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Science Teachers' Conception Of Nature Of Science: An Exploratory Study

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Abstract:

Achievement of scientific literacy is one of the major goals of science education. Nature of Science plays a critical role in achievement of scientific literacy. Teachers are vital component in achieving this goal. Improvements in NOS conceptions of students is largely dependent on how the teachers understand the concepts of NOS. The purpose of this study was to assess the teachers' conception of NOS. This study used qualitative descriptive research design. This design was used for description of the phenomenon. Participants were selected purposefully on the basis of their subject teaching, qualification and participation in professional development programs. Teachers' NOS views were collected through open ended questionnaire VNOS followed by semi structure interviews. Data collected through open ended questionnaires and interviews were analyzed by organizing the responses in themes and subthemes by initial coding followed by focused coding. Findings of the study depicted that the participants do not have informed conceptions of NOS. The most frequent misconceptions were that there is a single step by step scientific method, experimentation is always required for science, creativity is not used and culture do not play any role in science. The misconceptions highlighted in this study can be utilized in developing training and development initiatives by education authorities.

Keywords: Nature of Science, Assessment of NOS, Teachers' concept

Introduction

Achievement of scientific literacy is one of the major goals of science education. Importance of scientific literacy has been highlighted in national and international educational documents (Ministry of Education, MOE, 2006; American Association for the Advancement of Science, AAAS, 2009 and National Research Council, NRC, 1996). NRC (1996, 2000) further explicated understanding of Nature of Science (NOS) as a vital part of scientific literacy and highlighted NOS as an important outcome of science education.

NOS is a complex arena and no single universally acceptable definition is available. However, there is consensus on different aspects and dimension of NOS. These aspects include components from philosophy, history and sociology of science along with their consequences on different features of scientific knowledge. Science has its own way of knowing and searching answers to questions about natural world. (Lederman & Lederman, 2014; McComas et al., 1998).

Several research studies on teachers' conception of NOS highlighted that both the teachers and students' conception of NOS are naïve and inadequate. On the basis of almost 50-year studies on NOS, Lederman (2007) generalized that teachers' and students' conception of NOS were inadequate with respect to national science standard documents and education policies. Additionally, studies conducted by (Iqbal, Azam, Rana, 2009; Posnanski, 2010; Buaraphan, 2010; Akerson, Cullen, & Hanson, 2009; Lotter, Singer, &

Godley, 2009) also reported inadequate NOS conceptions of the teachers.

Teachers are vital component of any educational reform program. Brining improvements in NOS conceptions of students is largely dependent on how the teachers understand the concepts of NOS and how well they translate it to students' learning. However, Hermen, Olson and Clough (2019) are of the view that promotion of NOS is challenging in an environment where the teachers, education managers and other stakeholders missed the experience of NOS learning during their own schooling. As a result, they do not acknowledge NOS as an outcome of science education. In this situation professional development of teachers become crucial to convince them about importance of NOS and equip them with content and pedagogy of NOS.

In Pakistan there are limited studies on teachers' conception of NOS. In national curriculum documents of Biology, Chemistry, and Physics only few aspects of NOS have been highlighted. It is also an undermined component both in pre-service and in-service teacher education programs. The research studies on NOS which are available in Pakistani context mostly used quantitative methods for measuring NOS conception. These studies (Iqbal et.al., 2009; Ahmed and Bhatti, 2018; Halai, 2004, 2010; Halai and Hodson, 2011, Shah, 2009, Halai and McNicholl, 2004) did not address all the common aspects of NOS, most of the studies only discussed 2-5 aspects of NOS in detail, which brought out incomplete profiles of the teachers. This situation demanded an in-depth analysis of teachers' conceptions of NOS. This study provided complete NOS profiles of the teachers with respect to seven common aspects of NOS.

Purpose of the study:

Teachers' conception of NOS is limited researched area in Pakistan. Only few studies are available and most of them used quantitative methods for measuring NOS conception. Additionally, these studies did not provide complete NOS profiles of the teacher and are limited to only 2-5 aspects of NOS. This situation demanded an in-depth analysis of teachers' conceptions of NOS. Study of NOS conceptions needs in-depth explorations of participants' thoughts and experiences. Keeping in view the complexities of NOS, most of the studies on NOS preferred qualitative methods. The purpose of this study is to examine the teachers' conception of nature of science.

Methodology

This study used qualitative descriptive research design. According to Lambert & Lambert (2012) qualitative descriptive studies have the tendency to approach something in its natural state to a possible extent. Besides being different design, it may have shades of other qualitative designs, especially the grounded theory. This study was conducted in Secondary Schools and 20 Secondary Teachers were purposefully selected. At first phase, teachers' conceptions of NOS were collected through open ended self-reporting questionnaire VNOS-C which was adopted from Lederman, Abd-El-Khalick, Bell, & Schwartz (2002). Secondly, semi-structured follow up interviews were conducted for better insight of the data and its triangulation.

Contextualization of the Study

The study was conducted in Secondary Schools of District and Tehsil Rawalpindi. Secondary Science Teachers of Biology, Chemistry, Physics and Mathematics were part of the study. There were 959 Secondary Science Teachers in District and Tehsil Rawalpindi. Academic qualification of most of the participants was Master degree in Biology, Chemistry, Physics or Mathematics. Professional qualification was Master of Education (M. Ed) or Bachelor of Education (B.Ed./B. Ed Hons). Although the phrase NOS is missing in National Curriculum documents and textbooks of science subjects, but some

aspects of NOS have been highlighted. One of the reasons NOS did not get attention of the education professionals is that they have missed the experience of NOS learning during their own schooling. It was also a less focused area in in-service training programs for science teachers. Most of the previous research studies were limited to quantitative analysis of NOS conceptions and its practices. Additionally, these studies did not provide detailed NOS profiles of the teachers and were limited to explain only 2-5 aspects of NOS.

Selection of Participants of the Study

Participants were selected purposefully on the basis of their subject teaching, qualification and participation in professional development programs. This study used qualitative descriptive research methods and 20 participants were selected.

Tool Development Procedure

This study adopted VNOS-C due to its suitability with the nature of the study. This qualitative study required a tool of extensive and open-ended nature which allowed participants to narrate their conceptions in detail. VNOS-C has highest number of questions in context as compared to other VNOS versions. Constructs of the instrument were based on tenets of NOS which were included in the objectives of study for measuring conception of the teachers.

Validation/Credibility

The VNOS-C questionnaire was validated in context of the study, participants NOS profiles generated through questionnaire and interviews were analyzed separately to achieve high degree of congruence. Peer and colleague data scrutinizing was carried out for ensuring transparency and dependability. Procedures along-with detailed steps were documented to ensure qualitative reliability. Self-perceptions, biases and change in thinking was monitored with the help of notes and journal.

Procedure of the Study

On completion of approvals of the study, potential participating schools and teachers were sent invitation for seeking their consent and raise questions. The researcher visited the schools for addressing the queries. On receiving consent of the participants, researcher visited the schools for getting responses of the teachers on open ended self-reporting questionnaires. According to the recommendations of Lederman, Abd-El-Khalick, Bell, & Schwartz (2002) the participants were provided orientation that this is not a test nor any form of assessment. No time limit was assigned for completing the questionnaire. Questionnaire data provided views on conception of Nature of Science. Follow up interviews were conducted for deeper insight into the concepts and terms used by the participants in response to the questionnaire.

Collection of Data

In the first stage of the study, the researcher visited the schools for collecting data regarding teachers' NOS conceptions by using open ended self-reporting questionnaire VNOS-C. Interview data was collected through interview protocol. Questionnaire was administered and interviews were conducted till achievement of saturation.

Data Analysis

Data collected through open ended questionnaires were analyzed by organizing the responses in themes and subthemes by initial coding followed by focused coding. Recurring ideas, concepts, patterns and interconnections was identified. In addition to analyzing the item-wise responses, cross item responses were also be analyzed for finding relationships between the items. Interviews data was be analyzed following the same steps to support and elaborate the questionnaire responses. Explanation, finding and conclusion was drawn by combining questionnaire and interview responses.

Findings

Overall, the results of the study depicted that most of the participants' conceptions of NOS are not inadequate and naïve. The most common misconception held by the participants was that scientists follow pre-defined steps and single step by step scientific method for their investigations. They also overemphasized the role of experiments in development of scientific knowledge. Additionally, they also held misconception that scientists do not use creativity and imagination during their investigations. The least frequent misconception was regarding nature of theory, they depicted informed views that theories can be change with advancements in research.

Responses from the questionnaire and interviews provided following results:

Participants were asked about science and its difference from other disciplinary inquiry. Most of the respondents mentioned that science knowledge is developed through standard steps of research. They also emphasized the role of scientific method and especially the importance of experimentation in finding solutions to the problem.

> "Science is a discipline in which scientific method is used to learn knowledge through experiments. In maximum cases (e.g. religion and philosophy) there are specific ethics and beliefs which are believed without any proof. In science subjects, experiments are performed for getting knowledge"... (Respondent 3)

Additionally, participants were asked to share their views regarding experiments. Most of them shared that experiments are part of scientific method and it is usually used for accepting or rejecting the hypothesis. Some respondents highlighted experiments as foundation of scientific knowledge for exploring the world.

> "An experiment is the scientific standard way to testify the validity of the hypothesis made on the basis of observations. Experiment is designed according to the nature of hypothesis and phenomenon to be tested/verified..." (Respondent 1)

In response to the question regarding requirement of experiments for developing knowledge, most of them explained that it is basic requirement of scientific knowledge, it increases the validity of the knowledge. Some respondents also shared that observation, exploration, objectivity and discovery skills also play their part in development of scientific knowledge.

> "Experiment is an essential ingredient of any scientific knowledge and if it is not there, it can be only philosophy or a guess…" (Respondent 7)

Responding to the question for sharing views about changing nature of theories, most of them shared that theories can be evolved, modified and rejected with progression in of scientific knowledge. However, the common misconception was also highlighted that "experiments proved again and again becomes a theory".

> "Yes, theory may change according to the needs and facts. Accepted theories may be modified or overturned as new evidence and perspective emerges. Theories can be changed and replaced when new information disprove the current theory becomes available…" (Respondent 15)

Regarding difference between theory and law, most of the respondents highlighted a sequential order between theory and law i.e. theory becomes law. Law describes how the phenomenon takes place while theory describes why the phenomenon is taking place. A common misconception mentioned in the responses is that theory can be changed but law cannot be changed.

> "A scientific law is the description of an observed phenomenon. The

> explanation for a phenomenon is called a scientific theory. In simplest terms, a law predicts what happens while a theory proposes why?..." (Respondent 17)

In response to question that how certain the scientists are regarding structure of atom, commonly held participants views were that the scientists were certain about the structure of atom in respective time period, however further research added value to their incomplete or inaccurate knowledge about structure of atom.

> "Scientists were sure that atomic structure consists of nucleus and orbits. Nucleus having protons and neutrons. Electrons are revolving around the nucleus. Electrons have negative charge…" (Respondent 4)

Similar responses have been received about characterization of species that scientists are certain about different characters of the species. Most of respondents further shared that scientist are convinced with the similar characteristics, interbreeding and producing fertile offspring component.

> "Scientists are certain about definition of species, member of species resembles one another, they interbreed with other individuals within the same group to produce fertile offspring under natural conditions…" (Respondent 14)

Regarding the question about scientists arriving at different conclusions on the basis of same set of data, most of the participants were of the view that scientists can have different conclusions based on their background, research approach, knowledge, skill set and available research equipment.

> Definitely both conclusions can be possible. Scientists have different facilities knowledge and skills… (Respondent 10)

Most of the participants held views that science is universal and it has nothing to do with values and culture. It is not affected by the social and political values. In support to their views some of them shared examples of gravity and set of physical laws operating everywhere following same procedures.

> "Science is universal with respect to the fact that laws, rules and phenomenon associated with science are same everywhere irrespective of any region, country, society or culture. The remain same always…"(Respondent 8)

Similar responses were received with respect to scientists using creativity and imaginations; most of the respondents shared that scientist do not use creativity and imaginations. They follow well defined set procedures to solve the problems. Some of the highlighted that scientist can use creativity at planning stage only.

> "Scientist do not use imagination and creativity. Science is on the base of facts. Scientists use scientific method to solve the problems. For this they pass through a series of steps" (Respondent 2)

At the stage of open coding most frequent codes appeared in the participants responses were; theory can change, values do not influence science, pre-defined steps, nature of species, experiments to test hypothesis, theory is explanation, different approaches towards data, each step creativity, evidences required, scientific knowledge and different skill set. Among the least frequent codes were; theory never change, theory lacks worldwide acceptance, law accepted worldwide, no creativity usage, sequential order, surety of atom's structure, values do influence science and different working conditions.

On focused coding stage according to the connection and linkage between the codes, categories emerged as; experimental nature of science, nature of theory and law, nature of experiment, values infusion in science, nature of species, same data-different conclusions,

involvement of creativity and role of science-religion. The emerged categories are coherent with widely accepted seven aspects of NOS. Major findings of the cross item analysis revealed that the participants those conceptions were naïve with respect to first item regarding difference of science from other disciplines; the participants emphasized sequential order in study of science, these participants views also remained consistently naive in second item regarding experimentation i.e. they overemphasized the role of experimentation in science. Furthermore, same conceptions were repeated in response to item six whether scientific knowledge requires experiment or not. Another pattern was noted between item six regarding structure of atom and item seven regarding the definition of species; those participants who shared that scientists were sure about structure of atom also shared same responses regarding definition of species i.e. scientists are sure about characterization of species.

Discussion and Conclusions

The focus of this study was to assess the teachers' conception of NOS. Overall, the teachers do not have informed conceptions with respect to major aspects of NOS. Common misconception held by the participants were related to the strategies scientists use to investigate the problems, they shared that scientists follow pre-defined step by step scientific method for their investigations. Another common misconception was that they considered experiments as integral part in development of scientific knowledge.

Furthermore, they also claimed that there is no role of creativity and imagination in science. However, some participants held partial informed conceptions about creativity and imagination that scientist use imagination at planning stage only. The participants held partially informed conception about nature of theory that theories are not durable and can be changed with advancements in scientific knowledge.

The findings about naive and inadequate conceptions of the participants are consistent with findings of the studies conducted by Posnanski, 2010; Buaraphan, 2010; Akerson, Cullen, & Hanson, 2009; Iqbal, Azam & Rana, 2009; Lotter, Singer, & Godley, 2009. All these studies highlighted that teachers' conceptions of NOS are inadequate and naive.

The finding of the study is also consistent with study conducted by Shim, Young & Paolucci (2010) with 348 in-service science teachers, they have reported that most of the teachers have uninformed views especially with respect to effects of society and culture on science. This study also found that most of the teachers did not acknowledge the infusion of science with culture. Second most frequent misconception highlighted by them was that teachers were of the view that scientific investigations follow single step scientific method. This study also reported similar findings about misconception of the teachers that scientist follow single step by step method.

On the basis of finding of this study, it can be concluded that teachers lack the basic understanding about NOS and without improvements in the teachers' conception of NOS, achievement of scientific literacy by students will remain incomplete. The misconceptions highlighted in this study can be utilized in developing training and development initiatives by education authorities.

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