Understanding of Nature of Science (NOS) among Pre-service Teachers and Teacher Educators

Mamta Singhal*

Abstract

The place of Nature of Science (NOS) in science curricula has been emphasised worldwide. NOS is considered an important component of scientific literacy. Science educators and researchers have given various arguments to support the inclusion of Nature of Science as an important component in science education. The policy frameworks and the researches in the field of science education have indicated the need to conduct systematic research on Nature of Science at all levels—school, college and teacher education—and disseminate the findings widely at the national level. In India, the concerns about NOS are being raised at the level of curriculum reforms. Position paper (1.1) on Teaching of Science, NCERT (2006) advocated scientific literacy; distinction between science and technology; relationship of science, technology and society; process of science; and understanding the historical and developmental perspectives of science at all levels of school education. These goals cannot be accomplished without an emphasis on Nature of Science. Despite these recommendations, the traditional pedagogical approach, lack of resources and lack of support to the teachers lead to no significant changes in the practical scenario in terms of inclusion of NOS. The teacher education programmes have also recognised the need of developing an understanding of NOS among prospective teachers and hence included some units on Nature of Science in their syllabi. However, most teacher educators and prospective teachers do not seem to give enough importance to this. The study explored the understanding of NOS among pre-service teachers and teacher educators of Bachelor of Education (B.Ed.) programme of three universities in Delhi.

* Tower- 1 / 902, Vipul Greens, Sohna Road, Gurgaon – 122018, Haryana, India.

Introduction

Nature of Science (NOS) has been emphasised by several curricular reforms worldwide over the last hundred years. In two major reports, 'Science for All Americans' (AAAS, 1990) and 'Benchmarks for Science Literacy: Project 2061' (AAAS, 1993), the importance of understanding NOS for different stages of school education is emphasised. According to AAAS (1993), the study of science as an intellectual and social endeavour, the application of human intelligence to figuring out how the world works, should have a prominent place in any curriculum that has science literacy as one of its aims. Driver, Leach, Millar and Scott (1996) present the following five arguments in favour of NOS as a goal of science education—

Utilitarian: Understanding NOS is necessary to make sense of science and manage the technological objects and processes in everyday life.

Democratic: Understanding NOS is necessary for informed decision-making on socio-scientific issues.

Cultural: Understanding NOS is necessary to appreciate the value of science as part of contemporary culture.

Moral: Understanding NOS helps in developing an understanding of the norms of the scientific community that embody moral commitments that are of general value to society.

The arguments in favour of teaching NOS are supported by several other researchers. According to Duschl (1994), "Knowledge about the scientific enterprise is potentially more important than knowledge content". He further asserts that students are learning 'what' of science but are not learning the 'how' of science.

The teacher education programmes have also recognised the need of developing an understanding of NOS among prospective teachers and hence included some units on Nature of Science in their syllabi. However, most teacher educators and prospective teachers do not seem to give enough importance to this. The study explored the understanding of NOS among pre-service teachers and teacher educators of Bachelor of Education (B.Ed.) programme of three universities in Delhi, India.

Objectives of the Study

1. To explore understanding of Nature of Science (NOS) among pre-service teachers pursuing B.Ed. programme.
2. To explore understanding of Nature of Science (NOS) among teacher educators teaching in B.Ed. programme.
3. To suggest a theoretical framework for developing an understanding of Nature of Science (NOS) among pre-service teachers and teacher educators.

Design of the Study

In the current study, the researcher used the mixed method research design (embedded form). Both the qualitative and quantitative tools were used for data collection simultaneously. The data was triangulated to arrive at the interpretations and findings. The researcher used the following tools and techniques to collect data.

- Understanding of Science and Scientific Inquiry (SUSSI, 2008) scale.
- Semi-structured interviews with pre-service teachers and teacher educators.

Sample

- **Pre-service Science teachers in the B.Ed. programme** — A total of 70 students from the B.Ed. programme of three universities located in Delhi participated in the study. These students had opted for at least one Pedagogy of Science course in the B.Ed. programme. While the data using the standard tool SUSSI was collected from all 70 students, interviews were conducted with only 40 of them.
- **Teacher Educators in the B.Ed. programme** — A total of 30 teacher educators from the pedagogy of science courses in the B.Ed. programme of the three universities participated in the study. While the standard tool SUSSI was administered to 30 teacher educators, interviews were conducted with only 15 of them.

Insights from Data Collection and Analysis

The data was collected using the standardised test SUSSI (2008), developed by Ling L. Liang, Sufen Chen, Xian Chen, Osman Nafiz Kaya, April Dean Adams, Monica Macklin and Jazlin Ebenezer of La Salle University, Philadelphia, USA. The test had both subjective and Likert-type items which were analysed separately, following the guidelines given by its authors. The SUSSI instrument used for data collection consisted of 24 Likert-type items categorised under six themes. Each of these items was marked from SD (strongly disagree) to SA (strongly agree) on a five-point Likert scale. Also, each item was marked as positive or negative as per the scoring guidelines given by the authors. The positive items scored from 1 (for SD) to 5 (for SA). The negative items scored from 5 (for SD) to 1 (for SA). For the Likert items, the subjects' views were classified as naïve views if none of the four responses received a score > 3 within each theme. The subjects' views were classified as informed views if all the four responses received a score > 3 within each theme. Further interviews were conducted to gain deeper insights about the various aspects of NOS.

The following aspects of NOS were examined using SUSSI as well as interviews.

Aspect 1: Observations and Inferences — Science is based on both observations and inferences guided by scientists' prior knowledge and perspectives of current science. Multiple perspectives can lead to multiple valid inferences.

Aspect 2: Tentativeness of Scientific Knowledge — Scientific knowledge is both tentative and durable. Scientific knowledge is reliable; though it may be abandoned or modified in light of new evidence or re-conceptualisation of existing evidence and knowledge. The history of science reveals both evolutionary and revolutionary changes.

Aspect 3: Scientific Laws and Theories — Both scientific laws and theories are subject to change. Laws describe generalised relationships, observed or perceived, of natural phenomena under certain conditions. Theories are well-substantiated explanations of some aspect of the natural world. Theories do not become laws even with additional evidence; they explain laws.

Aspect 4: Social and Cultural Embeddedness in Science — Science is a part of social and cultural traditions. People from all cultures make contributions to science. As a human endeavour, science is influenced by the society and culture in which it is practised. The values and expectations of the culture determine what and how science is conducted, interpreted and accepted.

Aspect 5: Creativity and Imagination in Science — Scientific knowledge is created from human imagination and logical reasoning based on observations and inferences of the natural world. Imagination and creativity are used in all scientific investigations.

Aspect 6: Scientific Method — There is no single universal step-by-step scientific method that all scientists follow. Scientists investigate research questions with prior knowledge, perseverance and creativity. Scientific knowledge is constructed and developed in a variety of ways including observation, analysis, speculation, library investigation and experimentation.

The data collected using SUSSI and interviews was triangulated to arrive at the interpretations. For this purpose, the researcher calculated the weighted average of percentages obtained on the basis of SUSSI score on quantitative aspect, written responses on qualitative aspect of SUSSI and the interview responses. The SUSSI score was assigned a weightage of 40 per cent, written responses on SUSSI a weightage of 20 per cent and the interview responses a weightage of 40 per cent.

(A) Quantitative Analysis of Pre-service Teachers' (B.Ed. Students') and Teacher Educators' Understanding of NOS based on SUSSI

The percentage of B.Ed. students and teacher educators on each aspect of NOS under the three categories— Naïve, Transitional and Informed — on the basis of their scores on SUSSI, is shown in Tables 1a and 1b.

Table 1a
Percentage of B.Ed. Students in Each Category based on SUSSI

	Aspect 1	Aspect 2	Aspect 3	Aspect 4	Aspect 5	Aspect 6
Naïve	10%	19%	80%	57%	44%	24%
Transitional	55%	28%	18%	28%	34%	28%
Informed	35%	53%	2%	15%	22%	48%

Table 1b
Percentage of Teacher Educators in Each Category based on SUSSI

	Aspect 1	Aspect 2	Aspect 3	Aspect 4	Aspect 5	Aspect 6
Naïve	25%	17%	76%	58%	30%	29%
Transitional	45%	28%	13%	27%	25%	28%
Informed	30%	55%	11%	15%	45%	43%

(B) Qualitative Analysis of B.Ed. Students' and Teacher Educators' Understanding of NOS on Various Aspects of SUSSI

The qualitative analysis included the responses to the subjective part of SUSSI. The responses on each dimension were studied thoroughly and compared with a rubric constructed by the researcher for each dimension on similar lines as suggested by researchers of SUSSI (see Tables 2a and 2b). The rubric had four categories—'Naïve views', 'Informed views', 'Transitional views' and 'Not classified'.

Table 2a
Percentage of Pre-service Teachers in Each Category based on Written Responses

	Aspect 1	Aspect 2	Aspect 3	Aspect 4	Aspect 5	Aspect 6
Naïve	25%	25%	58%	44%	45%	28%
Transitional	32%	22%	12%	16%	28%	35%

Informed	18%	48%	2%	18%	19%	30%
Not Classified	25%	5%	28%	22%	8%	7%

Table 2b
Percentage of Teacher Educators in Each Category based on Written Responses

	Aspect 1	Aspect 2	Aspect 3	Aspect 4	Aspect 5	Aspect 6
Naïve	22%	10%	68%	51%	32%	30%
Transitional	40%	24%	18%	27%	18%	35%
Informed	27%	54%	6%	15%	40%	30%
Not Classified	11%	12%	8%	7%	10%	5%

(C) Interviews with B.Ed. Students and Teacher Educators

The researcher conducted in-depth interviews based on various aspects of NOS with the participants in order to supplement the data collected through SUSSI. The interviews were semi-structured in nature. The researcher prepared 4–5 questions on each aspect of Nature of Science. The questions were prepared after going through the subjective dimensions of SUSSI so that some questions that could not be addressed through SUSSI can be understood through interviews. The same set of questions was used with students as well as teachers; however, a flexible approach was used both with the teachers and students. Before administering the interview questions to the actual sample, the interviews were pilot tested on a similar sample of teachers and students. The students and teachers were categorised into naïve (N), transitional (T) or informed (I) category based on their responses.

The analysis of participants' responses during interviews on various aspects is presented in Tables 3a and 3b.

Table 3a
Percentage of Pre-service Teachers in Each Category based on Interviews

	Aspect 1	Aspect 2	Aspect 3	Aspect 4	Aspect 5	Aspect 6
Naïve	23%	27%	81%	55%	44%	30%
Transitional	50%	23%	17%	25%	33%	41%
Informed	27%	50%	2%	20%	23%	29%

Table 3b
Percentage of Teacher Educators in Each Category based on Interviews

	Aspect 1	Aspect 2	Aspect 3	Aspect 4	Aspect 5	Aspect 6
Naïve	23%	14%	74%	51%	32%	30%
Transitional	47%	30%	14%	30%	22%	37%
Informed	30%	56%	12%	19%	46%	33%

(D) Overall Analysis

As discussed earlier, the SUSSI score was assigned a weightage of 40 per cent, written responses on SUSSI a weightage of 20 per cent and the interview responses a weightage of 40 per cent to arrive at the final score under each category (Table 4).

Findings

Aspect 1 — Observation and Inference

A very significant percentage of respondents (48 per cent students and 45 per cent teacher educators) showed transitional views on the aspect Observations vs Inferences. These participants indicated that

Table 4
Overall Analysis (Based on Weighted Average of Responses under A, B and C)

Category	Aspect 1		Aspect 2		Aspect 3		Aspect 4		Aspect 5		Aspect 6	
Students (S)/ Teacher Educator (TE)	**S**	**TE**	**S**	**TE**	**S**	**TE**	**S**	**TE**	**S**	**TE**	**S**	**TE**
Naïve	18%	24%	23%	15%	76%	74%	54%	54%	44%	31%	27%	30%
Transitional	48%	45%	25%	28%	16%	14%	24%	28%	32%	23%	35%	33%
Informed	29%	29%	51%	55%	2%	10%	18%	17%	22%	44%	37%	36%
Not Classified	5%	2%	1%	2%	6%	2%	4%	1%	2%	2%	1%	1%

observation and inference could be different for different people, but the reason was often thought to be the change in external conditions of an experiment. Also, they believed that newer observations are made by scientists with time that often add to the scientific knowledge. Inference can be different as that depends upon how one interprets the theory. Participants in this category were not able to understand the limitations of observation and what led to the difference in observation or inference by different people.

The participants in the 'naïve' category equated observation in science to facts. They believed in the objectivity of scientific knowledge. Any observation that contradicted previous observation was considered an error or limitation of the instrument and should be discarded. Some of them mentioned that interpretation/ inference could be different but the reasons were not clear. Some of them equated inference with perception.

The interviews indicated that most students and teacher educators fail to appreciate the significance of observation in science. For them, it is related to verifying theories given in the textbooks. If they come across any discrepant observation, they usually discard it or repeat it. Although some teacher educators said they encouraged students to think about the difference in their observations, however the teacher educators agreed that they were also not able to follow up and discuss their views.

The respondents in 'informed' category (29 per cent students and 29 per cent teacher educators) indicated that observation as well as inference depended upon the previous knowledge and background of the person. This meant that observation is theory laden. These participants understood the limitations of observation and why generalisations based on observations were problematic. They also mentioned fallibility of observation and limitation of inductive method in science. They were likely to be aware of the problem of inductive method in science, as has been emphasised by Popper. In a similar study, Liu and Lederman (2002) explored pre-service teachers' conceptions on various aspects of NOS. The study indicated that only 40 per cent participants held adequate conceptions about NOS. The majority of the participants held naïve views about the role of observation and difference between observation and inference in science. Some of the participants even believed that they can actually see atoms through microscopes. Similar responses were indicated by participants in the current study also.

Aspect 2 — Tentativeness of Scientific Knowledge

This particular aspect indicated maximum number of participants (both students and teacher educators) in the 'informed' category. Approximately 51 per cent B.Ed. students and 55 per cent teacher educators were found in the 'informed' category. The participants believed that scientific knowledge is tentative and were able to give examples of replacement or modifications in scientific theories. However, the change was reported as a series of discarding or modifying one theory due to some deficiency. The process, problems, reasons and time taken in the change were not usually understood. Some students and teachers were able to discuss Kuhn's paradigm shift in relation to this aspect. Both students and teacher educators were able to give examples related to the tentativeness of scientific knowledge. Most common examples given by both students and teacher educators included replacement of geocentric theory by heliocentric theory, changes in theories of evolution, changes in the solar system and various atomic models. Many of them were able to cite only these examples as these are commonly given in textbooks. The reason for the change was often cited as the deficiency in the previous model, but hardly an explanation of what factors, including technological and theoretical advancements or social and cultural influences, could have affected these changes. The interviews suggested the need to incorporate these aspects in the curriculum if one desires to develop students' understanding of NOS. The study by Liu and Lederman (2002) also showed that all pre-service teachers who participated in their study believed that theories do change, but the majority related the change with new information and technology. The explanations for change were not adequate, as is found in the current study as well.

Aspect 3 — Scientific Laws and Theories

This particular aspect had maximum number of participants in the 'naïve' category. The informed view was indicated by only a very small percentage of participants (only 2 per cent students and 10 per cent teacher educators). This showed lack of understanding about the process by which laws or theories may get established in science. For most of them, laws are supposed to be crisper and simpler form of theories. A vast majority of students and teacher educators believed that laws have higher credibility than theories, as theories are tentative. Most students and teacher educators believed that laws are universal and cannot change, whereas theories may get modified. The laws were supposed to be mathematical proofs of theories. Theories were not proved as per most students and teacher educators. All of them were able to give some examples of laws or theories they have studied in science, but none of them was able to explain the process through which a law or theory would have got established. Some said that, it was the first time they were thinking about these issues. As they said, this has never been taught but it may be interesting to know the history or the work scientists would have done in order to establish a law or theory. The responses mostly were in conformity with the responses on SUSSI.

Aspect 4 — Social and Cultural Embeddedness in Science

The 'naïve' category had maximum number of respondents on this aspect. Almost 54 per cent B.Ed. students and 54 per cent teacher educators exhibited naïve views as per the interviews. These respondents held the belief that scientists work to provide explanation to the natural phenomenon or for the benefit of the society without any bias and their work is not affected by the society and culture. Scientists are supposed to be objective and hence scientific knowledge is universal. The respondents with transitional view appreciated the role of science (per say technology) in the progress of society. They were also aware of the negative impacts of these technological developments, but they failed to appreciate scientific research as a social activity. Scientific research was supposed to produce universal and reliable knowledge as scientists' work is not affected by their personal choices and their culture. Less than 20 per cent participants belonged to 'informed' category on this aspect.

During interviews, almost all students as well as teacher educators indicated influence of science on society. However, the examples that they gave only meant to support how technology affected the society or how the demands of society may have triggered technological advancements. None of them understood how science may influence people's thought and decision-making in general. For most of them, science is a value neutral and objective enterprise. Scientists are logical and objective in their approach. They may use their imagination and creativity while forming hypothesis, but their aim is to arrive at unbiased and universal conclusions. Only very few students and teacher educators mentioned that scientific activity gets influenced by the funds a country may give for research, or gender biases in the society in general may have deterred women to participate in scientific activity. However, many students (including girls) said that males have a more scientific bent of mind by birth only and hence are more suitable for scientific research.

Aspect 5 — Creativity and Imagination in Science

About 44 per cent students exhibited naïve views on this aspect. According to them, scientific knowledge is strictly based on experimentation and logic. Imagination and creativity are not the forte of scientists as they were supposed to be rational and objective. Scientific knowledge is based on facts. It is reliable and reproducible and hence cannot be based on scientists' imagination and creativity. Only 22 per cent students had informed views and were able to give examples to support that scientists can be imaginative and creative. In fact, scientists' creativity and imagination are essential for the growth of science and it is not the antithesis for logic and rationality. The teacher educators' understanding on this particular aspect was shown to be better and about 44 per cent of them were found to have informed views. The interviews also indicated that the respondents who had informed views felt that even though there is scope of imagination and creativity in real scientific investigations in the field, the science classrooms do not have such possibility. The students could not be expected to work like scientists at least at school level as they are too young. This was commonly stated by both B.Ed. students and teacher educators.

Aspect 6 — Scientific Method

About 26 per cent students and 33 per cent teacher educators had transitional views on this aspect. Most respondents agreed that scientists use multiple methods, and there is no universal step by step method, but they were not able to give examples other than the experimental method to support their views. A considerable number also exhibited informed views. The discrepancy indicated that though students appreciated the need and significance of multiple methods for scientific investigations, their practical exposure in classrooms was limited to experimental method and hence they were not able to support their views with examples.

During the interviews, almost all students and teacher educators denied a universal step by step scientific method, however, on probing what methods were used by the scientists, experimental method was the most common response. One teacher educator mentioned that on the one hand we have experimental science and on the other hand we have theoretical science, but she was not able to explain their nature or scope. Some awareness was indicated among students and teacher educators about multiplicity of methods in science but experimental method seemed to be the most common response on further probing. In fact, experiments and activities seemed to be the most dominant way of teaching science. Also, it indicated that experiments were used as means of verifying the theory given in the textbooks. Students and teacher educators indicated lack of awareness about how scientists conduct experiments in the field. They had not thought about what it takes to design an experiment in the field like techniques used, hypothesis making, controlling the variables, observations, interpretation of results and time taken. The experiments that the students conduct in the laboratories use well- established processes and focus on getting desired results. However, in a real scientific investigation the scientists may struggle for years to design and conduct a successful experiment.

The responses of both students and teacher educators on each aspect were very similar to their response on SUSSI, and interview data supported the results and conclusions obtained through SUSSI instrument. Since the participants were free to express and counter question the researcher in the interviews, sometimes the responses digressed from the actual question, nevertheless it has helped the researcher to develop a more holistic view. For example, many B.Ed. students mentioned that they joined B.Ed. as they lacked interest, conceptual clarity or skills in science. Such responses pointed towards the sad state and some of the problematic assumptions associated with science teaching in school. The pre-service teachers believed that teaching science did not require much interest, skills or conceptual clarity. They considered teaching school students as an easy job as there were laboratory staff in the schools to conduct experiments, etc. Though these responses were not directly related to the current study, but definitely require attention by teacher education programmes.

Conclusion

The overall analysis suggests that the maximum number of B.Ed. students and teacher educators were in 'naïve' category on Aspect 3 (Scientific Laws and Theories). Laws and theories form the core of knowledge in science and also the teaching-learning process. However, laws and theories are often taught as products of science without any attempt to understand the process. As a result, most students as well as teacher educators failed to distinguish between laws and theories. The most informed views were exhibited by the participants on Aspect 2 (Tentativeness of Scientific Knowledge). Both students and teacher educators were aware of the tentative nature of science and could give examples of change and modification in scientific knowledge. Some of them could also refer to Kuhn's work (1962) while explaining the reasons. A relatively high percentage of participants was found in the transitional category on Aspect 1. This reflects that though students and teacher educators recognised the importance of observation and inference in science but they were not clear of the distinction, role and limitation of both. On Aspect 4, maximum number of students and teachers educators were found in the 'naïve' category. They also believed in the relationship between science, technology and society but understanding about the nature of this relationship was limited. Most of them equated science with technology. Though there were variations in pre-service teachers' and teacher educators' understanding of NOS on various aspects, both the groups lacked in their understanding of NOS.

Suggestive Framework for Promoting NOS Understanding in Teacher Education

Though the pre-service teacher education curriculum had some topics that are supposed to help in developing NOS understanding among pre-service teachers and teacher educators, but that did not seem to be the reality. There was a lack of

NOS understanding in general among the groups. Following are some suggestions to improve the place of NOS in curriculum and develop a better understanding of NOS.

- **Historical Case Studies and History Rich Material** — Use of historical case studies and history rich material is very helpful for developing better understanding of NOS. However, if history of science is presented as a sequential chain of scientific developments, the desired impact cannot be achieved. For historic cases to be effective, science educators need to revive the sense of being present at the moment and making sense of events in the historical contexts. Allchin (2012) mentioned that sociologist Bruno Latour called this Situated Perspective 'Science in the making' as contrasted to retrospective 'readymade science'. Usually this readymade science forms the content of our curriculum books about history of science. Reconstructing historical perspective is challenging and requires a lot of research and trial by the science educators. It may not be feasible or even necessary to discuss all historical case studies in the discipline. However, a few of these such as 'History of DNA replication' or 'Copernican Revolution' could be accommodated as part of classroom experiences and the rest can be referred as sources of reading.
- **Authentic Scientific Practice** — Authentic science practice means involving the students in the scientific investigations in the field. The students can work in collaboration with a group of scientists or researchers and learn authentic science practice from the field. However, it is important that after such experiences, students are asked to reflect on their own learning with respect to different aspects of NOS.
- **Inquiry-based Contexts** — Inquiry-based contexts that provide an explicit opportunity to reflect and discuss on the various aspects of nature of science are helpful in developing students' understanding of NOS. However, inquiry alone, without any specific focus on NOS aspects, is not a very effective way of developing NOS understanding. Abell, Martini and George (2001) and Clough (2006) in their independent studies have indicated the importance of inquiry-based contexts.
- **Argumentation, Discussions and Debates** — An understanding of different philosophical perspectives on nature of science helps to improve learners' understanding of nature of science. This teaching of various philosophical positions by Popper, Bacon, Kuhn, Lakatos and Feyeraband, etc., could be an important aspect of science curricula. However, instead of direct teaching about these philosophical perspectives, debates, discussions and argumentation among the

students are suggested with reference to some pre-determined issue. The explicit NOS instruction and argumentation is useful in improving pre-service teachers' conceptions of NOS (McDonald, 2010).

- **Science–Technology–Society (STS) Approach** — An STS curriculum that can be offered as a separate course or could be integrated as a unit in the methods course in teacher education is an effective strategy for teaching nature of science according to several researchers. An STS curriculum involves an interactive set of concepts, content and skills that demonstrate how science and technology affect each other and are mediated by society and are value laden. Through the STS curriculum, the students should be able to examine the actual science, technology and society interaction in the world around them. The study by Bradford, Rubba and Harkness (1995) compared the outcomes related to NOS understanding among university level students enrolled in STS course and general physics course. The STS course was found to be effective in enhancing students' understanding of NOS.
- **Assessment** — For NOS to gain a significant place in curriculum, it is important to assess students' as well as teachers' understanding of Nature of Science. Some of the assessment strategies that can be used for assessing students' understanding of NOS are as follows:
  - ➢ **Standardised Assessment Tools based on Research** — Research in the area of NOS has led to the development of various assessment instruments on NOS. The teachers can select the suitable assessment instrument for testing students' understanding of NOS. Such instruments can be effectively used to assess students' understanding pre and post instruction to determine the effectiveness of instruction. However, these assessment instruments should be used in combination with other qualitative assessment techniques like interviews, observations during laboratory and field work, students' reflective writings, etc.
  - ➢ **Self-assessment (Create your own Nature of Science profile)** — It is important for teachers to examine their own understanding of Nature of Science and make attempts to improve it suitably. Nott and Wellington (1993) suggest the use of self-assessment techniques for this purpose. The assessment of teachers' understanding of NOS can be done by self-administration or peer administration of such tools.

- **Using STS Approach for Assessment** — An STS approach could also be used as an effective assessment strategy for NOS. Students could be given individual or group assignments that involve analysis and reflection on a number of STS issues. The purpose is to promote thinking skills about a particular topic and also about the nature of knowledge itself.
- **Making Lesson Plans based on NOS Aspects** — Lesson planning is an integral part of any pedagogy course in most teacher education programmes. These lesson plans focus on concepts, skills and values that the pre-service teachers intend to teach. Therefore, if NOS is to be emphasised as an important aspect of science education at school level, pre-service teachers can be encouraged to make model lesson plans for teaching NOS. These lesson plans should include activities and concepts that would explicitly relate to NOS. Assessment of students could be done on the basis of these lesson plans and their execution.

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