Exploring Pre-Service Teachers' Understanding about Scientific Inquiry

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Abstract

The aim of this study is to examine the pre-service teachers' (PSTs) views about scientific inquiry. A descriptive survey is conducted for this purpose using open ended 'Views About Scientific Inquiry (VASI) Questionnaire' developed by Lederman et al (2014). The sample constitutes 107 Pre-service teachers of undergraduate four-year teacher education program. Data was analysed using qualitative research methods by coding and categorising responses into 'informed', 'mixed' and 'naïve' categories. It is found that a majority of PSTs have mixed and naïve views in most of the aspects of scientific inquiry. A majority of PSTs have 'informed view' in two aspects of SI namely "all scientific research begins with a question, but does not necessarily need to be tested with hypothesis" and "Inquiry procedures are guided by the question asked". However, they have naïve and mixed understanding in four aspects— 'There is no single scientific method', 'Inquiry procedures can influence results', 'Scientists performing same investigation get same results' and 'Scientific data and evidence are not the same'. The study has implications for a pedagogical discourse for promoting scientific inquiry in pre-service teacher education program.

Key word: *Scientific Inquiry*

Introduction

One of the major aims of science education is development and promotion of scientific literacy. Scientific literacy encompasses the contemporary ideas of science, science-society interface, spirit of scientific inquiry and it requires an understanding of nature and processes of science so that citizens can make informed decisions about scientific issues. Scientifically literate people can make informed decisions about socio scientific issues through their understanding of scientific inquiry and scientific processes (Lederman, Lederman et al 2014).

Two important facets which contribute to scientific literacy are Nature of Science (NOS) and Nature of Scientific Inquiry (NOSI). NOS is "epistemological underpinnings of the activities of science" and NOSI is "the process by which scientific knowledge is developed" (Lederman 2004). Scientific inquiry entails using a variety of science process skills, creativity, and critical thinking to develop scientific knowledge (Lederman et al 2014). Though SI broadly refers to "diverse ways in which scientists study the natural world and propose explanations based on evidence derived from their work" (NRC 1996, 2000) it is not limited to the scientists' work or

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the manner in which scientific knowledge is constructed. Scientific inquiry can be interpreted in three ways—what scientists do (scientific investigations and construction of scientific knowledge), how students learn (inquiry, critical thinking, problem solving, etc.) and a pedagogical approach that teachers use (designing investigations and inquiry) (Minner D.D, Levy A.J 2010). The second and third aspects have important implications for science curriculum and pedagogy. In this context, teachers play an important role in the process of adopting scientific inquiry in science lessons and developing students' views on the targeted aspects of NOSI. Lack of understanding about scientific inquiry is one of the major reasons for teachers to apply scientific inquiry in their pedagogical discourse. Research reveals that Nature of Scientific Inquiry (NOSI views) of the majority of students at all levels are naive and undeveloped (Lederman et al., 2019; Lederman, 2012). The studies investigating NOSI views of pre-service teachers, are insufficient (Baykara & Yakar, 2020; Şenler, 2017). The studies reveal that school students, pre-service and in-service teachers have insufficient and partial views about SI. It is also challenging to capture and understand various perspectives and views about scientific inquiry due to lack of valid and reliable tools (Lederman et al., 2019). This study explores pre-service teachers' views about various aspects of scientific inquiry (SI).

Methodology

The present study which focussed on PSTs views and understanding about scientific inquiry used a descriptive survey approach.

Lederman et al (2014, 2019) identified eight aspects of scientific inquiry. These are "(1) all scientific investigations begin with a question and do not necessarily test a hypothesis; (2) there is no single scientific method; (3) inquiry procedures are guided by a question asked; (4) all scientists performing the same procedures may not get the same results; (5) inquiry procedures can influence results; (6) research conclusions must be consistent with the data collected; (7) scientific data are not the same as scientific evidence; and (8) explanations are developed from a combination of collected data and what is already known". These aspects were used as the framework for development of the views about scientific inquiry (VASI) questionnaire, i.e., an instrument used to assess teachers' understandings about scientific inquiry. As it is very difficult to capture PSTs real position on various aspects of SI, the study used qualitative analysis method by coding and categorising the responses to explore PSTs views about SI.

Sample— Purposive sampling is used to select the participants for the study. The sample constitutes 58 PSTs of year 1 and 49 PSTs of year 3 of a four-year integrated teacher education program in India. All the PSTs voluntarily participated in the study and as per research ethics, the purpose of data collection was shared with the participants.

Instrument— the data was collected using the adapted version VASI (Views about Scientific Inquiry) Questionnaire developed by Lederman et al (2014, 2019). All the eight aspects of VASI questionnaire were represented on a 3-point rating scale, followed by open ended questions for giving their reasons. The questionnaire was administered at the beginning of the session. As the aim of the study was to explore the PSTs understanding and views about SI, qualitative analysis was used. All the responses to the above mentioned eight aspects of SI were coded as per the understanding of SI cited in the related literature (Lederman and Lederman, 2008, Lederman et al 2014, Lederman et al 2019). A scoring rubric was developed to categorise the responses as per the above literature review. The responses

on the VASI questionnaire were coded as 'informed', 'mixed', 'naive' and 'unclear' (Lederman et al 2014). The scoring rubric is depicted in Table 1.

Table 1: Rubric for coding responses

Informed View	Mixed View	Naïve View
Complete and consistent with contemporary understanding of SI Able to substantiate with examples.	Consistent with contemporary understanding but not able to give reason for their view or incomplete and wrong reasoning. Partially consistent view.	Inconsistent understanding. Wrong or incoherent reasoning

All the responses which were completely incoherent or partly written or left have been coded as "unclear'. Exemplar responses were validated by two experts before final categorisation.

Discussion

This section presents the analysis of the responses of the PSTs on various aspects of SI. Table 2 represents the PSTs responses for the eight aspects reflected in the questionnaire in the four categories.

Aspect 1— Regarding the aspect that *all scientific research begins with a question, but does not necessarily need to be tested with hypothesis*, majority of respondents (51%) have informed view. Qualitative analysis of responses revealed that majority of PSTs are of the view that question plays a very important role in investigation but some of them had differing views regarding the hypothesis. "*Scientific investigations begin with a problem/question since initially the reason to start an investigation is a question that arise in our surroundings*". (S 43). Another PST remarked that*" I think the initiation of a scientific investigation do begin with a question. For example: when an apple fell on Newton's head, his first question was "Why did it fall?" which was a question and led to the discovery of gravitation. It was the starting point for a scientific investigation without any hypothesis".* (S7). Some of the responses which reflected mixed view are "*Yes I do agree that scientific investigations begin with a question but it does not mean*

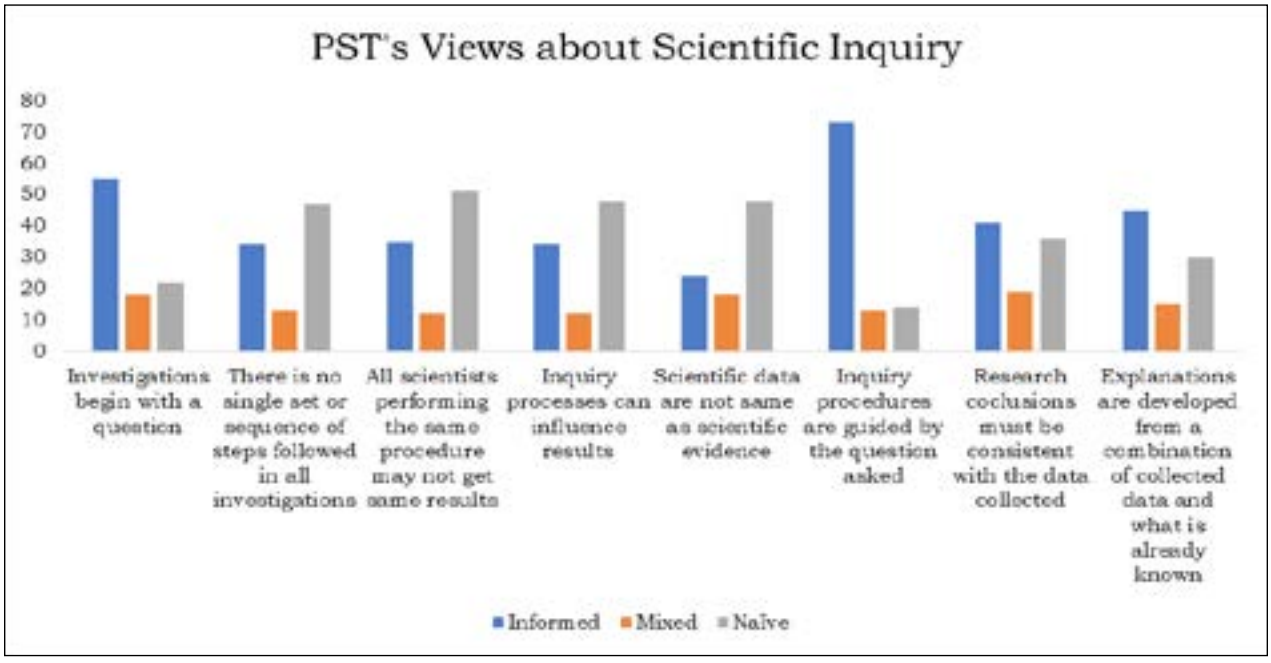

Table 2

Percentages of PSTs having Informed, mixed, naïve and unclear views about Scientific Inquiry

S. No	Aspect of SI	Informed			Mixed			Naive			Unclear		
		Year 1(N-58)	Yr 3 (N-49)	Total (N-107)	Yr 1(N-58)	Yr 3(N-49)	Total (N-107)	Yr 1(N-58)	Yr 3(N-49)	Total (N-107)	Yr 1(N-58)	Yr 3(N-49)	Total (N-107)
1	"Investigations begin with a question"	28 (48.3%)	27 (55.1%)	55 (51.4%)	8 (13.8%)	10 (20.4%)	18 (16.8%)	12 (20.7%)	10 (20.4%)	22 (20.6%)	10 (17.2%)	2 (4.1%)	12 (11.2%)
2	"There is no single set or sequence of steps followed in all investigations"	13 (22.4%)	21 (42.9%)	34 (31.8%)	8 (13.8%)	5 (10.20%)	13 (12.1%)	29 (50%)	18 (36.7%)	47 (43.9%)	8 (13.8%)	5 (10.2%)	13 (12.1%)
3	"All scientists performing the same procedure may not get same results"	11 (19%)	24 (49%)	35 (32.7%)	5 (8.6%)	7 (14.3%)	12 (11.2%)	38 (65.5%)	13 (26.5%)	51 (47.7%)	5 (8.6%)	4 (8.2%)	9 (8.4%)
4	"Inquiry processes can influence results"	12 (20.7%)	22 (44.9%)	34 (31.8%)	7 (12.1%)	5 (10.2%)	12 (11.2%)	27 (46.6%)	21 (42.9%)	48 (44.9%)	11 (19%)	2 (4.1%)	13 (12.1%)

5	"Scientific data are not same as scientific evidence"	11 (19%)	13 (26.5%)	24 (22.4%)	8 (13.8%)	10 (20.4%)	18 (16.8%)	25 (43.1%)	23 (46.9%)	48 (44.9%)	11 (19%)	6 (12.2%)	17 (15.9%)
6	"Inquiry procedures are guided by the question asked"	41 (70.7%)	32 (65.3%)	73 (68.2%)	8 (13.8%)	5 (10.2%)	13 (12%)	3 (5.2%)	11 (22.4%)	14 (13.1%)	6 (10.3%)	1 (2%)	7 (6.5%)
7	"Research conclusions must be consistent with the data collected"	19 (32.8%)	22 (44.9%)	41 (38.3%)	12 (20.7%)	7 (14.3%)	19 (17.8%)	21 (36.2%)	15 (30.6%)	36 (33.6%)	5 (8.6%)	6 (12.2%)	11 (10.3%)
8	"Explanations are developed from a combination of collected data and what is already known"	22 (37.9%)	23 (46.9%)	45 (42.1%)	9 (15.5%)	6 (12.2%)	15 (14%)	17 (29.3%)	13 (26.5%)	30 (28%)	9 (15.5%)	8 (16.3%)	17 (15.9%)

that hypothesis will not be tested" (S17). "*According to me, scientific investigation may arise from questions while checking the hypothesis at the same time. think testing hypothesis is not necessary as this gives us a new and fresh way to look at things and then later on in our research we can compare and analyse our results with the given hypothesis and we can compare them*" (S72). "*A scientific investigation typically begins with observations. Observations often lead to questions*" (S42). An example of naïve view is "*A hypothesis is a possible logical answer to a scientific question, based on scientific knowledge"* (S23). The trend also shows that senior PSTs (Year 3) have more informed and mixed views in this aspect as compared to the junior batch of PSTs (Year 1).

Aspect 2—"There is no single set or sequence of steps followed in all investigations"—In this aspect majority of PSTs have 'naïve' view of predominance of one single or correct method of investigation and that the sequence of steps followed in an investigation or experiment is both predetermined and fixed. One PST remarked that, "*to carry out any research objectively, there has to be a sequence that is to be followed"* (S 22). Another one shared that, "*generally a scientific inquiry should follow a set a procedure so as to not create any biases. Follow a set of guidelines minimises the chances of a mistake"* (S 17). Another PST shared that, "*I think in science we have predetermined steps to do an activity or experiment and if we skip or change the any step of the experiment, we may not get the same or right result"* (S 9). Few PSTs with mixed views shared that there may be more than one method in any scientific investigation but were not able to substantiate further. Only (32%) PSTs gave informed view about the multiplicity of scientific processes. For example, a PST remarked "*Set and sequence of steps followed in a scientific inquiry may vary from person to person as different people have different opinions and the questions and conclusion which arise in their minds may be different as well'* (S 21). Few responses also showed that PSTs have interpreted experimentation as different from investigation. For instance, one PST remarked that "*An experiment will have one method only which can be replicated but an investigation can be done in various ways'*(S14). The percentage of informed views increased with the year of study i.e., senior PSTs have more informed view than fresh PSTs.

Aspect 3 — "*All scientists performing the same procedure may not get same results*"—In this aspect too, a majority of PSTs have naïve and mixed views. Majority of them expressed the view that scientific investigation is determined by the steps, not by the working of a scientist. So if the same procedure is followed, results also need to be the same. The subjectivity in interpretation of data and influence of other factors were not acknowledged by PSTs. The trend across the years shows increase in the informed view in the senior PSTs as compared to junior PSTs. Some of the naïve views are "*conclusions must be the same if they are figuring out the same thing as science is universal(S3). "Even for the same thing, different procedures will lead to the same conclusion. If research results can be replicated, it means they are more likely to be correct. Replication is important in science so scientists can check their work.* (S34) Some of the mixed views are – '*Sometimes it holds true sometimes it doesn't, two scientists working on the same matter can come across very different conclusion but in some case no matter how many scientists work on it, the result is universal*!' "*It depends on the experiment that the scientists are testing out the universal experiments will have same conclusion but there can be different conclusions for other procedures'(S22)*

Analysis of responses reveal that few PSTs have informed view like '*True, as all the scientists cannot come on the same conclusion, every scientist would have a different point of view, perspective and analysations*' (S 27). Another PST shared that "*Socio cultural beliefs and working culture of the scientists influence the outcome of their research*" (S78).

Aspect 4 — "Inquiry processes can influence results". In this also majority of PSTs have naïve views as compared to informed views though the difference between the two groups is less. However, it is interesting to note that majority of senior PSTs (45%) have informed views whereas similar number of fresh PSTs have naïve views. Some of the responses which reflect naïve understanding are--

> *"No inquiry procedures don't influence the conclusion because what we get as a conclusion is well researched and conclusion is the end result after all the inquiry procedures have taken place". (S43)*
>
> *"If an inquiry is about the same thing, then their conclusions must be the same as science is universal" (S 53). Few PSTs with mixed views though agreed with the aspect, were not able to substantiate with any examples or further elaborate their understanding. Few exemplars are—*
>
> *"Yes, if different inquiry procedures are followed then it will definitely influence the conclusions". (S64). One PST shared that, "Yes, I think inquiry procedure can influence the conclusions for example again in the case of periodic table the inquiry procedure by Mendeleev included atomic mass where's the modern periodic table included atomic no. Which actually influenced the conclusion" (S19). In this example, it can be seen that PST did not have clarity regarding inquiry procedure and assumptions on which theoretical models are based.*

Aspect 5 — "Scientific data are not same as scientific evidence".

Majority of PSTs have not understood the difference between data and evidence as the responses in the naïve and unclear category is highest in this aspect. Very few had informed view that data are observations gathered by scientists during investigation whereas evidence is interpretation and product of data analysis. Some exemplars of naïve view are:

> *"Scientific Data can become a Scientific Evidence But it is not necessary that every Scientific Evidence is Scientific Data" (S 18)*
>
> *"Scientific data can be variable but scientific evidence can't be variable" (S27)*
>
> *"Scientific evidence is a body of fact showing whether a hypothesis is true or not while scientific data is the basis of evidence" (S 58)*
>
> *"Data means numbers and evidence means what we observe directly"* (S 7)

Some examples of informed views of PSTs are:

> *"Scientific data is defined as information collected using specific methods for a specific purpose of studying or analysing which is considered to be as scientific evidence" (S 23)*
>
> *"Scientific data is raw information with no judgment attached. Evidence is when data is used to try to prove or disprove a particular point" (S14)*

The mixed responses were correct but explanations were not clear or specific. For instance, a PST with mixed view share that *"Data means information whereas evidence means proof. They may not be same"*. (S 71)

Aspect 6 — "Inquiry procedures are guided by the question asked". In this aspect, it is found that majority of PSTs (68%) have informed view and shared that the question forms a basis for inquiry. Some of the responses which reflect this view are as follows:

> *"Questioning is the first step in every inquiry which is followed by the whole procedure. So yes, the Questions play an important role in giving a direction to whole of the inquiry" (S 18)*

"Yes, I agree. Inquiries are very much guided by the question asked for example major investigations like periodic table are more accurate today from when it was first made, which are guided by questions" (S19)

"Initially inquiry procedures may be guided by the question but during an inquiry many other different questions will arise as well which can also move an inquiry in a completely new direction" (S 61).

In this aspect also, senior PSTs have more informed view than first year PSTs.

Aspect 7 – "*Research conclusions must be consistent with the data collected*" — Majority of PSTs have informed mixed regarding this aspect also. *The data is the key source of conclusions hence the conclusions will not be accurate unless consistent with the data collected (S14).* However Significant number of PSTs (33%) have naïve view also.

Some examples of naïve view—

Conclusion may or may not be consistent with the data collected. The data collected may have some other inference which wasn't evidently visible. (S33)

Conclusion cannot be consistent as it gets evolved and accurate with many discoveries(S21).

In this also, third year PSTs have better understanding and reflects informed view than the new entrants.

Aspect 8 — "*Explanations are developed from a combination of collected data and what is already known*". In this aspect only 42 per cent have informed view and expressed that both present data and existing literature on the topic are essential to develop an explanation. Some of the exemplars of naïve and mixed views are:

"Explanations are surely developed from a combination of researched data but it's not necessary that we need an already known information too. The explanation could be even about what previously was known is now false" (S 41).

"Sometimes it can be true but it is not compulsory as we live in a dynamic world and explanations can be developed from critical thinking and logical reasoning and not just from data collected, some facts are known but there is a lot more to discover and explore". (S 45)

"Not always, many theories are just hypothesis like the shape of electron cloud." (S12).

The trend across the years suggests that though there is increase in informed views in senior students, however, naïve view is almost the same.

Conclusion and Implications

The present study explored the pre service teacher's views about various aspects of scientific inquiry using adaptation of VASI tool developed by Lederman et al (2014) for meaningful assessment of Scientific Inquiry. Qualitative analysis of the responses of 107 PSTs helped not only in categorising the views into 'informed', 'mixed', 'novice' understanding but also provided a rich insight into their conceptions about various aspects of SI. It is found that majority of PSTs have 'informed view' in two aspects of SI namely "all *scientific research begins with a question, but does not necessarily need to be tested with hypothesis"* and "Inquiry *procedures are guided by the question asked*" . However, they have naïve and mixed understanding in four aspects— "There is no single scientific method", "Inquiry procedures can influence results", Scientists performing same investigation gets same results" and "Scientific data and evidence are not same".

The qualitative analysis reveals that some reasons for these naïve and mixed views are— the manner in which science is presented in textbooks, emphasis of particular method of investigation and experimentation,

overreliance on prescribed curriculum and textbooks, inadequate opportunities for self-directed inquiry in science. This paper is a part of a larger research which includes baseline study of PSTs understanding and views about various aspects of SI and further designing the intervention on the basis of these. The study has important implications for teacher education programs. In order to promote scientific literacy in prospective teachers, it is important to incorporate Nature of Science (NOS), Scientific Inquiry (SI) through engagement in scientific processes (SPs) in self-directed experiential manner. TEPs need to provide scope to engage PSTs in laboratory and non-laboratory methods of inquiry and research. Both the foundation and pedagogy courses need to provide opportunities to engage in depth in various aspects of SI and reflect on their understanding. TEPs should have modules designed to address these and include historical aspects of science and socio scientific issue in the curriculum. It is important that prospective teachers have informed views about SI so that they can promote scientific inquiry and scientific literacy in their students during their professional engagement.

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