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Exploring the Conceptions of a Science Teacher from Karachi about the Nature of Science

Mir Zaman Shah
RMIT University, Bandoora, VIC, AUSTRALIA

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The main purpose of this study is to investigate a science teacher's beliefs and understanding of the nature of science (NOS) in order to be able to relate these beliefs about the NOS to classroom practice and therefore student experience. Teachers' beliefs about the NOS are embedded in their experiences of learning and teaching science and hence, this research contains elements of a life history approach within a qualitative interpretive design. A single science teacher, Ikraam (a pseudonym), working in a community-based co-education school in one of the socio-economically disadvantaged areas in Karachi, was the focus of the research. His life story plays a vital role in this study to illustrate his views of the NOS. The data includes six life history interviews, two group interviews with his students, eight classroom observations and document analysis. The study revealed that the teacher's beliefs about the NOS were embedded in his own experiences of learning and learning to teach and indicates that in some cases Ikraam held informed conceptions about the NOS but in some important areas he displayed naïve views.

Keywords: Science Teacher, Epistemological Beliefs, Nature of Science (NOS), Life History Approach

INTRODUCTION

The main purpose of this study was to investigate a science teacher's concept and understanding of the nature of science (NOS). The study was conducted on a single science teacher, Ikraam (a pseudonym), a young male teacher working in a community-based co-educational school in one of the socio-economically disadvantaged areas in Karachi. Though gender was not a part of the variable in my study, for purely pragmatic reasons, I have chosen to select a male science teacher. His life story plays a vital role in this study in order to illustrate his views of the NOS. The data includes six interviews with Ikraam, two group interviews with fourteen students in two groups, eight classroom observations with post-lesson discussions, documentary analysis, and a number of informal conversations with Ikraam, his colleagues and students. Findings included how Ikraam's own experiences initially made him see science as difficult but he was able to change this perception when presented with opportunities to study in an Advanced Diploma in Education: Science (ADES) program. This study program allowed Ikraam to critically reflect on his practice and to develop theories about the contradictions between beliefs and practice that were identified during observation sessions. These were ascribed to a combination of constraints in resourcing and pedagogical skills. The ADES program was also found to have some limitation as there were assumptions in the approach about implicit knowledge and there was no acknowledgement that some learning may need to be explicit.

Correspondence to: Mir Zaman Shah, Doctoral Student, School of Education, RMIT University, PO Box 71, Bundoora 3083, VIC, AUSTRALIA
E -mail: *mirzaman.shah@akesp.org*

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Background to the study

My experiences of working as a teacher and teacher educator for 15 years reveal that what a teacher considers to be desirable ways of teaching and learning, are likely to be influenced by his/her own knowledge of the nature of the subject s/he teaches. Similarly, all teachers of science have implicit and explicit beliefs about science, inquiry, teaching, and learning (National Research Council [NRC], 1996). Hence, in Harlen's (1992) words, "We teach according to how we understand the nature of what we are teaching and according to how we understand the nature of learning" (p. 1). Therefore, what constitutes good science teaching can be better determined by understanding what the teachers understand about the nature of scientific knowledge.

Many previous studies have shown that in most cases, both pre-service and in-service science teachers' understandings of the nature of science (NOS) are inconsistent with contemporary concepts of the scientific endeavour (Abd-El-Khalick & Lederman, 2000). The situation of Pakistani science teachers is no exception. They also have a linear understanding of science and so they consider science to be a body of knowledge characterized by facts, concepts, laws, and theories that are absolute and cannot be challenged. Most teachers assume that only scientists can construct scientific knowledge and learners have to strictly follow them. They believe that knowing science is to learn the scientific concepts translated by the teachers from the textbooks. Hodson (1998) calls such views a depersonalized image of science, which he considers a serious misrepresentation of the NOS and scientific practice. Thus teachers impart factual information to their students at the expense of "the most important objective of science instruction [NOS]" (Lederman, 1992, p. 340).

Such naïve conceptions of teaching science lead to classroom instruction that strongly emphasizes rote memorization of science content presented by the teacher or read from the textbooks. As a result of such instructions, students may learn facts, hypotheses and theories of science – the *what* of science, but they do not necessarily develop an understanding of where this knowledge originates from – the *how* of science (Duschl, 1994). While in the learning process, there is a place for memorization, this does not help the students to understand and develop concepts that enable them to make sense of new experiences and apply their learning in decision-making in their daily lives (Harlen, Marco, Reed & Schilling, 2003). In addition, learning science becomes a dry, difficult and boring activity for the students, and so they develop a negative perception of science and find it irrelevant to their daily lives.

Therefore, it appears that practices of teaching and learning science reflect the teachers' own ignorance of the nature of the scientific enterprise. Thus not knowing about science, science teachers continue to teach science as a collection of facts, and such teaching practices foster students who go on to become teachers who follow their own teachers, and the cycle continues (Halai, 2000). Esler and Esler (1996) state: "What science is *not* is a set of facts. Those who work with science know that what a fact is today is questioned tomorrow, and often ridiculed as nonsense a year from now" (p. 6).

The following comments of Lederman, McComas and Matthews (1998) rightly endorse the problem of the study:

> *What seems to be the problem? First, science teachers persist in portraying science in a highly idealized, stereotypic fashion. Even those teachers who do have more adequate views of science typically fail to address questions about the nature of science in their daily instruction. There is also inconsistency in how science is portrayed in textbooks. Most texts … [also] portray science in a distorted, positivistic, and 'final form' fashion. (p. 507)*

Science teachers in Pakistan, in most cases, have an inadequate understanding of the NOS (Halai, 2004). In their classrooms they dictate notes from the textbook and the students memorize them without understanding. Thus, not knowing about the NOS, they present science as a product, but they are unable to guide students to understand how scientific knowledge is constructed.

This paper identifies a problem related to the teaching and learning of science and describes a research project examining the experience of a science teacher in a community-based school in Pakistan. The teacher was chosen as a participant as his experience of science teaching, as both a pupil and a teacher, had not been positive until he had the opportunity to study for an advanced diploma in education. For the purposes of this present paper two of the findings are discussed (1). Science is seeing and doing and (2). Observations are independent of theory. These are important as the influence that teachers have on students can be intergenerational and therefore a case can be made that the teaching and learning of science needs to be reconceptualised.

The Research

This research posited the question of what is a science teacher's understanding of the nature of science, while teaching science in a school in Pakistan? The study was based on certain fundamental assumptions. Firstly, teachers can play a major role in developing students' understanding of science if they themselves have a sufficient understanding about the nature of scientific knowledge because conceptions/beliefs are likely to influence classroom instructions. Secondly, an exploration of teachers' concepts about the NOS will shed light on their beliefs about science, and the teaching and learning of science. This exploration in turn, will help science educators to identify ways to

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enhance teachers' conceptions through professional development programmes.

To contextualise the study I examined the literature on the meaning and the important aspects of the NOS, and the importance of teaching about the NOS to students in science education. I also reviewed some key studies on the teachers' conceptions about the NOS, including the relationships between their concepts and their classroom practices.

The literature

What is the nature of science?

The concept of the nature of science is a complex notion. Science educators are quick to disagree on specific definitions for the NOS (Abd-El-Khalick, 2001). Various writers have defined it differently. Cobern (2000) points out that "NOS researchers do not offer a single answer to the question, what is science? The variation reflects in part the variation among philosophers of science" (p.219).

Lederman (1992) picked up some common themes within the varied definitions and noted the phrase nature of science typically referring to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge. With this definition, he also notes that the nature of scientific knowledge and inquiry is neither universal nor stable. This is one the contemporary and frequently quoted definitions of the NOS in science education literature. Lederman, Wade and Bell (1998) further unpack the definition and explain that "these values and assumptions include, but are not limited to, independence of thought, creativity, tentativeness, empirically based, subjectivity, testability, and cultural and social embeddedness" (p. 596). Bell and Lederman (2003) further add "parsimony" to these values and assumptions.

Gess-Newsome (2002) defines the NOS as the epistemological underpinnings of science, which include characteristics such as empirically-based, tentative, subjective, creative, unified, and cultural and socially embedded. Both definitions share similar characteristics. Furthermore, McComas, Clough and Almazroa (1998) explain:

> *The nature of science is a fertile hybrid arena which blends aspects of various studies of science including the history, sociology, and philosophy of science combined with research from the cognitive sciences such as psychology into a rich description of what science is, how it works, how scientists operate as a social group and how society itself both directs and reacts to scientific endeavors. (p. 4)*

The philosophers of science have adopted, and continue to adopt a range of positions on the major questions and issues about science and scientific knowledge, which is problematic (Driver, Leach, Millar & Scott, 1997). Abd-El-Khalick and Lederman (2000) recognize that "this lack of agreement, however, should not be disconcerting or surprising given the multifaceted, complex, and the dynamic nature of scientific endeavour" (p. 666). However, Abd-El-Khalick (2001) points out that at one point and at a certain level of generality, there is a shared wisdom (though not complete agreement) about the NOS. Moreover, he also argues that at such a level of generality, some important aspects of the NOS are non-controversial. For this research, the NOS is understood to be directly related to the epistemology of science - the knowledge of the construction of scientific knowledge and the operation of scientific enterprise.

School science and conceptions of the nature of science

This study is focused on the aspects of the NOS in the context of school science. Halai (2005) points out that there is a measure of agreement on a number of points relevant to the school science curriculum. Lederman (2000) indicates that students of science at the school level should learn about the aspects of the NOS such as: scientific knowledge is tentative (subject to change), empirically-based (based on and/or derived from observations of the natural world), theory-laden (subjective), necessarily involves human inference, imagination, and creativity (involves the invention of explanations), necessarily involves a combination of observations and inferences, and is socially and culturally embedded. One additional aspect is the function of, and relationships between scientific theories and laws.

More recently, Halai and Hodson (2004) provided an abridged version of the aspects of the NOS as identified in the National Science Teachers Association (NSTA, 2000) position paper. This affirms the following premises that are important to an understanding of the NOS in the context of school science:

- ✓ *Scientific knowledge is simultaneously reliable and tentative.*
- ✓ *Although no single universal step-by-step scientific method captures the complexity of doing science, a number of shared values and perspectives characterize a scientific approach to understanding nature.*
- ✓ *Creativity is a vital ingredient in the production of scientific knowledge.*
- ✓ *A primary goal of science is the formation of theories and laws, which are terms with very specific meanings.*
- ✓ *Contributions to science can be made and have been made by people the world over.*
- ✓ *The scientific questions asked, the observations made, and the conclusions in science are to some extent influenced by the existing state of scientific knowledge, the social and cultural*

context of the researcher and the observer's experiences and expectations.

✓ *The history of science reveals both evolutionary and revolutionary changes. With new evidence and interpretation, old ideas are replaced or supplemented by newer ones. (Halai & Hodson, 2004, p. 106)*

The characteristic features of the NOS for school science mentioned by a number of authors are, to a great extent, similar and overlapping. I found the aspects of the NOS given by Halai and Hodson (2004) appropriate to use for my study because they encompass the characteristics and elements mentioned in other reform documents. Therefore, I have used these definitions of the NOS for the purpose of my study.

Methodology

For the purpose of this research a life history method was used to examine the impact of experience on a science teacher's understanding and teaching of science. Direct observations and interviews with key players, in this instance with students in the science teacher's classes, were also used. Life history has its roots in narrative research. A narrative inquiry is a form of inquiry in which a researcher explores the lives of individuals by asking them to provide stories or narratives about their lives (Creswell, 2003). In a life history study, the researcher and researched co-construct stories, that are interpreted and analyzed to draw conclusions about the understanding of the researched, regarding the topic under investigation. The fundamental assumptions behind using this approach are well stated by Goodson (1995):

That the teacher's previous career and life experiences shape his/her view of teaching and the way he/she sets about it; that the teacher's life outside school, his/her latent identities and cultures, may have an important impact on his/her work as a teacher. (p. 84)

Hence, there is a link between past, present and future, as Hitchcock and Hughes (1995) state, "The life story approach facilitates a deeper appreciation of an individual's experience of the past, living with the present, and a means of facing and challenging the future" (p. 186). As such, a life history approach lies within the qualitative research paradigm. As Hitchcock and Hughes (1995) state about life histories:

This approach uses qualitative techniques, in particular the unstructured or semi-structured interview, which are designed to provide individuals with the opportunity of telling their own stories in their own ways. This facilitates the reconstruction and interpretation of subjectively meaningful features and critical episodes in an individual's life. (p. 186)

Researchers have used a number of methods and tools to study teachers' conceptions about the NOS including: the use of critical incidents (Halai, 2005; Nott & Wellington, 1995), open-ended questionnaires (Abd-El-Khalick, Bell & Lederman, 1998), a life history framework (Halai, 2002; Halai & Hodson, 2004), combination of interview and classroom observation (Halai 2000). An open-ended approach using life history interviews provides more freedom for the respondents to express their own views on the scientific enterprise while helping them to avoid the impositions of the researcher's views (Bell & Lederman, 2003). During the past decades, there has been an increasing interest in the use of life history and narrative approaches to study teacher thinking and teacher development (Carter & Doyle, 1996; Cole & Knowles, 2001).

As a number of researchers advocate using a more open-ended approach to explore teachers' conceptions of the NOS, I used a life history framework for my study. For example, Hitchcock and Hughes (1995) advocate the life history approach because "it enables the researcher to build up a mosaic-like picture of the individual and the events and people surrounding them so that relations, influences and patterns can be observed" (p. 186).

The teacher's views were embedded in his talks about ordinary day-to-day life and the practice of teaching. Discussing and analysing examples from everyday and classroom experiences illustrate the teacher's knowledge. Similarly, his perceptions were grounded in professional practice (Nott & Wellington, 1998) and personal life (Goodson 1995; Halai, 2002). Interviews dealing with his personal and professional life, a combination of classroom observations and informal conversations capture the teacher's views and practices. As Smith (2001) states:

Teacher beliefs develop throughout their lifetime and are influenced by a variety of factors, including events, experiences, and other people in their lives. Teachers' life experiences and background affect what they believe, and consequently, how they teach. Consequently, a life history approach enables us to understand a teacher's life and work in terms of the meaning they have for the individual teacher. (p. 112)

DATA COLLECTION TECHNIQUES AND ANALYSIS

Data was collected from a variety of sources including interviews, classroom observations, post-lesson discussions, document analysis (including lesson plans, the teacher's diary, syllabus, and reading texts), group interviews from students and informal talks, with the major sources being interviews and observations. These were very helpful in maintaining the rigour of the data because as Maxwell (1996) observed, "triangulation of observations and interviews can provide a more complete and accurate account than either could alone" (p. 76). The main protagonist in the study was a science teacher who had undergone a change in his perceptions, about science and science teaching, after being given the chance to do some advanced study on the teaching of science. The document analysis also included handbooks from the Advanced diploma this teacher was undertaking.

Semi-Structured Interviews

In a life history study, data collection is primarily through semi-structured or unstructured interviewing (Goodson & Sikes, 2001). Hence I used an 'oral life history interview' as one of the main techniques. The interviews allowed me to invite information from the respondent about situations from his own perspective and in his own words (Kvale, 1996). The focus was on this stories of learning and teaching science, while opportunities to reflect on the meanings of his experiences were also provided.

Initially, I conducted three interviews of 45 to 55 minutes with Ikraam, the science teacher who was the focus of this research. The first interview was general discussion regarding his life. In the second and third interviews, we had specific and intensive discussions about his experiences of learning and teaching science, and his understanding of the nature of scientific knowledge. Whilst constructing his life story, I sought information from the participant on particular periods of his life such as his childhood, primary school experiences, middle and high school experience, college experiences and teaching experiences (Bogdan & Biklen, 1992). I often asked follow-up questions, probing questions and interpreting questions.

In addition to the three initial interviews, I had three more interviews during and after the classroom observations. The first of these was about a science exhibition which the school had organized and the other two interviews were conducted at the end of the data collection period in order to fill in gaps and double-check with the teacher on specific issues. I also interviewed the principal to collect information about the background of the school. I interviewed the science coordinator about the kind of support he provided to Ikraam. All the interviews were audio recorded and transcribed verbatim.

Group Interviews

A popular interviewing technique is group interviewing. A focus group has the potential for discussion that gives a wide range of responses (Cohen & Manion, 1994). I conducted two interviews with his students in groups to get some ideas regarding Ikraam's teaching practices. The first one was from a random sample of 10 students of Class 8. In the interviews, I inquired about their views of their experiences of learning science in Ikraam's class. The second interview was with a group of 6 students of Class 5 who were involved in the science exhibition.

Classroom Observations

Observation is a valid and direct way of obtaining data from people. Gillham (2000) argues: "it [observation] is not what they say they do. It is what they *actually* do" (p. 46). I therefore observed Ikraam's teaching during 4 lessons, four with Class 5 and four with Class 8, making a total of eight observations, Maxwell (1996) endorses the purpose of this observation when he states:

> *Observation often enables you to draw inferences about someone's meaning and perspective that you couldn't obtain by relying exclusively on interview data. This is particularly true for getting at tacit understandings and theory-in-use, as well as aspects of the participants' perspective that they are reluctant to state directly in interviews. (p. 76)*

The observations were intended to find out to what extent Ikraam's stated views were manifested in his classroom practices. The choice of two different grades was to get a better and broader picture of practice. During the classroom observations, I mainly focused on Ikraam's teaching techniques, use of resources, questioning skills, and interaction patterns with his students. I was hoping that these observations would allow me to see the translation of his views of the NOS in his practice. I took descriptive and analytic (Glesne, 1998) anecdotal notes of my observations of the classroom activities.

Analysis –Ikraam's Conceptions of the Nature of Science

The analysis of the data from the life history interviews and classroom observations showed that the following aspects of NOS were explicit in Ikraam's views and practices:

1. *Science is an in-depth inquiry and explanation of natural phenomena.*
2. *Science is "seeing and doing".*
3. *Observations are independent of theory.*
4. *Scientific knowledge is empirically-based while religion is belief-based.*
5. *Scientific knowledge is simultaneously reliable and tentative.*
6. *Scientists may not necessarily follow a single step-by-step scientific method.*
7. *Scientific theories evolve into laws on further evidences.*
8. *Models are not actual representations of a reality.*

In the following sections, I discuss two of the above findings (2 and 3) to exemplify Ikraam's concept of the NOS.

Science is "Seeing" and "Doing"

Ikraam believed that human senses play an important role in generating scientific knowledge, and observation is the starting point of a scientific inquiry. He considered science as a practical subject and believed that in the science classroom, in order to understand science, the students must be given the opportunity for *seeing* and *doing*. He was of the view that providing the children with abstract explanations is just like 'building castles in the air'. To understand science, they must see and do it, that is, experience it.

The analysis of his life history showed that this practice was rooted in his biography. While describing the characteristics of his favourite teacher, he mentioned that one of his teachers provided him the opportunity to "see" and "do" science in the classroom which helped him in understanding certain scientific concepts that were taught that way. But there had been very little opportunity for him to learn science by seeing and doing. He had pointed out that he did not get the opportunity to "do science", and due to this he could not develop an understanding of most of the scientific concepts. His teachers would mostly read the textbook, dictate notes, and he would memorize them.

The idea of seeing and doing for effective learning of science was also explicit in his classroom practices. He demonstrated the ambition to let his students see and do science, but he has not been able to do so yet. He stated that to learn science in a more effective way, such as through group work, it is necessary for the students to get the opportunity to manipulate the materials and discuss the emerging scientific concepts. He particularly highlighted the role of hands-on and minds-on activities in learning science. But because of the constraints, such as the lack of space and resources, fixed furniture and time limitation, he was unable to organize group work on a regular basis. Instead, he usually arranged for practical demonstrations in the classroom.

In Pakistan, carrying out practical work in the primary and middle classes is not a common practice. Practical work, if any, is done in Classes 9 and 10 only (Halai, 2002). Being a product of the Pakistani educational system both as a student and later as a science teacher, I myself have indulged in organizing practical work only in the secondary classes. But Ikraam's case was different. In his class, he was unable to provide children with an opportunity for doing hands-on activities individually or in small groups; therefore, he often made a concerted effort to arrange demonstrations for them.

He used low cost and no cost teaching materials. Out of the eight lessons I observed, he gave demonstrations in five lessons in the class. In a lesson about the *forms of energy* he gave five demonstrations by using a candle, matches, torch, toy car and electric switch respectively. The activities aimed at involving the students in discussions about the topic. The text was about atomic energy, which the students were asked to read from the textbook and discuss in the class. Similarly, while teaching the uses of carbon dioxide, he brought a fire extinguisher to the classroom and explained its structure and function to the students. He also brought a bottle of Pepsi to the classroom to show that it contained carbon dioxide, and he also explained why carbon dioxide was mixed in the drink.

During his demonstrations, he tried to involve students by using interactive dialogues and questions. While talking about the purpose of demonstrations, he said that demonstrations helped him in developing the students' scientific process skills such as how to predict, observe, infer, and compare their findings.

In the post-lesson discussion, he claimed that sometimes he used to arrange practical work in the seminar hall where the students themselves manipulated materials. During my presence in the school, he did not manage such group-based practical experiences for the students. I asked the students how often they got the opportunity to work in groups for doing practical work. They told me that it depended on the teacher's intention and the nature of the topic. One student reported, "Once a week or in two weeks, when our teacher wants us to do practical work, he takes us to the seminar hall and assigns us group work…but mostly he does arrange demonstrations for us" (Group interview, February, 17, 2004). During an informal talk, the science coordinator of the school said:

> *We are aware of the importance of the practical work for learning science and also about the factors that hinder our attempt to do so. For example, one of the problems is the lack of space in the classroom. But we often use the seminar hall for the purpose of group work. He [Ikraam] is a resourceful teacher who has brought a lot of innovative ideas from the course he is presently taking. (Informal conversation, February 17, 2004)*

One day he did not arrange any demonstrations for a lesson, and during the post-lesson discussion, he said that, as there were no materials, activities or demonstrations, the students did not take much interest in learning. Thus, according to him, giving demonstrations captures the students' interest. He considered the use of demonstrations as an economic and effective way of teaching science. While demonstrations are beneficial and cost effective in terms of expense, equipment, time, safety and effective teaching, there are a number of problems associated with demonstrations. The assumption underlying the use of demonstration is that "if a teacher arranges for an effect to be clearly seen, it will be clearly understood. But we all know that this is not true" (Ogborn , Kress, Martins & McGillicuddy, 1996, p. 2). The same idea is shared by Solomon (2002) who states, "If the teacher arranges for an effect to be clearly seen, will it be clearly seen? We all know that this doesn't happen" (p. 26). The problem with demonstration is that often students do not see what a teacher intends them to see. Ogborn et al. (1996) share interesting comments about students' feelings about demonstrations by saying:

> *Many a student [sic] has gone away from a demonstration saying, 'I don't know what it was supposed to show, but…. The event is there but it lacks meaning. The student remembers what could be seen, but lacks an idea of what the events are supposed to mean. (p. 79)*

This creates a problem if a teacher believes that seeing and doing is always necessary to learn and understand science. Sometimes we cannot "see" or "do" science for there are a number of concepts/phenomena that we learn and understand through other ways and means.

Regarding practical work Hodson (1998) states: "We seriously mislead students when we pretend that the kinds of experiments they perform in classroom constitute a straightforward and reliable means of choosing between rival theories" (p. 95). It is important that teachers realize that what they want the students to understand, is not necessarily what they have understood. Some teachers must conclude activities and demonstrations in such a way that they can be quite sure that the students have understood the purpose behind the activity.

Observations Are Independent of Theory

Ikraam's efforts in bringing activities to his class for demonstrations are to be appreciated. But he was not fully aware of the theory-dependent nature of observations. He often shared with me that students are not empty vessels and they come to school with their own ideas. In the classroom, eliciting children's ideas through brainstorming was his routine practice. He did not seem to realize that students' prior conceptions can influence their observations too. And this influence can affect observations positively and negatively.

In the classroom, Ikraam would sometimes use the Predict-Observe-Explain (POE) model and the students were asked to apply this to the demonstration under discussion. Looking at the same activity, the students' responses varied to a great extent. Though he did not discourage the students from giving diverse responses, he wanted them to believe in what he saw. His actions during the demonstrations showed that he was disappointed when he got responses that were not congruous with his expectations. Regardless of the students' responses, he explained his own inference from the observation of the activity. For example, in one of the demonstrations, the teacher fixed a candle on a saucer with some water in it. Then he inverted a transparent glass over the burning candle. Before that, he asked the students to make predictions by posing a question, "What would happen if the glass is inverted on the burning candle?" The students made predictions and later on compared their predictions against their observations. During "seeing" of the demonstration, a number of contradictory observations were made and shared by the students. For example, some students reported that there was smoke inside the glass while others pointed out that as carbon dioxide is a colourless gas, it should not be visible. A number of other inconsistent observations were reported regarding the rising of water into the glass.

Hodson (1998) maintains, "because knowledge is assumed to derive directly from observation, emphasis becomes concentrated on *doing* rather than on *thinking*, and little or no time is set aside for discussion, argument and negotiating of meaning" (p. 94). This seemed true for Ikraam as well, because he focused on the activities more than on the making of meaning from them. He perceived observation and experimentation as objective sources of scientific knowledge, and therefore expected his students to see what he himself saw during a particular demonstration.

During the post-lesson discussions, I drew Ikraam's attention to his expectations of the students during observations of demonstrations. He pointed out that his students were unable to see what he wanted them to see. He argued that different students explained a single phenomenon differently, which he thought was problematic. He explained this issue with the help of an example. He put a cassette on the table and explained that both he and I could see it differently because both of us were different. He explained that the same was happening with his students while observing the demonstrations.

Hodson (1998) contends that "doing science (choosing a focus, designing and conducting an inquiry and communicating findings) depends on who we are, what we know and what we have experienced. Some view of the world, some theoretical perspectives, precedes observations" (p. 11). Hence, teachers have their theoretical frameworks with them that guide their observations, but students usually lack such frameworks so it is very natural for them to come up with alternate inferences. Therefore, a teacher should guide the students without devaluing their ideas by challenging their ideas with thought-provoking questions. Halai (2002) argues that "even with very guided activities, students do not see 'eye-to-eye' with the teacher" (p. 272). Thus there always remains a gap between what the teacher expects the children to learn and what the students actually learn. Hodson (1998) explains the theory-laden aspect of observation, by saying:

> *The traditional school curriculum [practice] says two things about observation. First, nothing enters the mind of the scientist except by way of the senses – that is, the mind is*

tabula rasa on which the senses inscribe a true and faithful record of the world. Second, the validity and reliability of observation statements are independent of the opinions and expectations of the observer and can be readily confirmed by other observers. Neither is true. In reality, we interpret the sense data that enter our consciousness in terms of our prior knowledge, beliefs, expectations and experiences. (p. 10)

The purpose of this discussion does not necessarily mean that students should not be encouraged to observe correctly, but it means that students should be provided with "a sound theoretical frame of reference" (Hodson, 1998, p. 11), if they are expected to observe correctly. Making correct observations should not be the ultimate purpose, although making objective observations is not possible either). Thus one should be aware that though observation plays a central role in scientific investigations, this skill is tied closely to the knowledge, thinking and motivation of the observer (Chiappetta, Koballa & Collette, 1998). If teachers are aware of the theory-laden nature of observation, they can guide the students properly without confusing them further.

FINDINGS AND CONCLUSION

During this research study, several features about this elementary (Classes 1-8) teacher's conceptions of the NOS and its implications for classroom practices emerged. The following section discusses some of the general findings of the study.

Teachers' Conceptions of NOS are Not Innate and Stable

The study suggests that the teacher's conceptions about the NOS are not innate and stable. They were acquired, modified and changed as he experienced more appealing conceptions and plausible approaches to learning and teaching science. The data showed that many of Ikraam's long-held conceptions were inherited from his former teachers and the learning experiences he had had during his life. He frequently pointed out that he had been teaching the way he was taught. Before joining the Advanced Diploma in Education: Science (ADES) programme, he exclusively relied on the *chalk and talk* method as the only teaching method he was familiar with. The ADES programme helped him re-conceptualize his beliefs and practices about science, and shifted him towards more child-centred approaches for the teaching and learning of science.

When Ikraam was a student, he assumed science to be a difficult, in his own words it was "like climbing a mountain". He was not enamoured with science because of his teachers' practices and his own poor learning experiences. But later on, his conceptions about the NOS and the teaching and learning of science were changed. After being exposed to the ADES programme, he claimed that he loved science and its teaching and learning, which showed a significant change in his attitude towards science. He believed that the ADES programme changed his professional life as a science teacher.

Ikraam frequently compared his experiences after the course, and before the course. The study affirmed that a well-planned teacher education programme helps teachers transform their beliefs in a significant way. There are assumptions that teachers' conceptions/beliefs are resistant to change. But this study provides some evidences that one's epistemological conceptions change when s/he experiences alternative beliefs, which are more plausible and appealing to him/her. The study also highlighted some evidence of change in Ikraam's beliefs because of the influence of the course. This clearly showed that teachers' beliefs and practices may be reshaped as a result of the opportunities and the environment they are exposed to.

Change in Conceptions Occurs Through a Critical Reflection

The analysis of the findings indicated that a critical reflection on one's own beliefs and practices are can help to bring about change in an individual's belief system. There is a debate amongst educationists whether change in beliefs lead to change in practices or change in practices leads to a change in beliefs (Guskey, 2002). The analysis of Ikraam's experiences showed that he needed external assistance, in this case the ADES programme to challenge existing beliefs and provide alternative approaches to practice. Similarly, it is necessary to implement the new learning in the real classroom situation. Guskey (2002) found that neither training alone nor training followed by implementation is sufficient for effective change. Changes in attitude and beliefs occur only when training and implementation are combined with evidence of students' improved learning outcomes.

Mismatch Between Teacher's Conceptions and Practices

The comparison of the data collected through the interviews and field notes showed that in some cases there was a gap between the teacher's conceptions about the NOS and his classroom practices. For example, Ikraam strongly believed in certain aspects of science and its teaching and learning although the classroom observations revealed that in some cases he could not practice his stated beliefs.

Several times during the post-lesson discussions, Ikraam's attention was drawn towards those apparent contradictions between his conceptions and classroom practices. In response he frequently referred to the factors such as time constraint, a lack of space in the classroom, lack of resources (e.g. science apparatus), students' poor academic and socio-economic background, their lack of proficiency in English and his own lack of pedagogical skills in managing the class as major constraints. However, it was evident that the teacher had the commitment to accept and promote change in his classroom. He was persistent in his efforts to implement his learning from the ADES program into his classroom teaching.

Ikraam's also felt that his lack of pedagogical knowledge was hindering the translation of his conceptions (e.g. managing group work, holding discussion, etc) into desired classroom practice. It would therefore appear that conceptions about the NOS cannot be successfully translated into practice where the teacher lacks pedagogical skills.

Teachers Need Follow-up Support in the Real Classroom

The study indicated that a sound knowledge of content and knowledge about knowledge (meta-cognition) is essential, but this is not a guarantee that teachers can translate such knowledge into their classroom practice. For example, in some cases, Ikraam's classroom practices did not show a translation of his conceptions of the NOS into his classroom teaching. The reasons/factors, other than the teacher's conceptions of NOS, mentioned by Ikraam and my own observations were: a lack of resources, limited space, the socio-economic background of the students, and some internal factor of the teacher such as a lack of content knowledge and pedagogical content knowledge (PCK). These are not inconsiderable constraints. Therefore, in spite of Ikraam's willingness, he was unable to implement his learning for a number of reasons. This observation suggests that it is crucial to provide effective follow-up support in the real classroom situation, which is inevitable in dealing with the uncertainties and challenges, situational factors and conditions (Guskey, 2002).

Explicit NOS Instructions are More Effective

The analysis of the handbook for the ADES programme and conversations with Ikraam showed that there were no explicit instructions on the NOS. The programme assumed that the participants would come to understand about the NOS by doing science, which is known as an implicit approach of the NOS instruction (Gess-Newsome, 2002). Science educators point out that implicit instructional approaches to develop teachers' understanding about the NOS have been usually ineffective. This study found some evidence of the impact of an implicit approach for NOS instruction. For example, in Ikraam's case, the course he was taking, had a significant impact on his conceptions about NOS, and the teaching and learning of science. The study shows that to some extent the assumption seemed to be acceptable, as Ikraam understood some important aspects of the NOS. In some cases, Ikraam exhibited certain naïve conceptions about the NOS. As advocated by a number of educators (e.g. Abd-El-Khalick & Lederman, 2000; Gess-Newsome, 2002), explicit approaches to develop teachers' conceptions of the NOS have been more effective. This has a strong implication for teacher education programmes in Pakistan that explicit approaches should be employed while teaching about the NOS, so that teachers can develop an adequate understanding of it.

CONCLUSION

This study was focused on the understanding of a single teacher's conceptions about the NOS, the findings of which cannot be generalized to a large community of science teachers. However, the insight gained from the findings can be useful for others.

The nature of science is the soul of science, and so I propose it as a knowledge-base for the teaching and learning of science. Developing students' understanding of the NOS to help them learn science in a meaningful way is an important goal of science education.

Apart from teachers' conceptions of the NOS, there are other factors (e.g. content knowledge, pedagogical skills and PCK) that can also influence teachers' classroom practices. As teachers are the primary mediators between subject matter and the students, their conceptions of what science is and how it should be taught seems to direct their decisions in the classroom. Since teachers' conceptions are communicated to their students through their actions and attitudes, they should possess well-informed conceptions of the NOS. In conclusion:

We are confident that science education will be a richer discipline and our students will be more adequately prepared for their lives as citizens when they are afforded a fuller understanding of the nature of this thing called science (McComas, Clough and Almazroa, 1998, p. 33).

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