International Review of Contemporary Learning Research
ISSN (2210-1438)
Int. Rev. Cont. Lear. Res. 3, No. 2 (July-2014)

Examining the Views About the Nature of Science Among Elementary Pre-service Teachers

Issa M. Saleh [1] and Myint Swe Khine [2]

[1] *Bahrain Teachers College, University of Bahrain, Kingdome of Bahrain*
[2]*Emirates College for Advanced Education, Abu Dhabi, United Arab Emirates*

Received 1 February 2014, Revised 15 April 2014, Accepted 15 May 2014, Published 1 July 2014

Abstract: Despite the curricula differences in science teaching, science educators tend to agree that the adequate understanding of the nature of science or an understanding of science as a way of knowing is a desired outcome of the science instruction. Many approaches has been introduced and contextualised in different situations. Some researchers argue that teacher preparation programs in the Arab countries do not expose the preservice teacher education students with epistemology and sociology of science, but merely focus on the scientific content knowledge. A study was conducted in the United Arab Emirates to find out the views about the Nature of Science (NOS) among Emeriti preservice teacher education students using the Views on Nature of Science Form C (VNOS-C). The paper reports the findings and suggests some possible areas of future research in this context.

Keywords: Nature of science; Preservice teacher education; VNOS-C; Religion; Science education

1. Introduction

Countries around the world recognize the fact that science and technology contribute to their economic prosperity, social advancement, and help sustainable development of their nations. Science education has always been a priority in their education planning. Different approaches have been used to popularize science and to encourage curiosity and imagination of students with respect to science, both in schools and out. There are still many challenges lie ahead in promoting science education to a wider range of students, so a multifaceted approach will be needed in formal and non-formal education settings (Khine and Saleh, 2010).

Education authorities in each country decide on what topic to teach at what level, so science curricula vary from one country to another. Lederman (1992) notes that despite the differences in curricula, science educators tend to agree that the adequate understanding of the nature of science or an understanding of science as a way of knowing is a desired outcome of the science instruction. Many approaches have been made to introduce the nature of science in the past. Akerson and Donnelly (2010) highlight the importance of contextualised NOS instruction that can be embedded into science content. Haidar (1999) argues that teacher preparation programs in the Arab countries mostly focuses on teaching scientific content knowledge, therefore pre-service teachers were usually not exposed to the epistemology and sociology of science.

2. The Nature of Science: Definition and Characteristics

The phrase ‘nature of science’ (NOS) has been defined by academics and researchers in different ways. While there is no universally accepted definition, a widely quoted explanation is provided by Lederman (1992). He refers to NOS as the epistemology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development. Clough and Olson (2008) argue that “NOS refers to issues such as what is science, how it works, the epistemological and ontological foundations of science, how scientists functions as a social group and how society influences and reacts to scientific endeavours”.

E-mail: mskhine@ecae.ac.ae; ***isaleh@uob.edu.bh***

3. Importance of the Nature of Science in Science Education

It is important to distinguish 'scientific knowledge' from 'knowledge about science'. Taber (2008) noted that science education traditionally involves teaching science concepts, developing students' attitudes towards science, engaging in practical experiments and develop thinking skills. But in recent years there has been increased focus on teaching students about the NOS. He describes NOS as a complex theme, which continues to be the subject of interest among science educators, as well as scholars from other disciplines.

Lederman and his research team and colleagues over the past 20 years have focused on the following characteristics of scientific knowledge in their research on NOS (Lederman, 2006):

- Scientific knowledge is empirically based and is generally derived from observations of natural phenomena. These observations are always influenced by human assumptions and previous knowledge and thus theory-laden.
- Science knowledge is never absolute or certain although it is generally considered to be highly reliable or durable. The advances in technology and knowledge provide new evidence and questions previous claims. Scientific theories are subject to change, thus science has a tentative nature.
- Scientific knowledge is socially and culturally embedded. The traditions and values of a scientists' culture exert and influence on his/her attitudes and interests. Science is not confined to a narrow and western view of knowledge, ideas and theories from all other cultures contribute to the world view of science.
- There is the distinction between observation and inference in science. Observations are descriptive statements about natural phenomena that are directly accessible to the senses. Inferences are statements about phenomena that are not directly accessible to the senses.
- Scientific knowledge is subjective and can never be totally objective. The scientists' background such as training, beliefs, and experience affects the decisions on the how the study is conducted and interpreted the observations.
- Scientific laws and theories are different types of knowledge and serve different roles in science. Therefore scientific theories cannot become scientific laws, and scientific laws are not a higher form of scientific knowledge.
- Science is empirical and scientists are involved in creating hypotheses, making inferences, explaining phenomena and constructing theories, so there is also a creative and imaginative aspect to scientific knowledge.

4. Elementary Pre-service Teachers' View of the Nature of Science

The views, understanding, and conceptions about the NOS among elementary pre-service teachers are widely researched topics in the science education literature. Abell and Smith (1994) note that science literacy, the ultimate goal of science education, is understanding not only scientific knowledge but also the NOS. They have analysed the definition of science as described by 140 mostly female preservice teachers who were undertaking an elementary science content course. The authors assert that students have a view of the NOS dominated by a naïve realist perspective. They also note that students fail to see science as a unique discipline and display lack of understanding of the NOS. It was suggested that richer images of science are needed to be portrayed to the preservice teachers in order to deepen their understanding of the NOS.

Gustafson and Rowell (1995) attempted to find out the conceptions about learning science, teaching science and the nature of science among students in an undergraduate elementary science education course. At the beginning of a science course a total of 27 students were given an initial questionnaire to elicit their background information and opinions about how children learn science. A final questionnaire was administered at the end of the course to comment on how and why their views had or had not changed. Interviews were also conducted to probe further on these issues. The result from the initial questionnaire reveals that majority of them believe that learning means gaining information and children learn science through hands-on physical manipulation. The analysis of the final questionnaire shows the evidence of students expanding their initial ideas about science teaching.

Another study by Craven, Hand and Prain (2002) explored the perception of NOS among elementary preservice teachers. They designed a 15-week course to teach the students about NOS and move the students' limited view of NOS to a richer, socially constructed view. They found notable changes in the langue students used to describe both NOS and the scientific enterprise. They suggest that continued efforts are needed to address the understanding of NOS at the primary level and that teachers should not expect students to learn the NOS implicitly. They further suggest that providing students with opportunities to express both their tacit and explicit knowledge of the science may lead to developing a richer and fuller conception of science.

As described above, numerous studies have been conducted on the views, understanding and conception about the nature of science among preservice teacher education students in the past decades. However the study involving preservice teachers in this context is minimal. This study made an attempt to find out the views about the NOS among Emeriti preservice teacher education students.

5. The Research Instrument

Lederman, Wade, and Bell (1998), in a review of assessment instruments used to determine NOS conceptions, noted that most of these instruments were of the forced-choice nature (agree/disagree, Likert scale and multiple choice). The authors criticised many of the instruments used over the last forty years. Of the major difficulties encountered, the validity of the instruments were called into question on two accounts. Firstly, the instruments were predicated upon the assumption that the respondent would interpret the instrument items in the same manner as the researchers. Secondly, as they were forced-choice, the instruments tended to reflect the biases of the developers on the respondents.

As a result, researchers began to develop open-ended instruments, with emphasis on descriptive questions, together with interviews that allowed meaningful assessments of the individuals' NOS views. Lederman et al. (2002) developed such a questionnaire, focusing on aspects of the NOS such as (a) its empirical nature; (b) the relation between observation, inference and theoretical entities in science; (c) the distinction between theories and laws; (d) the creative and imaginative nature of scientific knowledge; (e) the theory- laden nature of scientific knowledge; (f) the social and cultural embededness of scientific knowledge; (g) the myth of the scientific method; and (h) the tentative nature of scientific knowledge.

After passing through 2 prior versions of the questionnaire (Forms A and B), with VNOS-B being validated by comparison between expert and novice groups, the authors propose VNOS-C. Validity of this latter instrument was tested with undergraduate and graduate college students, pre-service elementary teachers, and pre-service and in-service secondary teachers. By comparing and contrasting NOS profiles of participants produced from separate analyses of the questionnaire and interview transcripts, it was found that "interpretations of participants NOS conceptions as elucidated from the VNOS-C were congruent to those expressed by participants during individual interviews". (p. 511)

The authors stress that the validity of such an instrument is not a final "once-and-for-all" state, and emphasize that the principal source of the instrument's validity evidence stems from the follow-up interviews, where it is possible to check respondents understanding of items. Lederman and co-workers also claim that the questionnaire is developed with an interpretive stance in mind, with aims to elucidate learners' views rather than for labeling their views as adequate or inadequate.

6. Procedures for Data Collection

The sample for this study consisted of pre-service teacher education students who are studying The Teaching of Science II module as part of their third year degree program. The students were given the VNOS-C questionnaire during the normal class time. They are instructed to respond to each question stated in the questionnaire. They were reminded that they must use their own opinion and not to discuss with each other or refer to any sources, either textbooks or the internet. They were also assured that the questionnaire is not a test and will not be part of the assessment. The total number of 42 students participated in the study which amount to 30% of the entire cohort of third year students.

The responses were coded by one of the researchers. For each question, a category was assigned as informed, ill-informed, or ambiguous. The assigned categories were checked again by an independent inter-coder. It was found that the agreement between two coders was 90%.

7. Analysis, Results, and Discussion

The following paragraphs enumerate and describe the detail analysis of each question.

- *Question 1:*

  What in your view is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?

"Science is the study of entities that exist in the universe. Scientific disciplines are more logical than other disciplines and the former provides explanations with facts and proofs."

61% of the answers for this question were ambiguous. None of the students made any reference to the definition of science as a study. Most of the students made a comparison of science to religion which is interesting. This could be due to the context in which the study was conducted. All the students in the study follow the Muslim faith. Also, it was obvious from the response of the students that many did not pay attention to the question itself rather they reacted in responding. For example, Student 1 writes "Science is connecting to religion and philosophy. In other words, when we have idea, the science explains how it happens." As we can see from this example how the student is not only vague but also not answering the question at all but somehow relating it to religious beliefs. Another similar example of an unclear answer is from Student 2 who writes " The difference in science that knowledge to learn from live, school but other religions learn about our religion what we must do in our life." As we can see from the response of this student, not only was the student unclear but it also very difficult to follow what the student is trying to say. This is partly to so with the challenges of the Arabic speaking students' in the Middle East with the English language. Student 3 writes, "The science is the different than another inquiry because it solves the people problem from the discovering new things." Here the Student 3 attempts to answer the second part of the question; however, the student negates the fact that other disciplines of inquiry do try to solve people problems. Student 4 writes for this question, "the study of life" and fails to answer the second part of the question. Here the Student 4 does not consider that in science we do study non- living things as well and fails to compare science with other areas disciples.

- *Question 2:*

  What is an experiment?

  "A carefully planned activity designed to answer a question or test a hypothesis."

The result of this question was similar to the first question, in that 61% of the students' answers were ambiguous. Most of the students made a reference to the importance of applied knowledge but did not answer the question. 28% of the students did not answer the question at all and only 9 % answered the question. Some of the answers of the students were about the importance of students applying what they learned. For example, Student 5 writes for this question " an experiment is to put things to create the new product." As we can see from the answer Student 5 does not attempt to answer the question, but rather attempts to give an explanation on what an experiment can produce while failing to define what an experiment is. Another example was from Student 6 who writes, "Through the experiments we can prove the theories." Again Student 6 does not define what an experiment is, hence his answer is vague. Student 7 looks at experiments as procedures and writes, "Use some materials and follow the steps to prove something". However, this student does not explicitly tell what the steps are for and what the purpose of having these steps is. Similarly, Student 8 writes, "observe something, to discover new thing or to know how or why something works." which does not address the core of experiment which is a question.

- *Question 3:*

  Does the development of scientific knowledge require experiments?

  -If YES, explain why. Give an example to defend your position.

  -If, NO, explain why. Give an example to defend your position

"Yes. To confirm truth and validity of scientific theory and inquiry [experiments are necessary]. Without experimental validity, there is no scientific knowledge. There is only blind faith."

50% of the students were able to answer this question which was surprising compared to question one and two, where only 14 % had an informed answer to the question. The students emphasized in their answer the importance of validating scientific knowledge through experiment. The 50 % that answered the question correctly expressed in their writing what a theory is in detail. Example of some of the response of the students is as follows: Student 9 writes, "Not necessarily". The only way we can understand what is going on in the mind of Student 9 would be to conduct a structured interview. This could be that the student either did not understand what experiment stands for or the idea of scientific knowledge. On the other hand Student 10 writes, "I think yes, to know if you're explaining correctly." This student answers the first part correctly but the second part of his answer is vague. Another interesting answer was from Student 11. She writes, "Yes because experiment is evidence about scientific proofs and ideas." Student 11 does not seem to understand the reason for doing experiments by the mere fact that she thinks that an experiment is evidence. Student 12 gives an example but it is difficult to make sense of what the student is trying to say. The student writes, "Yes, volcano, how it is happen? Explain by experiment and see the relationships of the reactions". Hence this response was categorized as vague. Student 13 writes, "Because the scientists did the experiment to discover the world." Here we are not sure what the student is trying to say. She does not link scientific knowledge with experiment and does not explain how they are linked.

- *Question 4:*

  After scientist have developed a scientific theory (e.g. atomic theory, evolution theory), does the theory ever change?

  -If you believe that scientific theories do not change, explain why. Defend your answer with an example.

  -If you believe that scientific theories do change: (a) Explain why theories change? (b) Explain why we bother to learn scientific theories? Defend your answer with example.

"Scientific theories do change because theories are suggested proofs and are not actual proofs or facts."

The majority of the student teachers had answered this question correctly (54%) and only 6 out of the 42 students had ill-informed views about this question. A lot of the students had long answers for this question by making a reference on the constant expansion of knowledge and information over the years. Furthermore, many students gave many examples to make this point. For example, Student 14 writes, "Yes, because the scientists when discover something the other scientists complete what they do and get new results." Even though, this student answers the first part to the question correctly, his explanation is a bit vague. The Student14 talks about the idea of building of one idea to another idea and building it to make other ideas. The answer is not clear at all. Student 15 writes, "No, the theory does not change for the life but we can improve and add on it." This student view not only has ill informed view but also his explanation does not make sense. Another interesting answer is form Student 16 who writes, "Yes, because the world is moving and continuous changing. For example the earth is moving around itself and around the sun. The speed of moving is changing because the environment is changing." The problem here with Student 16 is his explanation, which is vague and does not make sense. Student 17 links the change of theories over time with technology, which is also problematic. She writes, "Yes, in my opinion I think some scientific theories change because we have (now) useful and better technology than before. We learn theories because it's helps to understand some issues that we cannot understand." Does that mean that the only reason scientific theories change is when we have technology. She will be a great candidate for a structured interview to clarify her views about this question.

- *Question 5:*

  Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.

"Scientific theory is a hypothesis that has not been proven yet. For example, evolutionary theory."

20 out of the 42 students had ill- formed views for this question and only 13 had informed view. The ill-informed view is not all surprising because even in some science text books this misconception still exists. The misconception that a theory eventually becomes a law over time. Some of the students did not make a distinction between a scientific theory and a scientific law but explain what a theory is. For example, Student 18 writes, "Yes, I believe the scientific theories do change because in every moment we can correct the wrong are or complete the other" others were very general and also did not explain the difference between a scientific theory and a scientific law. For instance, Student 17 writes, "Because every day the world change and our life develop." Similar response to Student 17 was from

Student 19 who writes, "Some of the scientific theories can be change if we do more search and have more results." In contrast, some students did not think that scientific theory can change but think that it can be improved without being changed, an example of this type of an answer was from Student 20 who writes, " I think it not change but it can developed or improve it." Interesting for the examples and from the whole sample, most of the students did not make a comparison between scientific theory and a scientific law with the exception of the students that had an informed view.

- *Question 6:*

  Science textbooks often present the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting that nucleus. How certain are scientists about the structure of the atom? What specific evidence do you think scientists used to determine what atom looks like?

"Since they can provide the structure of the atom universally in textbooks and reference books, I think that they must be very certain of it. Maybe they look at it at a microscopic view."

66% of the student teachers had ill formed view of the structure of the atom and how scientists decide on the models of the atom. Very few students mentioned the Rutherford alpha scattering experiment but none of the students talked about black box type experiments that are commonly mentioned in most text books. Overall most of the students did not try this question, they just state that they did not know the answer to this question. Some of the students did not understand the question judging from their answers. For example, Student 21 writes, "In my opinion, it depends on hypothesis." This student would be a good candidate for a follow up interview for clarification of her answer. Student 22 writes, "They use experimenting, searching, completing each other's study to proof each. They also develop the knowledge through depending on other theories and facts that support their researches." Student 22 answer does not address the question that has been asked, but rather describes the process of doing research in science. Also, he does not explain the idea of certainty of knowledge in science. Student 23 writes, "The earth has magnetic N--- S." I was not sure what the north and South Pole or the magnetic field of the earth had to do with this question. This will be another example of a student not understanding the question being asked. Student 24 and Student 25 write," I think they use sold and liquid stuff to make experiment on them and maybe they discover and determine what atoms looks like" and " I think they did experiment, use materiel, use rocks and many else" respectively. Here both students describe what scientists could have used to determine the structure of atoms but does not again address the idea of certainty of knowledge in science.

- *Question 7:*

Science textbooks often define a species as a group of organisms that share similar characteristics and can interbreed with one another to produce fertile offspring. How certain are scientists about their characterization of what a species is? What specific evidence do you think scientists used to determine what a species is?

"Single type of organism; individuals of the same species can interbreed to produce fertile offspring."

More than 50 % of the participants did not have the correct view about how scientists characterize species and they could not come up with evidence to support their view point. Also, most of the students did not understand what a species is and, as a result, they cannot answer the question that follows. This could be due to the extent of this particular topic being addressed in the high school text books. In retrospect, most of the students that participated in the study come from an Art stream high school and not from the science stream. This could be the cause for not answering the question correctly. Looking at some of the specific examples that were categorized as ambiguous, Student 11 writes, "Use plants type and do experiment with it. Make the experiment then". Here Student 11 does not explain how plants can help to characterize what a species is and does not give evidence as well to support his view. Similar example is from Student 17 who writes, "By observing and experimenting." This student states the process but fails to give specific evidence to support his answer. Student 19, "Throw the experiment and separate the organisms to group that share similar characteristics such as amphibious, predatory, and tame." This particular student states a process but does not address the question being asked. Student 30 gives evidence but the evidence does not make sense or the explanation, she writes," They build their research on other old researches they experiment first to get a result that can proof their views. Such as DNA, genes, and other characters. " Some of the students writes about the process of doing research, but do not answer the question directly. For instance, Student 31 writes, "they do a lot of experiment to collect the information about the characterization of species." This student writes on the procedure how to go about doing the investigation but fails to give evidence about the specific evidence that scientists use to determine what a species are.

- *Question 8:*

It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?

"The same piece of evidence or the same set of data can be subject to multiple interpretations."

27 of the 42 participants had an ill-informed view and only 7 participants had an informed view. Most the participants did not attempt even to answer this question. This could be due to the length of the question or not understanding the question. The questions were translated, which makes the question even longer. We are planning to investigate this question further in structured interview with the participant to find out if the students understand the question or not. Some of the students failed to talk about the idea of data interpretation in science. For instance, Student 8 writes, "different science has different views and depends on different knowledge." This particular student fails to mention the notion of interpretation of data but states an unclear view. Others try to explain in terms of religion but fail to clarify. For example, Student 9 writes, " In my opinion, nothing of what they did or discovered is write because in our religion we know that the life is change depends on the time so if we think if we have dinosaurs know in our life we will we be life?". Close look at this response seems that the student is reacting at the question without understanding the question when the student writes. She does not believe there is an objective truth in science but only in religion. Student 19 writes, "Maybe because they have different thinking and factors that help them analyse this hypothesis." This particular student did not understand the whole question because the factors are the same for both situations and the only difference is the interpretation of the data and not the factors. Another example of not understanding the question is from Student 3 who writes, "dependence of situation or solve skills." This particular student fails to state the fact a piece of data or evidence can be subjected to multiple interpretations.

- *Question 9:*

  Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.

  - *If you believe that science reflects social and cultural values, explain why. Defend your answer with example.*
  - *If you believe that science is universal, explain why. Defend your answer with examples.*

"Science should be universal and scientific knowledge should be the intellectual property of all mankind / Social and political values are sometimes reflected in interpretation of data .Statistics and data on the causes and effects of ozone depletion and the subsequent warming of the globe may be interpreted differently by different interest groups. Wealthy industrialist economies tend to downplay these effects as they stand to lose most if any curbs on industrial activities were to be implemented."

64% of the participants think that science reflects social and cultural values and only 7% believed that science is universal. Most of the students who had ambiguous answers could not defend their view correctly or their answer was not clear at all. Similar to question number 8, the length of the question could have played a role to this question as well. If the students' comprehended the question or not could be addressed in structured interview with the particular students. Some of the students also confuse the difference between social science and natural sciences. This could be due to the fact that in some schools in United Arab Emirates their social science courses like religion are integrated with the hard sciences like biology. The following were the response of some of the students that either the responses were not clear or did not give a specific examples:

- Student 1 writes," I think this true because science connects between experiment and universal."
- Student 11 writes "I believe science is universal."
- Student 41 writes," I think it could be both because some scientists build their knowledge by collaborating with others from countries around the word."

As we can see from the responses above, none of the students gave a specific example and the answers were vague as well. Other responses had a religious angle but it was a bit difficult to make sense of the examples the student used to answer the question. For instance, Student 27 writes, "absolutely I believe that science reflect social and cultural values and if you ask me why I can tell you that only science things we can read about it in Holy Quran and some of our Prophets Mohamed peace be up on him Hadith. It is all according to what Islam teach us."

- *Question 10:*

  Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?

  - *If YES, then at which stages of the investigations you believe scientists use their imagination and creativity: planning and design, data collection, after data collection? Please explain why scientists use imagination and creativity. Provide examples if appropriate.*
  - *If you believe that scientists do not use imagination and creativity, please explain why. Provide examples if appropriate.*
  -

"Yes, I think [the scientists] do [make use of creativity and imagination]; especially in the early stage of their investigation when they are trying to frame the problem, and make sense of it. But as they proceed to verify their prediction they employ the objectivity and critical mindset required of them"

23 out of the 42 student teachers had an ill-informed view about this question, which is more than 50% of the participant on the study. It is interesting that so many students did not think that creativity and imagination played a role in investigations. From the student answers, they related creativity and imagination with social sciences and not with the hard sciences. Some of the students considered creativity and imagination not to be as important to do investigation. For example, Student 9 writes, "I think the science could not be from scientist's imagination because we need to be real." The response of this student implies that imagination is not real hence cannot be used in an investigation, which is an interesting view. Similarly, Student 42 has the same view she writes, "Because if they use their imagination so all their prediction will not be true and their prediction will not be sure." Some of the others that view imagination to be

important in an investigation did not mention that the imagination was critical during the framing of the problem and not during later stage of the investigation. For instance, student 37 writes, "Yes they use imagination and creativity because that they called scientists, in planning and designing, data collection,…etc to discover the new information right ."

CONCLUSION AND RECOMMENDATIONS

This study attempted to explore the views about the NOS among Middle East preservice teachers who are predominantly females. The results show that many of the NOS aspects are either ill-informed or ambiguous. This seriously challenges the science educators to make NOS more explicit and thereby foster scientific habits of mind among students. This study opens up many possibilities for further research and investigations. Among these possibilities are (i) the causes of high number of students being ill-informed and ambiguous on the views of NOS, (ii) are these phenomenon gender related, (iii) what instructional materials are they exposed to and how well these materials cover various aspects of NOS and (iv) which strategies will work better in weaving NOS aspects in their everyday science lessons.

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