Representation of Nature of Science in Pre-service Teacher Education Programme

Mamta Singhal*

Abstract

Science education holds a prominent place in our education system. The fact that the Constitution stresses on developing scientific temper as one of the fundamental duties of Indian citizens speaks of the high value attached to science education in our country. While earlier curricular reforms and policies have emphasised on the 'product' or 'process' approach in science, the recent reforms have paid attention to the epistemological aspects of science. This paper examines the pre-service teacher education curricula (B.Ed.) of three universities for their focus on the Nature of Science.

Introduction

Questions of epistemology or Nature of Science (NoS) have been considered integral to science education worldwide. The 'Nature of Science' has been emphasised by several curricular reforms worldwide in view of broader goal of scientific literacy for all. In two major reports — *Science for All Americans* [American Asociation for the Advancement of Science (AAAS), 1990] and *Benchmarks for Science Literacy* (AAAS, 1993), Project 2061 emphasises on the importance of understanding the Nature of Science at different stages of school education. According to AAAS (1993), the study of science as an intellectual and social endeavour, and the application of human intelligence

* *Assistant Professor,* Institute of Home Economics, University of Delhi, New Delhi–110016.

to figure out how the world works should have a prominent place in any curriculum that has science literacy as one of its aims. In India, concerns about the Nature of Science are being raised at least at the level of curriculum reforms in schools. In the position Paper (1.1) on the teaching of science, the NCERT (2005) advocated scientific literacy; distinction between science and technology; relationship of science, technology and society; process of science; and understanding the historical and developmental perspective of science at all levels of school education. The framework also presents a brief description of the 'Nature of Science' and 'science and technology'. It emphasises on understanding the development of scientific knowledge, scientific method and the relationship of science with technology and society. However, there appears to be ambiguity about the implementation of these goals at various stages.

Objective

The objective is to examine the curriculum of pre-service teacher education programme (B.Ed.) of three universities located in Delhi for representation of various aspects of the Nature of Science.

Theoretical Background

The concept of the Nature of Science has changed over the years. The earlier attempts to define 'Nature of Science' equated it with science process skill, attitudes and interests. The epistemological meaning of the Nature of Science gained prominence in the 1970s and many researchers construed NoS as having multiple facets or aspects. The various aspects of NoS have emerged as an attempt to answer the most fundamental question — 'what is science?'. The answer to this, however, is not simple and often attracts various viewpoints. It is argued that the common view of science is — 'science is derived from facts' (Chalmers, 1999). These facts can be directly established by careful, unbiased use of senses. Science is based on what we can see, hear and touch, rather than on speculations. This means that scientific knowledge relies heavily on observations that result in so-called 'facts' in science. These observations are made with the use of senses, such as see, hear, touch, etc., with the sense of 'seeing' being the most commonly used. For an empiricist or positivist, two observers seeing the same object would form exactly the same image on their retina. This is, however, not true. For example, a student trying to observe the cell structure through a microscope for the first time without seeing its picture is rarely able to see the different components of a cell. Thus, observation does not depend solely on the images formed on our retina but also on existing knowledge, experience and expectations of the observer. So, even if there is a single, unique reality that exists, our access to it is limited through our senses. Secondly, the 'facts' in themselves have little meaning. These have to be expressed as statements that are later interpreted to generate knowledge. Another concern associated with knowledge based on observations is that observations are fallible in the light of new advancements in science and technology. Prior to the Copernican Revolution, the statement that 'earth is stationary' was a fact confirmed by observation. However, the assertions made under the Copernican Theory coupled with Galileo's telescopic observations led to the rejection of the earlier theories based on sensory observations.

Another important aspect of science is 'experimentation'. Scientists often need to isolate the phenomenon under investigation and control the effect of intervening variables. The challenge is that despite their best efforts, one can never be sure of having controlled all intervening variables. Also, with advancements in technology and availability of more sophisticated instrumentation, the results may vary significantly.

Another popular way through which scientific theories could be developed is based on 'logic'. Logic could be deductive or inductive in nature. Deductive reasoning employs logic of the sort. If the premises are true and the argument is valid, then the conclusion is also true. It can be explained with the following example:
Premise 1: All birds lay eggs.
Premise 2: House sparrow is a bird.
Conclusion: House sparrow lays eggs.

Based on Premise 1 and 2, the conclusion is a valid deduction. However, whether Premise 1 and 2 are true is questionable and that cannot be ascertained by logic.

In case of induction, the basic premises are used to arrive at generalisations. For example, based on our observations with certain metals, we can say that Metal 1 expands on heating, Metal 2 expands on heating, Metal 'n' expands on heating, and so on. But no matter, however, large 'n' is, we cannot logically conclude that all metals expand on heating. The problem here is not only ascertaining the truth of the premises but that the conclusion itself lacks logic. General scientific laws often go beyond the finite number of observations supporting them; hence, they can never be proven in the sense of being logically derived from evidence. The problem of induction was provided as an alternative by Karl Popper, who introduced falsification. He rejects the view that induction is the characteristic method of scientific investigation and substitutes it by 'falsifiability'. He proposed that science is a set of hypothesis that is 'tentatively' proposed in order to describe some aspects of the world. However, not all hypothesis will work. The condition that any hypothesis must satisfy if it is to be granted the status of a scientific law or theory is that it must be falsifiable. A hypothesis is falsifiable, if there is a logical possibility of falsifying or refuting the hypothesis with some observation statements. A scientific statement is 'falsifiable' but not yet 'falsified'. If it is falsified, it should be rejected. Popper stresses that even if a theory has withstood rigorous testing for a long time, it cannot be said to be verified; rather it should be recognised as a theory that has received a high measure of corroboration, and hence, should be retained as the best available theory of the time. Falsification also had several problems and there were alternative views given by several philosophers, like Kuhn and Lakatos, on how scientific knowledge takes place. No view was alone sufficient to explain NoS, however, together they provide a basis for understanding 'science'.

Some of the commonly acceptable tenets of the Nature of Science could be stated as below:

- Science is tentative,
- Science is heavily based on empirical evidence,
- Science involves imagination and creativity,
- Science has no universal scientific method,
- Science is influenced by culture and society,
- Observation and inference are distinct,
- Laws and theories are different forms of knowledge and there is no hierarchical relationship between the two.

These aspects of the Nature of Science can be considered of practical importance for various science curricula worldwide. The job of science teachers and educators is to appreciate the plurality of views and reflect it in their teaching.

Sample

The sample was purposive in nature to help identify the sites of data collection. Hence, the sample consisted of institutions offering pre-service teacher education programme called Bachelor of Education (B.Ed.) in the three universities located in Delhi. The pre-service teachers and teacher- educators studying or teaching in these institutions formed the sample. They were chosen on the basis of their availability and interest to participate in the study. A total of 70 pre-service teachers and 30 teacher-educators participated in the study.

Data Collection

The following tools were used for data collection:

i. Content Analysis of the Curriculum

A list of indicators related to the NoS was prepared. These were expected to be mentioned in the syllabi of different courses. The list was prepared by the researcher after carrying out the literature review of the research related to the NoS. The policy documents, research papers and instruments used for assessing NoS frequently mention certain terms, phrases or dimensions. The key terms or phrases were identified and after an expert validation, a few were retained and used for qualitative content analysis of the syllabus.

The terms and dimensions that were used for reference in content analysis were — Nature of Science; history of science; works of some philosophers, such as Kuhn, Lakatos, Popper and others; change in laws and theories; observation and inference; process of science; influence of culture and society; tentativeness; and life sketch of some scientists. The terms and phrases were used only for reference and the researcher was flexible to accommodate any other term or phrase that might be associated with the Nature of Science. The objectives, practical work and references mentioned in different syllabi were also examined for any explicit focus on NoS. The data included identifying NoS-related terms from the syllabi of pedagogy of science courses in the B.Ed. programme.

ii. Interviews with Pre-service Teachers and Teacher-educators

These interviews were conducted after qualitative content analysis of the syllabus and were meant to understand the implicit focus on NoS through curriculum transaction. The explicit focus was examined through qualitative content analysis of the syllabi of pedagogy of science courses of the selected universities. A semi-structured interview schedule was prepared by the researcher for pre-service student-teachers as well as teacher-educators to understand the implicit focus on NoS in the curriculum. It had questions on the following themes:

- objectives of the course,
- approaches or strategies used for curriculum transaction,
- laboratory work, project work or field visits, and
- problems and challenges.

The researcher framed open-ended questions on each theme for students as well as teachers to understand the implicit focus of curriculum on the Nature of Science. Implicit focus implies what aspects of NoS are indirectly taken care of through curriculum transaction.

Insights from Data Collection

Curriculum means both theoretical and practical aspects of the syllabus and the pedagogical strategies used by a teacher in a class for transacting the syllabus. The pedagogy papers are important in the B.Ed. curriculum as they enable the prospective teachers to do justice to the subject they would teach in schools. For this purpose, the syllabi of pedagogy of science courses of the selected universities were examined to see the representation of NoS-related aspects. Interviews were conducted with students and teachers of these courses to understand the pedagogical practices with respect to the NoS.

University 'A'— State University

The B.Ed. course of University 'A' has four papers based on pedagogy of science. These are— teaching of integrated sciences, teaching of physics, teaching of chemistry and teaching of life sciences. All these papers (any one) are being offered to graduates in respective science disciplines. The paper on 'teaching of integrated science' is offered to a science graduate, irrespective of his/her subject combination in graduation. Also, the courses are offered as per the number of students and availability of teacher-educators to teach a particular pedagogy paper.

Analysis of University 'A' Syllabus

The syllabus of different courses suggested that Nature of Science is mentioned in the overview of only one pedagogy paper, pedagogy of chemistry. They stated that "Nature of Science is not only the content but also a process". Also, they emphasised on the acquisition of certain skills, like observation, inference and experimentation in order to understand the process. While some important aspects of NoS, like observation, experimentation, inference, etc., were stated in the overview, they were only being seen as skills. The factors affecting our observation, difference between observation and inference, limitations of observations, place of experimentation in science, validity of experimental results, etc., are certain important aspects of NoS, which seem to be neglected if we take this view of developing observation, classification, inference, experimentation, etc., as skills to be developed. It appears as if the teacher would mechanically focus on certain steps that need to be followed for developing these skills. This is, in fact, the reality of many science classrooms, where the students are told what to observe, how to observe and also repeat if they don't get the expected results. Most observations are planned by the teachers in laboratory settings or occasionally, through field trips ruling out the possibility of observation in natural settings. Also, if the students share any such observation, they are often ignored, considered as not worthy of discussion and outside the scope of curriculum.

Pedagogy papers — 'teaching of integrated sciences' and 'teaching of life sciences' mentioned understanding the nature of integrated science/life science as an objective in their respective syllabi. The paper on 'teaching of physics' had neither an overview, nor objectives as a part of the syllabus. The syllabi of all pedagogy papers had certain commonly taught topics but indicated an overall lack of coherence in all science papers. The mention of NoS in two papers, 'teaching of life sciences' and 'teaching of integrated sciences' was also cursory and seemed that it was put in the syllabus as a 'buzzword' as currently a lot of discussion and debate, emphasising on the importance of NoS, are going on. There was no elaboration in any of the papers about what should form the content of NoS.

The syllabus of each pedagogy paper was divided into 4–5 units and invariably Unit 1 mentions Nature of Science. In fact, the first unit was named 'Nature and Scope' of the respective discipline. This suggested that the curriculum developers may have wanted to emphasise on NoS. However, there wasn't any further elaboration on what is expected to be taught as NoS in any paper. It appeared as if it was up to the teacher's interpretation and discretion as to what he/she understood of NoS and the way it should be transacted. While flexibility was important for teachers to approach the syllabus but such scanty and unstructured representation is unlikely to reflect the Nature of Science and facilitate its teaching. Most teachers have themselves not studied about NoS as part of their formal education; therefore, explicit mention of its aspects in the syllabus would actually help them in understanding and communicating about the subject. The reading list suggested in the end of all pedagogy papers had general references on teaching methodology. In some references, NoS is given as a chapter or as part of the chapter. The researcher specifically included questions in interviews to check the references, which teachers were consulting and whether even those mentioned in the syllabus were available to them.

The practicum work did not explicitly mention NoS. However, there is always a possibility of using practical work as a means for developing an understanding of NoS. The researcher tried to find this through interviews.

University 'B'— Central University

The B.Ed. curriculum of University 'B' had methodology of teaching biological sciences, methodology of teaching physics, methodology of teaching chemistry and methodology of teaching sciences as pedagogy papers. The methodology of teaching physics, chemistry and biological sciences are offered at Level 'A' (to prospective teachers preparing to teach up to the secondary level) and 'B' (for teaching up to the senior secondary level).

Analysis of University 'B' Syllabus

The examination of the syllabi in different pedagogy papers suggested a fairly good number of common strands. While Level 'A' intended to prepare teachers for the upper primary and secondary level, Level 'B' focused on the senior secondary level. The syllabi seemed to have been made on similar lines for all pedagogy papers.

Pedagogy papers at Level 'A' in all subjects reflected some common objectives and topics explicitly related to the Nature of Science. The common objectives as stated in the syllabus at Level 'A' was to enable the pupil-teacher to develop an understanding of the Nature of Science, in general, and the discipline, in particular, and its interface with the society. This suggested some common understanding among curriculum developers. Developing an understanding of the Nature of Science has been given explicit importance in the syllabi of all pedagogy papers. The relationship of science, technology and society was mentioned specifically in the objectives unlike many other aspects of NoS. This is an important aspect of NoS and the syllabus seemed to lay specific emphasis on the relationship between science, technology and society. However, the researcher also tried to understand through interviews what exactly was transacted under this topic? Was it treated as an aspect of NoS or understood in some other perspective?

The syllabi of all pedagogy papers seemed to give enough importance to NoS. Unit 1 of all pedagogy papers was dedicated to the Nature of Science. Unit 1 suggested that the development of science should be seen in a social and historical perspective. The syllabi reflected an emphasis on understanding the major turning points or landmarks in the history of science (specific discipline). This might throw light on some of the paradigm shifts in the discipline as Kuhn has suggested. To understand science in its historical context is important as it depicts the tentative Nature of Science. This helps one to appreciate how scientific knowledge is constructed. What may be the different processes used by scientists at a point of time and how these processes may change. Another important aspect is how the change is accommodated and validated as scientific knowledge. The researcher was, however, cautious of the fact that if the history of science is presented as a series of facts, laws or theories, the learners may not get a complete or accurate view about how scientific knowledge is constructed. Therefore, the researcher tried to explore the pedagogic strategies used in classrooms through interviews with both students and teachers.

The progress of science is mostly seen in terms of its technological applications and often one talks of the positive and negative aspects of the development of science (technology) in the society. However, how science and technology are different and also related is often not given much importance. Science is mostly seen as an objective and value -neutral activity not only by 'non-science people' but also by individuals, who are studying and practising in science domains. Therefore, the inclusion of the topic, 'Science Technology Society Interface', in the syllabi seemed appropriate and suggested the possibility of developing a better understanding of the relationship between science, technology and society among B.Ed. students. The syllabus also included development of scientific temper, public understanding of science and role of ethics in the context of a developing country.

The development of process skills such as observation, inference, hypothesising and experimentations were specifically mentioned in Unit 1 in all pedagogy papers at Level A. The researcher found it in alignment with the various aspects of NoS that have been time and again emphasised upon by various curriculum documents and tools used for research on NoS. For instance, the role of observation in science cannot be undermined. Though the objective view of science is based on verifiability and replicability of scientific observation, Popper has critiqued this view of observation. According to him, observation has its own role and limitations in science. The inductive view that is based on arriving at generalisation on the basis of observation has been critiqued by Popper, saying that no number of observation is good enough to arrive at a generalisation that is universal. This is because no matter how large the number of observations that support a particular generalisation is, only one observation that is contradictory can refute the generalisation. Similarly, the role of inference and making hypothesis is important in science, but at the same time, these have their limitations too. This suggests that observation, hypothesisation, experimentation, etc., are all important parts of the process of science but one must be aware of their limitations and should be able to reflect on what kind of knowledge these processes would generate. Is it objective and universal?

The researcher found it important to explore as to which pedagogic strategies or classroom processes were likely to develop these so-called skills in science, and this purpose was fulfilled through interviews.

The practicum work in biology Level 'A' mentioned that students would 'practise' at least 10 experiments that were to be conducted or demonstrated at the secondary level. This suggested that the students were trained to repeat the experiments suitable for the secondary level, so that they could demonstrate or conduct them as efficiently and as their teachers.

This portrayed a traditional image of science, where experiments were supposed to generate verifiable and reproducible results. The very spirit of scientific inquiry i.e., designing and conducting experiments to solve the problem at hand was lost in this approach. The physics and chemistry practicum suggested organisation of activities, experiments and laboratory work with a critique of the existing practices. This showed openness and flexibility in approaching the practicum work in a different way but how is that put into practice needed to be explored through interviews.

The pedagogy of physics syllabus at Level 'A' also mentioned providing exposure to the possible projects with academic, industrial or research organisations. This might provide the students with an opportunity to experience the process of science in the real context. The researcher tried to find out more about such projects and opportunities from students and teachers of the B.Ed. course.

At Level 'B', in all pedagogy papers, the first objective was geared towards developing an understanding of the Nature of Science (specific discipline) in a sociological and historical perspective. Also, in a pattern as in Level 'A', Unit 1 focused on various aspects of NoS. However, more explicit emphasis on NoS is placed at Level 'B'. The syllabi in all papers mentioned some science philosophers, like Popper, Kuhn, Lakatos, Lovelock and Prigogine. Besides, certain other aspects such as Science Technology Society (STS) interface, role of language and role of experiment were explicitly stated in the syllabi. This suggested that the course had an explicit focus on developing an understanding of NoS. However, the researcher found it strange that the reading list of pedagogy papers did not have any reference directly linked to the Nature of Science. In the reading list, there was no mention of original readings on Popper, Kuhn, Lakatos or other philosophers; however, these names were mentioned in the syllabi. The researcher felt the need to further probe this by interviewing students and teachers.

The practicum work had field work, investigatory projects and laboratory work that may be useful in developing an understanding of the Nature of Science. It was also important to know about the nature of the project work and field work in order to understand its potential to develop an understanding of NoS. This was achieved through interviews.

University 'C'— Another Central University

The B.Ed. curriculum of University 'C' had teaching of physics, teaching of chemistry and teaching of life sciences' as science pedagogy papers. The structure of the course was similar to that of University B.

Analysis of University 'C' Syllabus

The syllabi of pedagogy papers in University 'C' showed explicit focus on the Nature of Science. Unit 1 of all pedagogy papers mentioned various aspects of the Nature of Science (with specific reference to a particular discipline). The syllabi discussed the content vs. process debate in science, highlighting how knowledge is constructed in science. While on one hand, the syllabi mentioned process skills, such as classification, observation, inference, etc., on the other hand, it emphasised on product (laws, theories and principles) of science. The other significant aspects such as scientific attitude and relationship of science with technology and society were also explicitly stated in the syllabi. The history of the discipline was mentioned with content enrichment only in 'teaching of physics' but not in other papers. There was no specific reference to the Nature of Science except in case of 'teaching of physics' and that too was not adequate to deal with the topics mentioned in the syllabus. Though the syllabus had several aspects of the Nature of Science, the depth and the pedagogy to be used was left to the discretion of teachers. The analysis of the syllabi of pedagogy papers in University 'B' suggested some similarities with University 'C' in terms of content but with lesser depth. Also, in case of University 'B', the practical work was not mentioned. The syllabi raised similar concerns in both the cases.

Data Collected on the Basis of Interviews

The critical examination of the syllabi raised many questions and necessitated to conduct in-depth interviews with the participants. Also, while explicit mention of NoS and related terms and phrases is an important part of the curriculum, different researches have suggested that merely stating them in the curriculum without changing the focus of teaching-learning strategies may add to the curriculum load. The students (pre-service teachers) and teachers (teacher-educators) may see it as another topic to be studied for examination purpose and may not actually develop a good understanding of the discipline. Thus, the researcher found it important to examine the pedagogical strategies being used by teacher-educators in transacting the curriculum. This was done to understand how and what understanding of NoS is implicitly conveyed by classroom processes in the B.Ed. programme. For this purpose, the researcher interviewed 15 teacher-educators and 40 pre-service teachers.

Analysis of Data Collected during Interviews

The responses of the participants were divided into various categories and the percentage of responses in each category was calculated.

Though the syllabi of all three universities chosen for the study stated developing an understanding of NoS as the first objective; the students and teachers of the B.Ed. programme did not mention it as an important objective. The most common objective as mentioned by most students was that the pedagogy paper would equip them with innovative ways of teaching science. The other objectives mentioned were related to revising the school concepts and developing classroom management skills. A few students mentioned developing skills such as experimentation, analysis, inference, etc. On prompting that NoS is specifically mentioned in the objectives of the syllabus, most students agreed NoS to be an important objective but this was more of an agreement with the content of the syllabus and the researcher. Most students were unclear about the role of understanding NoS in their classrooms. Some answered vaguely that they may discuss the history of concepts and how theories develop. Only one student mentioned the tentative aspect of science that could be discussed in the classroom as there are many examples, which show that theories in science may change over a period of time. The researcher prompted them to think of ways in which NoS could be incorporated in classroom teaching but there was silence. Most of the students could not give examples about incorporating NoS in their everyday teaching. They said that transacting NoS was at no was difficult at the school level because they could not discuss philosophers. Understanding the work of eminent philosophers is only a means to understand NoS, but it seemed that students saw this as an end.

The teacher-educators also held similar views about objectives. Only two teacher-educators mentioned developing an understanding of NoS as an important objective without any prompt. One teacher-educator was instrumental in making this addition about NoS unit in the syllabus.

According to her, it is important to understand how science has changed over a period of time in terms of content and processes. Technology has also influenced science and that it affects the society in many ways. About 26 per cent (only four in the entire sample) believed that an understanding of NoS was important to strengthen students' content, ability to conduct scientific research and to have a scientific attitude. Out of these four, only two teachers said that B.Ed. students were able to reflect their understanding from the syllabus in their school teaching. She said it affected their outlook and they were able to deal with things differently. Many teacher-educators mentioned that NoS was a new topic in the syllabus and it was a struggle to teach it as they did not have proper references for teaching it. More than 70 per cent teachers said that the unit was done in the end and practically there was no significance of it.

The most common approach used for teaching NoS was to give readings related to it and ask the students to present it in class. Only 33 per cent teachers in the entire sample gave original reading of Kuhn, Popper and Lovelock. They also mentioned that all students did not read the original references as they found them terse. They teachers pointed out that only specific portion of the readings were discussed due to the lack of time. The teachers, especially from the state university, said they took some computer printouts about the characteristics of the Nature of Science and that was enough for teaching the topic. Some teachers even asked the researcher to suggest some readings. The original readings mentioned by some teachers were not included in the reference list. The researcher asked specific questions to teachers about teaching some topics, like public understanding of science, landmarks or turning points in their discipline, role of language, etc. None of teachers mentioned any specific reading or source for teaching these topics. Also, the understanding about what and how these topics were to be taught was limited.

The discussion with both students and teachers reflected that the former repeated the experiment that they were supposed to perform in schools. The experiments were mostly similar to what they had done in schools. Some teachers mentioned that they encouraged students to use local material in experiments as mentioned in Eklavya's publication *Balvaiganik* or from a popular website, arvindguptatoys.com. The purpose as stated by both the students and the teachers was to verify the theory, and improve the pupils' confidence through revision. The idea was to prepare the students to demonstrate or conduct the experiments efficiently in schools. Sixty per cent teachers said that they did not conduct experiments, rather they discussed experiments with their students. On asking how they critique the existing practices in schools, the teachers (total four in the entire sample) said that they encouraged them to think why they were not getting the expected result in the experiment. What might have gone wrong? The field work and the project work were found to be minimal.

Some students also mentioned that in schools, lab assistants helped them in conducting experiments and the teachers only checked the results and evaluated their practical notebooks. This suggests that they did not take it seriously and did not see it as part of the teachers' responsibility. There was no opportunity to reflect on the nature or process of science through this kind of work in the B.Ed. programme.

Findings

Based on content analysis and interviews of the pre-service teachers and teacher-educators, following are the major findings of the study:

- The term Nature of Science was mentioned explicitly in the curriculum of B.Ed. programme of all three universities — two Central and one state university located in Delhi.
- In the curriculum of the selected state university, the term NoS was stated only in Unit 1 without any further elaboration on content and scope. In the curriculum of two Central universities, Unit 1 had a detailed mention of various aspects of NoS.
- There was a lack of adequate referencing on NoS in the syllabi of all three universities. Though some teacher-educators mentioned referring to books and articles related to the works of Kuhn and Popper during their classes, the reference list given in the end of the syllabi did not mention the same.
- The project work or field work was similar to the work done in schools. The idea was to prepare B.Ed. students for school teaching. The students found the

work basic and simple, and it only helped them revise what they had done in schools.

- The syllabi mentioned skills such as observation, inference and hypothesisation as topics but development of these skills was not paid enough attention. There was a lack of engagement in true scientific inquiry with respect to understanding the role and limitations of these skills. A highly simplistic view of science was presented to the student-teachers as the curriculum only required pre-service teachers to do similar type of activities or experimentation that they had done in schools.
- Pedagogical strategies used by teacher-educators were not conducive to the development of understanding of NoS among pre-service teachers. There were some discussions about the work of Kuhn and Popper and features of the Nature of Science; however, the nature of these discussions was not reflective. The students often read some books (partially) and presented the summary in groups. The topics related to NoS were not given enough importance and were often discussed at the end of the syllabus. The teacher-educators seemed to make little attempt to integrate discussion about the history or philosophy of science with school subjects. These topics were being taught superficially, merely because they formed a part of the syllabi. Most teacher-educators did not consider it to be a significant aspect of the curriculum.
- Most pre-service teachers felt that NoS discussions in B.Ed. programme did not help them in school teaching or as science teachers. What they discussed in B.Ed. programme as part of NoS was difficult to teach students. Most pre-service teachers in B.Ed. programme did not see any linkage and usefulness of NoS discussion for school students. This clearly suggested the problem of implementation of their understanding of NoS at different levels of schools.

References

American Association for the Advancement of Science. 1990. *Science for All Americans.* Oxford University Press, New York.

____. 1993. *Benchmarks for Science Literacy: A Project 2061 Report.* Oxford University Press, New York.

Bryman, A. 2008. *Social Research Methods.* 3rd Ed. Oxford University Press, New York.

Chalmers, A.F. 1999. *What is This Thing Called Science?* Hackett, Indianapolis.

Creswell, J.W. 2012. *Educational Research: Planning, Conducting and Evaluating Quantitative and Qualitative Research*. 4th Ed. Pearson, Boston.

Kuhn. 1962. *Structure of Scientific Revolution*. The University of Chicago Press.

McComas, W.F. (Ed.). 1998. *The Nature of Science in Science Education: Rationale and Strategies.* Kluwer Academic Publishers, the Netherlands.

NCERT. 2006. Position Paper (1.1). *National Focus Group on Teaching of Science.* NCERT, New Delhi.

Sarukkai, S. 2012. *What is Science?.* National Book Trust, New Delhi.