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ARTICLE

PCK for Developing Understanding of NOS: A Review of Past Studies

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ABSTRACT

The term 'Nature of Science' (NOS) is often used to refer to distinctive characteristics of scientific enterprise and qualities of scientists. An adequate understanding of NOS is crucial for better decision-making and a positive scientific attitude. Teachers are expected to develop this understanding among their students for which they require an understanding of various aspects of NOS (e.g. scientific knowledge is tentative or science involves creativity). In addition, they need knowledge of how learners' misconceptions about NOS and scientists can be challenged with the help of appropriate strategies. This knowledge base of teachers is popularly referred to as 'PCK for NOS' (Pedagogical Content Knowledge (PCK) for teaching NOS). This knowledge base is complex. How far teachers possess it needs investigation. In the present paper, the authors have provided a review of studies revealing the status of teachers' PCK for NOS. Firstly, teachers' understanding of NOS is discussed. Then, the status of science teaching in schools is reviewed. Thereafter, studies specific to PCK for NOS are examined. The factors that influence the teaching of science and NOS are also highlighted. The review reveals that teachers do not understand some important aspects of NOS and hold the stereotypical image of scientists. The teaching-learning of science in schools is also not satisfactory and NOS is hardly addressed in science classrooms. However, the intentions and practices of teachers for teaching NOS evidently improve with interventions. Based on the review, the paper concludes that the way science is presented in science classrooms needs to be revisited. It is suggested that Teacher Education Programmes must play their role in developing PCK for NOS among teachers and suitable instruments must be developed for measuring PCK for NOS.

Keywords: Nature of Science, Pedagogical Content Knowledge, PCK for NOS, Instruments

Introduction

By developing an understanding of the Nature of Science (NOS) among learners, science education aspires to develop informed citizens who can deal with large amounts of contradictory information and issues interfacing with science and society (Fouad, Masters, & Akerson, 2015). The term NOS reflects upon the characteristics of scientific knowledge, scientific inquiry and scientists. Its contemporary understanding among scholars suggests that there are different ways of developing scientific knowledge. The developed knowledge is based upon both observations and inferences, and cannot be claimed as permanent. However, its empirical basis and openness to tests make this knowledge enduring and reliable. Scientists develop further upon existing ideas, and use their imagination and creativity while conducting scientific investigations. Scientific theories and scientific laws are distinct kinds of knowledge. Science has a cultural basis and scientists are a part of society. Science is different from other ways of knowing but the criteria to make such demarcation have been subject to debate. However, as evident in further discussion, the issue is that even the common characteristics of science are not well-understood by science teachers. Also, some notions are associated with scientists which portray them as 'different'. This issue needs attention because teachers' views get reflected in their teaching and their uninformed views may disengage learners from science and scientists.

The views of learners about science are found to influence whether they want to understand or memorise the subject of science (Songer & Linn, 1991). Learners also hold misconceptions about NOS (Das, Faikhamta, & Punsuvon, 2019) and even the formal modes of information like textbooks sometimes misrepresent science and scientists (Kaur, 2015). At the same time, the benefits of understanding NOS cannot be ignored and the Indian science curriculum has also recognised its role in science education. For instance, the document on 'Learning Outcomes at the Elementary Stage' developed by the National Council of Educational Research and Training (NCERT, 2017) expects to develop an understanding of the nature of scientific knowledge among learners.

For making subject matter comprehensible for learners, teachers require a special kind of knowledge referred to as 'Pedagogical Content Knowledge' or 'PCK' (Shulman, 1986). This concept of PCK also applies to the teaching of NOS. In this regard, the term 'PCK for NOS' is popularly used to refer to the knowledge base of teachers for teaching NOS. Development of understanding of NOS among students depends upon certain conditions. It requires inquiry classrooms. Teachers must understand the content of NOS to teach it. They must also know how to teach it by using appropriate materials and strategies. How far teachers possess this knowledge is questionable. In the discussion ahead, a review of some studies is provided which sheds light upon the understanding of teachers about NOS, how science teaching goes on in science classrooms, and how teachers address NOS while teaching. The factors that affect the teaching of science and NOS are also discussed. This review helps in evaluating the status of PCK for NOS among teachers.

Understanding of teachers about the Nature of Science

Studies show that teachers hold uninformed views about some characteristics of science and scientists. For instance, teachers in the study of Rampal (1992) (who were undergoing in-service training) believed that scientists are emotionless, lack creativity, look serious and lost, and remain uninfluenced by social pressures and biases. The views however varied with different years of training, and resource teachers who had earlier received such training held better views. The majority of pre-service science teachers in the study by Dogra (2011) believed that scientific models are copies of reality and that scientists must follow a step-by-step method of doing science. Many pre-service teacher educators in the study of Chopra (2015) believed that context and human experience have no influence on science, and imagination and creativity are involved only during the planning and designing of scientific investigations. The majority of them held uninformed views regarding the nature of scientific theories and laws. In the study of Singhal (2017) also, many pre-service teachers and teacher educators held naïve views about scientific theories and laws. They also did not believe in social or cultural influence on scientists' work. While discussing the influence of

science on society, they kept referring to technology. They did not understand how science affects the thinking and decision-making of people. They were not aware of how experiments are conducted in fields.

The studies indicate that teachers of different levels lack an adequate understanding of some crucial aspects of the nature of scientific knowledge and scientific investigations. They also hold some unfitting notions about scientists. The findings of the above studies are concerning because teachers may unintentionally translate these uninformed views to their students in the teaching-learning process.

Teaching science in classrooms

Studies have revealed an alarming situation of teaching-learning in science classrooms. About half of the teachers in the study by Masih (1998) viewed secondary-stage science as environmental, general or pure science but did not consider it as an integrated science. Their focus was limited to the assessment of conceptual understanding only. They did not know how to assess scientific attitudes among learners though they found it important. Nargund-Joshi, Rogers, and Akerson (2011) in their case study on two secondary science teachers noted that students were expected to provide the right answers to questions. They read aloud from the textbooks. A disconnect was there between theory and laboratory classes. Verification of concepts was the only purpose of conducting laboratory work. Teachers felt the pressure of preparing learners for board exams. Parashar and Singh (2011) found that teachers themselves concluded the activities instead of providing this opportunity to students. Learners lacked laboratory skills. Strategies of teaching were not changed in accordance with learners' needs, and assessment techniques used by teachers were also not satisfactory. In the study of Mohanty (2012), the majority of teachers had not participated in in-service training programmes. They found textbooks sufficient for attaining teaching objectives and used the lecture method of teaching. The majority of sample schools did not have a science laboratory and available teaching aids were also not suitable. Some student-teachers in the study of Karal (2017) were doubtful of whether it was possible to use

learner-centred orientations of teaching in actual classroom settings.

Multiple issues related to teaching-learning have been noted in the above studies. Learner-centred ways of teaching are not followed in science classrooms. Preparing learners for examination remains the focus while other areas of science learning get ignored. The needs of learners and the nature of the curriculum are also not paid much attention to. The dependence of teachers upon textbooks is another issue because textbooks often portray stereotypical images of scientists (Kaur, 2015) and leave no scope for inquiry by learners (Bansal, 2014). Science stories provided in textbooks sometimes represent science as a privileged form of knowledge (Milne, 1998). Moreover, studies like Mohanty (2012) have found that there are students who find the explanation of concepts and language of textbooks difficult to comprehend. It can be concluded that neither written curriculum nor teachers present science accurately. As teachers are found to face difficulty in different areas of teaching-learning (curriculum, instruction, assessment, learners' needs), it can be said that their PCK for science teaching is not well-developed.

PCK of teachers for teaching NOS

Some studies have been conducted to investigate how far teachers are capable of teaching NOS. These studies shed light upon their knowledge base and practices. These are mostly intervention studies and qualitative. The model of Magnusson, Krajcik, and Borko (1999) on PCK for science teaching has been extended for use in several studies on PCK for NOS. These studies focus on dimensions like teachers' intentions and rationales for teaching NOS, alignment of their teaching orientations with NOS, and their knowledge of NOS-specific curriculum, learners' needs, instruction and assessment.

Lack of instruments to measure PCK for NOS was observed during the review. Instruments like 'Beliefs about Science and School Science Questionnaire' (BASSSQ) (Aldridge, Taylor, & Chen, 1997) and 'Views on Science and Education' (VOSE) questionnaire (Chen, 2006) touch the area of NOS in science education but they do not cover PCK for NOS in a holistic manner. Multiple sources and techniques are used to collect data

in such studies. These include open-ended questionnaires, semi-structured interviews, lesson plans, field notes, journal entries, assignments, observations, discussions and so on.

Incorporating NOS in science teaching is difficult for teachers. They do not hold an adequate understanding of NOS and do not know how to teach it. Novice chemistry teachers in the study conducted by Supprakob, Faikhamta, and Suwanruji (2016) held informed views about subjectivity in science, partially informed views about the relationship between science, technology and society, and naïve or partially informed views about scientific theories and laws. They did not elicit the views of their students about NOS. They did not assess their students' understanding of NOS even when they used multiple techniques to assess their understanding of chemistry. Dependence on textbooks and promotion of rote memorisation was also observed by the authors. The school teachers in the study of Leden *et al.* (2015) had to implement a curriculum focused on NOS without much training. The views of these teachers differed when they talked about 'NOS' and 'NOS teaching'. While talking about NOS, they mentioned the tentative character of scientific knowledge. In the context of teaching, however, they viewed scientific knowledge as permanent and consisting of facts. They had many examples to support their views on NOS but did not have many examples concerning the teaching of NOS. According to them, teaching NOS required a shift from normal science teaching.

Interventions targeted at developing an understanding of teachers about NOS and its teaching are found effective. In the case study of Schwartz and Lederman (2002) on two new secondary science teachers, instruction on NOS and its teaching was found effective for one teacher who was able to support NOS views with examples and teach it in a less didactic manner. Lack of subject-matter knowledge and unsure views of NOS were found to be the reasons why much improvement was not observed in another teacher who taught NOS didactically, without integrating it with the content of science. After studying a PCK-based NOS course, more in-service teachers in the study of Faikhamta (2013) exhibited an informed understanding of NOS. More of them now held inquiry orientation and believed in

the explicit teaching of NOS. The majority of pre-service chemistry teachers enrolled in a course on NOS and its teaching in the study of Demirdöğen *et al.* (2016) had developed knowledge of instructional and assessment strategies for teaching NOS. In their lesson plans, they included only those NOS aspects which they understood.

Most of the middle school teachers in the study of Mulvey and Bell (2017) (who had undergone a professional development programme) had intentions of teaching NOS. They found NOS important because it is associated with scientific literacy and increased interest in science. Authors observed that prior to the programme, the lack of understanding of teachers about NOS stopped them from teaching it. Hanuscin, Lee, and Akerson (2011) studied how some elementary teachers (who had undergone professional development) successfully taught NOS in classrooms. It was found that those teachers used kid-friendly language for teaching NOS, operationally defined NOS for learners during inquiry activities, used children's literature and provided analogies for NOS. Their orientations changed from activity to inquiry after professional development. They were able to teach NOS with different strategies even in the scarcity of supporting material. However, they were not able to assess the development of understanding of NOS among their students.

It can be concluded based on the above studies that NOS is not generally taught in science classrooms. However, teachers tend to incorporate NOS in teaching when they are confident about their own understanding of it and when they find it important for their students. Interventions are found helpful in changing teachers' views about NOS from uninformed to informed, and in developing their intentions and PCK for teaching NOS. However, the assessment of learners' understanding of NOS remains the most difficult for teachers.

Factors influencing the teaching of the Nature of Science

Teachers face many constraints while teaching. Several studies have shed light on factors that influence the teaching of science in general and particularly the teaching of NOS. Lack of interdisciplinary knowledge was one of the constraints for teachers in the study of Masih (1998). For participants in the

study of Karal (2017), time, class size, school administration, learner motivation, availability of equipment, and subject-matter knowledge of teachers were the factors involved in the implementation of lesson plans. For teachers in the study of Jabeen (2013), focus on examination and workload were also the factors apart from time and class size that influenced NOS teaching. Rampal (1992) pointed out that teachers' understanding of the nature of scientific knowledge affected what qualities they associated with scientists. Teachers were found to avoid NOS during teaching in the study of Lederman (1999) because it was challenging for them and they did not believe in their students' capability to understand NOS.

Conclusion and Suggestions

The understanding of NOS among different stakeholders has been researched for a long but the area of research in PCK for NOS is relatively new. Studies have revealed a lack of understanding of NOS among teachers. The way science is taught in classrooms is also not satisfactory. Textbook dependence, examination dominance and avoidance of inquiry are prevailing issues in science teaching. Understanding of NOS among teachers and their knowledge of effective teaching of science are two crucial factors that decide how NOS is represented in science classrooms. However, the studies have shown a limited understanding of teachers in these two domains and thus the status of their PCK for NOS comes into question. The narrow scope in which science is taught leaves no space for the teaching of NOS. It is crucial to improve the way science is taught to present a true picture of science before learners. This can be ensured by developing PCK of teachers for science teaching in general and NOS teaching in particular. Teacher Education Programmes must play their role in this regard. Teachers should be prepared to assess and reflect upon their own science teaching practices including their understanding and teaching of NOS.

Another issue is related to the lack of availability of suitable instruments for measuring PCK for NOS. Instruments are required to generalise the findings on teachers' PCK for NOS. Some instruments covering different dimensions of this construct

(e.g. teachers' understanding of NOS-specific assessment strategies or teachers' PCK for teaching 'tentativeness of scientific knowledge') must be developed with the help of some guiding frameworks. Such instruments may prove helpful for the self-assessment of teachers as well as for intervention studies.

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