree**
M11 "Scientific knowledge in terms of laws hold regardless of cultures and independent of the backgrounds.	M17 "One's culture and social context does affect one's hypothesis which eventually lead to discovery."
M41 "Scientific knowledge should be based on theories, which are objective."	M43 "Pythagoras and his sect believed that numbers make up the universe. The Arab scientists were driven to study astronomy to determine prayer times, direction to Mecca, etc. The Mayans had an amazing arithmetic system to calculate the best times for human sacrifice."
P4 "Obviously. The knowledge gained from scientific observation and research does not involve culture and social context. If not, knowledge gained may be biased and distorted. "	P2 "Scientific knowledge can be formed from cultural and social inputs and various other attributes."
P7 "Scientific knowledge is built on observation of and understanding of nature and natural phenomena is independent of culture and social context."	P6 "Scientific knowledge is interfered by culture and social context in modern society. Something can be viewed as scientific knowledge in certain countries and rubbish in another."

Statement 4. Theories are made up of proven hypotheses. An agreement to the statement would suggest an ill-informed view. The informed view is a scientific hypothesis (or theory or a law) can never be absolutely proven regardless of the amount of accumulated evidence (Popper, 1963).	
Agree	**Disagree**
M11 "Hypotheses are formed from observations, tested and then are made theories."	M19 "Theories can be conjectured based on a body of hypotheses proven or not yet proven."
M42 "Well…this is what was written in my students' textbooks and what I taught them."	M27 "Proven hypotheses are considered law whereas theories are hypotheses which have not been proven."
P2 "Yes, proven theories are tested and verified by credible domain experts."	P6 "Sometimes hypotheses which remain unproven are considered as theories – if they makes sense and can give reasonable explanations for things that happen."
P4 "Hypotheses are just statements made by scientists without enough knowledge or research to prove it. Once hypothesis is proven, then it becomes a theory."	P8 "Not necessarily. Most theories are proven, but some are still not yet proven."

Statement 5. While a theory may be altered on the basis of new data, a physical law (e.g. Newton's law of gravitation) is permanent. This statement is related to statement 4. If a scientific hypothesis or theory or a law can never be absolutely proven, then it is subject to revision and change, and is thus not permanent (Lederman et al., 2002). The ill-informed view would agree with the statement .	
Agree	**Disagree**
M31 "A physical law is permanent as it governs how things work in our universe."	M42 "Laws, like theories, could be 'disproved' anytime."
M22 "Most physical laws do not change as they have been proven."	M7 "With new discovery, a physical law may be proved untrue."
M6 "Physical laws will be permanent; it is more likely that what will change would be when these laws can be applied and when they are not applicable."	M13 "Laws may be built on theories; when theories change, laws change."
P15 "Scientific laws are theories that have been subjected to much testing, and have been proven to be true. Thus laws are permanent while theories can be changed or discarded."	P5 "Physical law can be altered by elements that we have yet to discover."
P24 "A physical law is irrevocable, unlike a theory which can become outdated."	P37 "A physical law may be amended by new information or new discovery."

Statement 6. Emotions, feelings and values have no part in scientific acts of discovery or creation. This statement is related to statement 1. The ill-informed view would agree with this statement. In this view, observations are seen as objective, and the scientist is viewed as using the Scientific Method in an objective manner, without any involvement of emotions, feelings or values, to produce scientific knowledge through the process of induction. The informed view would regard emotions, strong feelings (passions) and values as playing an important role in acts of scientific discovery (Polanyi, 1967).	
Agree	**Disagree**
M39 "It will be best to exclude such factors into the scientific acts."	M3 "Many of the discoveries are due to the scientists' passion for the subject."
P4 "Emotions, feelings and values will distort information gained."	M22 "Very often, scientific discovery is not made known if it concerns ethical and cultural issues."
P7 "Emotions, feelings are difficult to control and are not reproducible. They introduce a lot of uncertainty."	M40 "For instance, stem cell research encounters lots of objections and research activities is hindered or stopped (just like in the U.S.)."
P23 "Scientists need to be very objective in their work. They should just follow the scientific method and not allow their feelings and emotions to affect their work."	P3 "Emotions, feelings and values do arouse the curiosity and interest in scientific acts of discovery."
	P6 "Sometimes feelings play an important role in scientific discovery."
	P6 "Emotions and feelings are products of neuronic reactions that are intricate scientific processes."

The responses show different interpretations of the statement. One interpretation concerns the involvement of emotions, feelings and values of the scientist doing the research; the other interpretation concerns the involvement of emotions, feelings and values of others or the society at large. Only one (2.4%) of the in-service respondents agree with the statement that emotions, feelings and values have no part in scientific acts of discovery or creation, compared with the 17 (21%) of the pre-service group who did so**.**

Discussion

The questionnaire returns show a shift in thinking from what might be called a "layman's" understanding of science demonstrated by the pre-service group to a thinking more in line with the accepted tenets of the NOS.

This layman's thinking of the NOS can be summarized in the following comparison with the scientist's representation of the NOS as represented by the eight basic tenets of the NOS identified by McComas, Clough, and Almazroa (1998). This layman's view is exemplified by many of the respondent comments. As with the previous tables, the letter "P" preceding an Arabic numeral denotes a response from the pre-service participant.

Lay view of the NOS	Scientists' view of the NOS
Scientific knowledge is absolute. Once an item of knowledge has been proven 'as fact' then it stands for all time. (P31)	Scientific knowledge, while durable, has a tentative character.
Scientific knowledge is elucidated through observation and experimental evidence. To be counted as science, theories must be tested through the scientific method. (P45)	Scientific knowledge relies heavily, but not entirely, on observation, experimental evidence, rational arguments and skepticism.
Science proceed by a well defined 'scientific method'. Any process that does not follow the scientific method is non-science. (P30)	There is no one way to do science (therefore, there is no universal step-by-step scientific method).
Theories become laws once they are proven to be true. (P15)	Laws & theories serve different roles in science, therefore students should note that theories do not become laws even with additional evidence.
Observations are objective. (P4)	Observations are theory-laden.
Science develops along its own lines that are independent of cultural development. (P4)	Science is part of social and cultural traditions.
Scientific knowledge transcends social and historical contexts. (P7)	Scientific ideas are affected by their social & historical milieu.

Why do the in-service teachers appear to have an understanding of the NOS that is slightly better aligned to the accepted NOS view when they have not been exposed to any specific NOS training?

We can make a number of speculations that are worthy of detailed investigation.

1. The in-service teachers have read widely about science topics outside the constraints of structured learning and have therefore developed a more mature understanding of the NOS than the pre-service teachers who are still heavily influenced by their structured formal education.
2. The in-service teachers have been motivated to take a wider view of science through having to answer their pupils' naïve questions.

Conclusion

The results show that the majority of the respondents gave answers which were classified as ill-informed (such as for statements 2 and 4); but at the same time gave responses to other statements (such as statements 3 and 6) which were classified as informed. This could mean that the majority of the respondents do not have informed views of NOS, which is not surprising since practically all of them had not yet been exposed to formal courses that include understanding of NOS as an explicit instructional objective.

The agree/disagree questionnaire has been found to be a fairly useful instrument for accessing the NOS views of pre-service and in-service teachers.

The first author will be including understanding of NOS as an explicit instructional objective in an in-service module and has the intention of using the questionnaire as a pre and post treatment measurement instrument. Consideration will be given to augmenting the questionnaire with interviews to determine more about the specific influences that determine change in NOS understanding.

A further potential area of application will be a longitudinal study with new teachers to determine more about how their NOS views develop through the years of professional development.

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Appendix

Read each statement below and circle 'A' if you agree with the statement and 'D' if you disagree with it. Please provide reasons. Use reverse side of paper & attach additional papers if necessary.

A or D 1. **The process of observation is objective.**
Reasons:

A or D 2. **Science involves constructing a body of knowledge by using the Scientific Method.**
Reasons:

A or D 3. **Scientific knowledge is objective, and independent of culture and social context.**
Reasons:

A or D 4. **Theories are made up of proven hypotheses.**
Reasons:

A or D 5. **While a theory may be altered on the basis of new data, a physical law (e.g. Newton's law of gravitation) is permanent.**
Reasons:

A or D 6. **Emotions, feelings and values have no part in scientific acts of discovery or creation.**
Reasons: