Evaluation of Secondary School Science Teachers' Knowledge about Nature of Science

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Abstract

Science teachers in Pakistan teach science in a way that adds to the mythology of science. These myths and misconceptions may be due to misunderstandings of nature of science. Therefore, this study was designed to evaluate the knowledge of science teachers about nature of science (NOS). The objectives of study were to find out chemistry teachers' understanding about: content, content situated nature of science and nature of science. Moreover, to find out relationship between content understandings, content situated NOS understanding and NOS understanding. The approach was quantitative; questionnaire was used to collect the data. The population of the study comprised of male and female secondary school science teachers who were teaching chemistry at secondary level in government schools of Azad Jammu and Kashmir (AJ&K). 105 secondary school science teachers; 59 females and 46 males were selected as sample of study through simple random sampling technique. Findings of study indicated that chemistry teachers did not understand content, content situated nature of science and nature of science. Content understanding, content situated nature of science understanding and understanding were positively significantly correlated with each other. It was recommended that capacity building programs for in-service science teachers may be designed immediately. Inclusion of nature of science in teacher training programs, in curriculum, in assessment, at all levels from school to university is recommended. It was recommended that prospective teachers may be provided opportunities to situate their nature of science learning in their lesson plans.

Keywords: *Nature of Science, Subject matter knowledge, content situated Nature of Science, scientific literacy, secondary level*

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1. Introduction

Science is a knowledge gained through a method which is based on evidence. In this way concepts and theories are formed in the field of science which can be tailored on more observations. Science also needs creative process (Safdar, 2007). It is a fact that science education is the key element behind the progress of any nation that distinguishes it in the world, and boosts it up in every walk of life. Hence it is considered need of the day. Because it prepares the students for higher studies in science, for workforce of different occupations and generally prepares citizens having scientific knowledge (Jones, 2006).

The term scientific literacy was introduced first time in the 1950's and soon used as a catchphrase in science education (De Boer, 2000). According to Laugksch (2000), it has been widely recognized that scientific literacy has potential benefits for countries, for societies as well as individual. Therefore, many scholars of science educations (Kolstö, 2001; Laugksch, 2000) considered scientific literacy as a major goal of science education. In the opinion of Saad and Boujoude (2012), many curricula all over the world emphasized on expanding scientific literacy. Even in US Next Generation Science Standards, promotion of science and technology in society has been emphasized (NGSS 2013).

Many countries aspire to having a scientifically literate population, and Pakistan is no exception to this. Presently science education in Pakistan includes primary level (grade 1-5), middle level (grade 6-8), matric level (grade 9-10), intermediate level (grade11-12) and degree level (above grade 12). Science education as a subject of General Science at primary and middle level (1-8) is a compulsory component of educational system. The purpose of teaching science subjects in elementary classes is to make them familiar with nature and environment. However, students are preparing for labor markets and university education at secondary and intermediate level. Therefore, science teachers should acquire competency in science subjects to fulfill their classroom responsibilities (VanDriel et al., 2014).

Ministry of Education (2006) developed The National Curriculum 2006-2007 for all Science Subjects (Grades 1-X11) which serves as a principal document for the promotion of school science education. One of its aims is to promote scientific literacy in students to ensure a future scientific community. Because members of scientific community are capable to discuss universal phenomena based on already established facts. In fact these facts are scientific knowledge. Moreover, they can themselves design researches to explore the phenomena by collecting data systematically and interpreting it by applying scientific methods. However, these competencies are developed only when members have command on content of science and trust on scientific method for creation of scientific knowledge (Program for International Student Assessment [PISA], 2015; Hodson, 2008). In the research literature, Nature of Science (NOS) has attained a good reason to represent such essentials of informed and updated picture of science (Vesternian et al., 2012). Therefore, NOS is considered a critical component of scientific literacy. Now it is included in curricula of science education all over the world.

1.1 Objectives of the Study

This study intended to achieve the following objectives:

1. To assess content understanding of chemistry teachers at secondary level.
2. To assess content situatedness NOS understanding of chemistry teachers.
3. To assess chemistry teachers understanding about the nature of science (NOS).
4. To find the relationship between content understanding and NOS understanding.
5. To find the relationship between content understanding and content situated NOS understanding.
6. To find the relationship between NOS understanding and content situated NOS understanding.

1.2 Hypotheses of the Study

Following hypotheses were formulated to test, in this study.

H_{01}: There is no significant difference between observed and expected no of teachers who understand the content.

H_{02}: There is no significant difference between observed and expected no of teachers who understand the content situated NOS.

H_{03}: There is no significant difference between observed and expected no of teachers who understand the NOS.

H_{04}: There is no relationship between content understanding and NOS understanding.

H_{05}: There is no relationship between content understanding and content situated NOS understanding.

H_{06}: There is no relationship between content situated NOS understanding and NOS understanding.

2. Literature Review

Weisberg et al. (2021) defined Nature of Science (NOS) as facts of science and process and practices of science. They emphasized the teaching of NOS because people having better understanding of NOS readily accept concepts and theories of science and trust scientific claims. As a result scientific literacy is promoted in society. Consequently, researchers in science education (Caps & Crawford, 2012) have advocated the incorporation of NOS in teaching practice.

Similarly, Shi (2022) and Naungchalerm (2010) also supported this point of view for the promotion of scientific literacy. In science teaching, inclusion of NOS is emphasised because it is base of scientific literacy. In teaching of science, inclusion of NOS is emphasized because it is base of scientific literacy. Researches (Caps, & Crawford, 2012; Hodson, 2008; 2009; National Science Teachers Association, 2020) showed that comprehension of NOS helps in understanding of content in science. Its knowledge motivates the students which enhance their interest in science. However, according to Haoli et.al. (2021), teachers who teach science do not possess adequate knowledge of NOS. Consequently, it affects students learning in science. As a result students are not capable to apply science concepts to solve daily life issues Therefore, according to Koponen (2021), emphasis is laid on understanding of NOS along with subject matter knowledge for science teachers. Moreover, it is also expected from teachers to know sources of scientific knowledge along with their justification (Deborah et al., 2009).

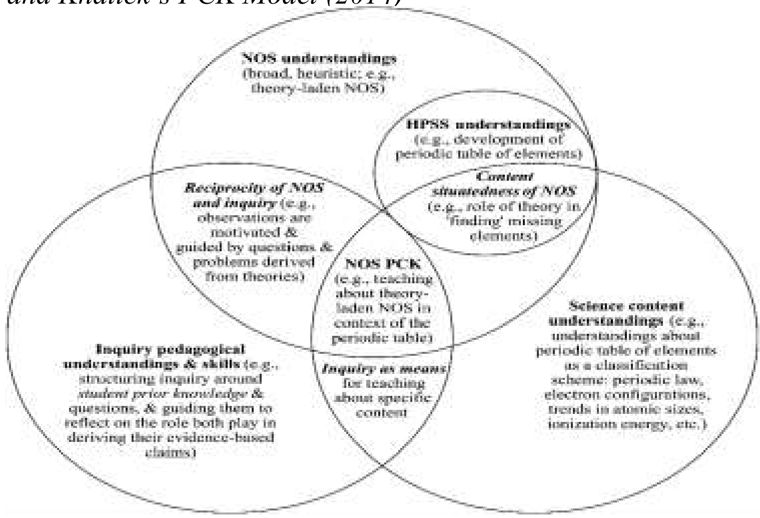
Research literature indicated that for NOS teaching, understanding of Pedagogical Content knowledge (PCK) is essential (Abd-El-Khalic, 2005; Russell, 2001). Command on PCK makes a teacher understandable to his/ her students. If this base is strong science teaching is effective. Otherwise students will not have understanding of basic science concepts. Understanding of basic concepts is a framework for higher order of learning. It motivates the students and develops interest in science learning. This concept of PCK was given by Shulman (1986; 1987) and advocated as essential element of science teachers' knowledge. He observed that in science teachers training programs, subject matter knowledge is offered along with pedagogical knowledge separately. He suggested merging these two courses in a single course and including this course in teacher training program. After studying this course teachers will be more competent in teaching of science. Hodson (2009) is also in favour of Pedagogical Content Knowledge (PCK) and idea of merging Subject Matter Knowledge (SMK) and Pedagogical Knowledge (PK). According to him, having clear concept of PCK will enable science teachers to discuss students' issues related to NOS with relevant and understandable examples.

Investigation of literature on PCK model showed that initially it was conceptualized by Shulman (1987). Realizing its importance, researchers worked on this model and developed it in more advanced form (Grossman, 1990; Magnusson et al., 1999; DeJong et al., 2004; Friedrichsen et al. 2009; Henze et al. 2008; Faikhamta, 2013; Hanuscin, 2013; Hanuscin et al. 2011). And researchers like Luft et al. (2015) used this model extensively in their researches on teachers' knowledge about NOS. However, researchers like Abd-EL-Khalick (2013), Jenny (2011) and Kim et al. (2005) developed themselves PCK models especially to study science teachers' knowledge about NOS.

After having a thorough study of available models, Schwartz & Lederman (2002) developed a PCK model for NOS. It is simple and easily applicable in classroom settings. It consists of three elements: knowledge of subject matter, knowledge of pedagogy, knowledge of NOS. Thus it was a comprehensive model. It was modified by Wahabeh and Khalick (2014). In this model, teacher's science content understanding seems to be first domain, pedagogical understandings and skills is second domain, while third domain is related to teachers NOS understandings. They further divided these domains into three sub-domains which are needed for teaching with and teaching about NOS. These sub-domains are:

a) Content situatedness NOS understanding
b) Inquiry as means for teaching the content
c) Reciprocity of NOS and Inquiry

Figure 1
Wahabeh and Khalick's PCK Model (2014)



Researcher used Wahabeh and Khalick's (2014) PCK model to investigate science teachers NOS understanding in specific content.

Ministry of Education (2006) revised the curricula in 2006-2007 for Science Subjects (Grade1-X1I). Clearly expressed goal of this curriculum is to promote literacy in science. For this, role of teachers was recognized as significant. However, without having understanding of nature of science, teachers cannot provide a conducive environment for learning of science. And this is possible only if they are trained for science teaching. But, according to Halai (2008), in Pakistan most of the teachers are teaching science without having proper knowledge of nature of science. Instead of developing true concepts of science, it is adding myth and misconception to the learning of science. Realizing this, Ministry of education revised curriculum of teacher education (Bhatti, 2009). Unit of NOS has been included in curriculum of B.Ed (Hons) program for prospective science teachers. NOS understanding was also a requisite for in-service teachers as they would also have to implement new curriculum in classroom. So the problem in this perspective was to find out in-service secondary school science teachers' knowledge regarding NOS.

3. Research Methodology

3.1 Research Design

This is descriptive and correlation research. Hence, quantitative descriptive approach was applied to collect data from sample for statistical analysis. Detail of each component of research design is as follows:

3.2 Population of Study

The population of this study consisted of all male and female secondary school science teachers of Azad Jammu and Kashmir who teach chemistry in government schools. Total population was 532 teachers. Detail is given as;

Table 1

Population of Study

Division	Mirpur		Poonch		Muzaffarabad		Total
Gender	Male	Female	Male	Female	Male	Female	
No of Chemistry Teachers	91	74	121	111	81	54	532

3.3 Sample of Study

Through convenient sampling technique, Mirpur Division was selected as sample of this study

Table 2
Sample of study

Districts	Bhimber		Kotli		Mirpur		Total
Gender	Male	Female	Male	Female	Male	Female	
No of Chemistry Teachers	22	13	39	30	30	31	165

3.4 Research Instrument

For this purpose relevant literature and previous researches had been studied and reviewed. Researcher developed a questionnaire keeping in view the problem statement and objectives of study. It comprised of 30 questions based on following three dimensions which are related to subject matter knowledge.

1. **Content Understanding**: Content was selected from the Text Book of Chemistry for IX- class of AJK Text Book Board. Only the core topics of first four chapters had been included.
2. **Content Situated NOS Understanding**: Understanding of knowledge in the selected content generated by nature of science.
3. **NOS Understanding**: NOS aspects in selected content i.e. tentative, culturally and socially embedded, creation and imagination, subjectivity, theory and law, observation and inference, models.

It consisted of two parts. First part contains 20 multiple choice questions carrying one mark each question while second part consists of 10 short questions carrying 3 marks each question. 30% questions address content, 30% questions address content situated NOS and 40% questions NOS understanding. All these questions belong to Understanding level of cognitive domain of Andersons and Krathwohl revised Blooms Taxonomy (Abd-El-Khalick, & Lederman,. 1998, 2004).

3.5 Validity and Reliability

Validity of the questionnaire was got checked by three experts. Cronbach's alpha reliability test was used to calculate the reliability of the questionnaires. The Coefficient of Alpha Reliability α was .70.

3.6 Data Collection

With the permission of Divisional Directors, researcher personally visited the schools and requested for their consent. Only 64 % of the total sample participated in the study. Teachers who secured 50 marks or above were considered pass while remaining were considered as fail.

Table 3

Participation rate of Chemistry Teachers in Data Collection

Districts	Bhimber		Kotli		Mirpur		Total
Gender	Male	Female	Male	Female	Male	Female	
Sample	22	13	39	30	30	31	165
No of Participants	12	13	18	20	16	26	105

4. Data Analysis and Interpretation

With the help of SPSS both descriptive (percentages and frequencies) and inferential (chi square, t-test, and correlation) analysis was used to analyze data. This part consists of content understanding, content situated NOS understanding, and NOS understanding. Descriptive and inferential analysis has been used to interpret the data.

4.1 Content Understanding

H_{01} : There is no significant difference between observed and expected number of teachers who understand the content

Table 4

Result of Content Understanding (N=105)

Gender	Test Result		
	Pass	Fail	Total
Male	10	36	46
Female	13	46	59
Total	23	82	105

Table 4 showed that in content understanding test, 105 Chemistry teachers participated. Frequency of male and female teachers was 46 and 59 respectively. In this test, 10 male teachers passed while 36 failed. Similarly, 13 female teachers passed while 46 failed.

Table 5

Chi Square Test for Content Understanding of Chemistry Teachers (N= 105)

Gender	Option	Observed N	Expected N	χ^2	*df*	*P*
Male	Fail	36	23.0	14.696	1	
	Pass	10	23.0			000
	Total	46				
Female	Fail	46	29.5	18.458	1	
	Pass	13	29.5			000
	Total	59				

Table 5 showed that the difference between observed and expected frequencies of pass and fail male teachers in the test of content understanding is statistically significant (χ^2 = 14.696, *df* = 1, p < 0.05). It means that male chemistry teachers do not understand the content. The difference between observed and expected frequencies of pass and fail female teachers in the test of content understanding is statistically significant (χ^2 = 18.458, *df* = 1, p < 0.05). It means that those females' chemistry teachers do not understand the content.

4.2 Content Situatedness NOS Understanding

H_{o2} : There is no significant difference between observed and expected number of teachers who understand the content situatedness NOS.

Table 6

Result of Content situatedness NOS Understanding (N=105)

Gender	Test Result		
	Pass	Fail	Total
Male	5	41	46
Female	6	53	59
Total	11	94	105

Table 6 showed that in content situated NOS test, 105 Chemistry teachers participated. Frequency of male and female teachers was 46 and 59 respectively. In this test, 5 male teachers passed while 41 failed. Similarly, 6 female teachers passed while 53 failed.

Table 7

Chi Square Test for Content Situated NOS Understanding of Chemistry Teachers (N = 105)

Gender	Option	Observed N	Expected N	χ^2	*f*	*p*
Male	Fail	41	23.0	28.174	1	
	Pass	5	23.0			.000
	Total	46				
Female	Fail			37.441	1	
		53	29.5			.000
	Pass	6	29.5			
	Total	59				

Table 7 showed that the difference between observed and expected frequencies of pass and fail male teachers in the test of content situated NOS understanding is statistically significant ($\chi^2 =$ 28.174, df = 1, p < 0.05). It means that male chemistry teachers do not understand content situatedness NOS. The difference between observed and expected frequencies of pass and fail female teachers in the test of content situated NOS understanding is statistically significant (χ2 = 37.441, df = 1, p < 0.05). It means that that female chemistry teachers do not understand content situatedness NOS.

4.3 NOS Understanding

H_{03} = There is no significant difference between observed and expected number of teachers who understand NOS.

Table 8

Result of NOS Understanding (N=105)

Gender	Test Result		
	Pass	Fail	Total
Male	2	44	46
Female	0	59	59
Total	2	103	105

Table 8 showed that in NOS understanding test, 105 Chemistry teachers participated. Frequency of male and female teachers was 46 and 59 respectively. In this test, 2 male teachers passed while 44 failed. Similarly, all female teachers failed.

Table 9

Chi Square Test for NOS Understanding of Chemistry Teachers (N =105)

Gender	Option	Observed N	Expected N	χ^2	*df*	*p*
Male	Fail	44	23.0	38.348	1	
	Pass	2	23.0			.000
	Total	46				
Female	Fail	59	29.5	All fail		
	Pass	0	29.5			
	Total	59[a]				

*This variable is constant Chi-Square Test cannot be performed.

Table 9 showed that the difference between observed and expected frequencies of pass and fail male teachers in the test of NOS understanding is statistically significant (χ^2 = 38.348, df = 1, $p < 0.05$). It means that male chemistry teachers do not understand the NOS. All the female teachers were failed therefore Chi-Square test cannot be performed.

4.4 Relationship between Content Understanding, Content situated NOS Understanding and NOS understanding

4.4.1 Relationship between Content Understanding and NOS Understanding

H_o 4: There is no relationship between Content understanding and NOS understanding.

Table 10

Pearson Correlation between Content Understanding and NOS Understanding

		NOS Understanding
Content Understanding	Pearson Correlation	.500**
	Sig. (2-tailed)	.000
	N	105

**. Correlation is significant at the 0.01 level (2-tailed).

Table 10 indicated that relationship between content understanding and NOS understanding is positive, modest and highly significant($r = .500, p < .01$). It means that chemistry teachers, who understand content, also understand NOS and vice versa.

4.4.2 Relationship between Content Understanding and Content situated NOS Understanding

Ho_5: There is no relationship between Content understanding and content situated NOS understanding.

Table 11

Pearson Correlation between Content Understanding and Content Situated NOS Understanding

		Content situated NOS Understanding
Content Understanding	Pearson Correlation	.446**
	Sig. (2-tailed)	.000
	N	105

**. Correlation is significant at the 0.01 level (2-tailed).

Table 11 indicated that relationship between content understanding and content situated NOS understanding is modest, positive, and significant ($r = .446, p < .01$). It means Chemistry teachers who understand the content also understand the content situated NOS and vice versa.

4.4.2 Relationship between Content situated NOS Understanding and NOS Understanding

H_{o6}: There is no relationship between Content situated NOS understanding and NOS understanding.

Table 12
Pearson Correlation between NOS Understanding and Content Situated NOS Understanding

		NOS Understanding
Content situated NOS Understanding	Pearson Correlation	.621**
	Sig. (2-tailed)	.000
	N	105

**. Correlation is significant at the 0.01 level (2-tailed)

Table 12 showed that relationship between NOS understanding and content situated NOS understanding is strong, positive and significant ($r = .621$, $p < .01$). It means Chemistry teachers who understand the NOS also understand the content situated NOS and vice versa. It means that content understanding, NOS understanding and content situated NOS understanding tend to increase together.

5. Discussion and Conclusion

Findings of this study indicated that chemistry teachers do not understand the simple content and this is also supported by previous researches (Venkat & Spaul, 2015; Zahng et al.,2015; Fleer., 2009; Nowicki et al.,2013; Abell, 2007; Kind, 2014).The results of content situated NOS understanding confirm the already established findings that teachers' nature of science understandings are not satisfactory (Abd-el-Khalick et.al 1998; Hodson 1993; Lederman, 1992, 1999; Akerson & Abd-el- Khalick 2003; Wahabeh, 2009).

Findings of this study showed that chemistry teachers do not understand NOS which is also consistent with findings of previous studies which showed that most teachers in many parts of the world lack sufficient understanding of some or all characteristics of nature of science (Abd-El-Khalick & Akerson 2004; Akerson et.al 2000; Bell et.al, 2000; Clough 2006; Dekkers, & Minsi, 2003; Mellado, 2007; Hogan 2000; Niaz, 2009)

Content understanding increases with the increase of NOS understanding and vice versa. The findings of this study are in consistent with the findings of Akerson et.al 2000; Lederman, 2007; Lederman et.al, 2014 which support the effectiveness of explicit NOS instruction to improve students understanding of subject matter. Content situated NOS understanding increases with the increase of content understanding and vice versa. This result is also in agreement with (Wahebeh & Khalick's 2014; Burgin & Sadler, 2016).

6. Recommendations

Following recommendations were made on the basis of conclusions:

1. Teaching of NOS may be emphasized in teacher training programs. For this purpose NOS should be given a considerable weightage in teacher training curricula.
2. Teacher educators can make meaningful connections between the generic NOS knowledge and the science content they are teaching to prospective teachers.
3. Content teaching may be considered the responsibility of teacher training colleges too, during training programs.
4. NOS may also be included in the assessment.
5. Teaching of NOS may also be emphasized in content in academic education at colleges and universities level.
6. For in service teachers, modules may be developed with the help of experts, and chemistry teachers may be trained by master trainers.
7. Future researches may be conducted by using Research Tools like Observation Sheet, Interviews, Student Achievement, Reflection Reports, Student and Teacher Portfolios may be used to collect the data about content understanding, content situated NOS understanding and NOS understanding.

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