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Bhutanese Pre-Service Science Teachers' Conceptions of the Nature of Science: A View from Cross-Sectional Study

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Science education and scientific literacy has gained enormous attention in the global educational scenario. In many cases, however, the holistic intent of science education is largely affected due to the lack of adequate understanding of the Nature of Science (NOS). This cross-sectional study was carried out to establish Bhutanese pre-service science teachers' conceptions of the NOS. One hundred and seven pre-service science teachers from one of the education colleges in Bhutan took part in the study based on convenient sampling design. The Myths of Science Questionnaire (MOSQ) adapted from Bauraphan (2009) was administered through online survey mode. The descriptive statistics in terms of frequency supported by written responses were employed to analyse the data. Findings showed that the Bhutanese pre-service science teachers do not possess matured and informed view of the NOS in many areas of scientific knowledge, scientific methods, scientists' practices, and scientific enterprise. Implications of the findings related to teacher preparation courses are discussed.

Keywords: Bhutanese pre-service science teachers, the nature of science, cross-sectional study, descriptive analysis, science education

INTRODUCTION

From the marvels of technology to the usage of principles and philosophical assumptions in daily life, science has rooted deeply in every sphere of our life. Science and its knowledge have manifested in the form of social, economic, political, physical development of any country (Dorsah, 2020; Khishfe, 2012). Hence, science education has evolved globally as a cornerstone of numerous developmental aspects. By and large, the overarching goal of science education is the production and promotion of scientifically literate individuals (Bybee & McCrae, 2011; McComas, 2017; Wangdi et al., 2019) to navigate successfully through our technological world (Akerson & Buzzelli, 2007) and solve real world problems. Widayoko et al. (2019) opined scientific literacy as one of the basic competencies of the 21st century. Although the term scientific literate is multifaceted and dynamic, Peterson et al. (2020) posit it as an ability of understanding and applying the scientific knowledge, methods, as well as the NOS while making decision on personal and societal issues.

To create a scientific literate society, the concept and understanding of the NOS has received much attention for long time. Many science educationists and researchers believe the NOS as the perennial theme to understand the attributes, relatedness, and significance of science (Liu & Lederman, 2007; Peterson et al., 2020; Wangdi et al., 2019). Therefore, it is important to have informed ideas about how scientists with their own set of values and assumptions perform their work to develop scientific knowledge (Dorsah, 2020).

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Despite the consideration of the NOS as the integral part of scientific literacy, studies have shown naive and inadequate understanding of the NOS by teachers (Buaraphan, 2010; Dogan & Abd-El-Khalick, 2008; Lederman, 2007; Seung et al., 2009; Wangdi et al., 2019). Teachers' instructional methods and their level of information on the NOS will affect students' view of the NOS (Golabek & Amrane-Cooper, 2011; Lederman & Lederman, 2019a; Prachagool & Nuangchalerm, 2019; Ural, 2016; Widowati et al., 2017). The naive view of the NOS by teachers will let students to develop an understanding of science as a list of facts to memorize. The inadequate understanding of the NOS can have adverse implications to communicate science in both informal and formal settings (Kampourakis, 2016), make informed decisions, evaluate the policy matters, and make judgments over scientific shreds of evidence.

Consequently, there is the need to examine the level of scientific literacy for the pre-service teachers seriously (Chin, 2014). Further, the foundation of producing a scientific literate society with informed conceptions of the NOS may perhaps be attributed to the teacher preparation programs (Wangdi et al., 2019). Thus, an analysis of the pre-service science teachers' knowledge and views on the NOS becomes significant as they will take up the role to teach science once they graduate from educational colleges (Demirbas et al., 2012). It is for this reason that exploring the conceptions of the NOS held by pre-service science teachers was planned. Thus, this study will explore and document the conceptions of the NOS by Bhutanese pre-service science teachers.

Findings from this study are expected to provide views related to Bhutanese pre-service science teachers' conceptions of the NOS. Therefore, findings can inform the Bhutanese policymakers, education officials, and curriculum developers regarding the status of Bhutanese pre-service science teachers' conceptions of the NOS to make an informed decision on policy-related matters; and provide a basis to design intervention programs related to the NOS. More importantly, the findings can not only serve as a basis for development of the NOS teaching modules, but also contribute for the inclusion of learning about the NOS in their course by science lecturers in the colleges of education.

Literature Review

The Nature of Science

As the Nature of Science (NOS) is an intricate enterprise with no generally accepted definition. The NOS involves numerous topics pertaining to history, sociology, and philosophy of science, making it difficult for experts to define and students to learn (Sumranwanich & Yuenyong, 2014). Considering all the components, Lederman et al. (2014) construed the NOS as epistemology of science, way of knowing science; or values and assumptions that contribute to form scientific knowledge. As a result, numerous global standard documents on science education have incorporated the NOS as its important component (American Association for the Advancement of Science [AAAS], 2007; Organization of Economic Cooperation and Development [OECD], 2017).

The convergent aspects of the NOS have been well expounded into four basic domains of scientific knowledge, scientific method, scientists' work, and the scientific enterprise (Buaraphan, 2010). These domains include but are not limited to the following aspects of the NOS: 1) Scientific knowledge is durable, yet tentative; 2) Scientific knowledge is the product of human creativity and imagination, and is socially and culturally embedded; 3) Scientific knowledge involves a combination of both empirical evidence (observations of the natural world) and subjective behaviour (scientists' backgrounds, experiences and biases); 4) A sound understanding of the NOS should also include an ability to distinguish between observation (data) and inference (result), as well as theory and law as different components of the structure of knowledge; 5) There is no universal step-by-step scientific method; and 6) Science and technology impact on each other. (Buaraphan, 2010; Lederman, 2007).

The Nature of Science in Bhutan

There is a dearth of literature in Bhutanese science education context in general and the understanding of the NOS in particular. Not much has been studied on the understanding of the NOS by Bhutanese in-service teachers, pre-service teachers, and students. Wangdi et al. (2019) and Dorji et al. (2022) carried out the study on Bhutanese in-service science teachers' conceptions of the NOS. They found out that the majority of in-service science teachers hold naive and uninformed conceptions of the NOS and lack a clear understanding of the NOS in several aspects of scientific knowledge, scientific method, scientists' work, and scientific enterprise.

Although Bhutanese science education goal demands both students and teachers to have explicit understanding of the NOS (Dorji et al., 2022), the trend of learning about the NOS is relatively new. According to Royal Education Council [REC] (2016b), science education in Bhutan includes scientific content and scientific process. Accordingly, they expounded that "the content ascribes the quantum of scientific knowledge critical in understanding about living and non-living things around while the scientific process elicits the variety of skills that facilitates learners to understand the nature of the scientific knowledge and how science works" (p.2). Building on this premise, Bhutanese science curriculum demands science teachers to provide scientific temper and competencies for learners so that they can develop their own understanding of the world around them.

Concordantly, working scientifically is one of the strands of Bhutanese science curriculum that entails the practice of the NOS. The strand expects learners to demonstrate understanding on how science works, use theories and models to develop scientific explanations, investigate, experiment, obtain and communicate evidence, and recognize that theories and models can help explain some ideas in science but that they also have their limitations (REC, 2012). Further, the inclusion of various practical works in the Bhutanese science curriculum necessitates science teachers to help learners understand the nature of scientific knowledge and how science works (REC, 2016a). Hence, the curricular emphasis on the NOS entails Bhutanese science teachers to have adequate understanding of the NOS and implement it effectively.

Pre-service Science Teachers' View of the NOS

Given the importance of the NOS and curricular emphasis on it, teachers' understanding of the NOS is must to ensure successful facilitation of knowledge transfer to the students. Literatures often pinned the quality of science teacher development courses to produce the potential future science teachers. Almuqayteeyb (2021) viewed the processes of preparing pre-service teachers as vital for their future classroom practices. Pre-service teachers' understanding of the NOS was considered to have central role on students' understanding of the NOS (Akerson et al., 2007; Khishfe, 2017). It is crucial for pre-service teachers to have sound understanding of the NOS and related pedagogical practices to help their students learn science (Cakmakci, 2012). This is because if teachers themselves do not possess clear conceptions of the NOS, then helping students to develop well-informed view of science and sophisticated scientific knowledge would be difficult (Dorsah, 2020). Therefore, the foundation for the success of having students with proper understanding of the NOS can be attributed to teacher training program with emphasis on the NOS (Wangdi et al., 2019) and developing pre-service teachers' knowledge and understanding of the NOS was considered important (Liang et al., 2009; Seung et al., 2009).

Pre-service science teachers' understanding of the NOS would provide information on what they are like to communicate about the NOS in their professional practice when they become science teachers (Ornek, 2014). However, research on the NOS in Bhutanese context is scarce. The study conducted by Wangdi et al. (2019) and Dorji et al. (2022) found that Bhutanese science teachers held naive and uninformed conceptions in many aspects of the NOS. They recommended future researches to

formulate interventions and establish strong status of the NOS in Bhutanese education setting. Hence, to fill the literature gap from the pre-service science teachers' perspective and to set the momentum of realizing the significance of the NOS right from teacher training days, this cross-sectional study was carried out. The study sought to answer the following research question:

1. What are Bhutanese pre-service science teachers' conceptions of the NOS, particularly scientific knowledge, scientific method, scientists' work, and scientific enterprise?

METHOD

Research Design

This study is a descriptive cross-sectional survey intended to document the snapshot conceptions of Bhutanese pre-service science teachers' on the NOS at one point of time (Sedgwick, 2014). The study is largely based on the principle of a positivist approach to fit pre-service science teachers' conceptions of the NOS in the domain of scientific knowledge, scientific method, scientists' work, and scientific enterprise (Buaraphan, 2009). This research used a descriptive survey design to provide a quantitative description of the Bhutanese pre-service teachers' conceptions of the NOS in terms of frequency and commonness.

Sample

This study administered the MOQS to all the final year bachelor of education in science (BEd) and postgraduate diploma in education (PGDE). One hundred and seven (n=107) out of 113 pre-service science teachers (77 BEd final year students and 34 PGDE) took part in this study. The overall response rate was 94.7% with 51 male and 56 female respondents. The details of the sample is as represented in Table 1.

The samples were drawn into the study using convenient sampling method. As colleges of education in Bhutan remained closed for a few months due to the COVID-19 pandemic, it was difficult to locate majority of the pre-service science teachers. Therefore, researchers chose to select respondents who were easy to contact. B.Ed final year and PGDE pre-service science teachers reported back to the college when colleges across the nation reopened in different phases after the lockdown, hence assuring convenience for data collection for this study.

Table 1
The profile of pre-service science teachers who took part in the study (n= 107)

Course	Gender		Number of pre-service Science Teacher
	Male	Female	
PGDE in Physics	7	3	10
PGDE in Chemistry	4	6	10
PGDE in Biology	6	4	10
B.Ed Physics/Math	20	21	41
B.Ed Biology/Chemistry	14	22	36
Total	51	56	107

Instrument

The understanding of the Bhutanese pre-service science teachers' conceptions of the NOS was explored using the Myths of Science Questionnaire (MOSQ) designed by Buaraphan (2009). The MOSQ comprised of 14 two-tier items. In the first tier, the questionnaire contained 14 Likert-type close-ended items that ascertained pre-service science teachers' view of the NOS in four domains: scientific knowledge, scientific method, scientists' work, and the scientific enterprise (Buaraphan,

2009). The respondents were asked to select one of the three choices: *agree, uncertain, or disagree*, which best suited their conceptions of the item statement in the first tier. The second tier required the respondents to provide their point of justification for the choice made against each item in the first tier. The aspects of the NOS items were categorized under the four different domains (Table 2).

As stated in Buaraphan (2010), the MOSQ items were validated through series of processes. Firstly, items were examined by five science educators in terms of their congruency to the domains of the NOS; or their comprehensibility and appropriateness to the respondents. Secondly, the revised MOSQ questionnaire was then pilot tested with 21 pre-service science teachers at one university in Thailand. Finally, uncertainties and ambiguities found during the pilot test were clarified and the MOSQ items were finalized. Furthermore, with the Cronbach's alpha reliability coefficient of 0.79, Sarkar and Gomes (2010) reported high internal consistency of the MOSQ while examining Bangladeshi science teachers' conceptions of the NOS.

Table 2
MOSQ items as per the domains

Domain	Item
Scientific knowledge	1, 2, 3, 4, 8, & 9
Scientific method	5, 6, & 7
Scientists' work	10 & 11
Scientific enterprise	12, 13, & 14

Data Collection

The data was collected through online survey mode towards the fall of 2020. After incorporating MOSQ items in the Google Forms, the questionnaire was administered to all the final year BEd and PGDE pre-service science teachers through email-correspondence. The researchers collected the list of email addresses of pre-service science teachers directly from lecturers teaching science courses to re-service science teachers.

The data collection procedure followed the due protocol of ethical standards. The respondents were informed about the rationale of the study. The study also sought informed consent from each respondent. Moreover, the respondents were also informed that their participation in the study is voluntary and will remain confidential. The "accepting responses" button in Google Forms was disabled by the end of second week of November 2020 when all the final year pre-service teachers responded to the questions. Subsequently, the data was downloaded for descriptive analysis.

Data Analysis

The data collected through MOSQ was analyzed using descriptive statistics. The responses to each MOSQ item were grouped into three categories, i.e. "agree", "uncertain", and "disagree". The frequency of each response category (agree, uncertain, and disagree) was computed and its percentage was subsequently calculated. Further, the responses to the "agree" were labeled as "uninformed" conceptions of the NOS, while responses to "disagree" and "uncertain" categories were described as "informed" and "uncertain" conceptions of the NOS respectively (Buaraphan, 2009). The written responses to MOSQ were employed in supporting the frequency of response to each category based on the themes.

FINDINGS

The findings are structured across the assessed dimensions of the NOS understanding as follows:

Pre-service science teachers' conceptions of the NOS: Scientific Knowledge

The Bhutanese pre-service science teachers' conceptions of the NOS in the scientific knowledge

domain are illustrated in Table 3.

Table 3
Conceptions of the NOS: Scientific knowledge (n=107)

Items	Response (%)		
	Agree	Uncertain	Disagree
Item 1: Hypotheses are developed to become theories only	61.7	11.2	27.1
Item 2: Scientific theories are less secure than laws	64.4	15.8	19.8
Item 3: Scientific theories can be developed to become laws	55.1	13.9	30.9
Item 4: Scientific knowledge cannot be changed	22	6.1	71.9
Item 8: Accumulation of evidence makes scientific knowledge more stable	88.0	7.0	5.0
Item 9: A scientific model (e.g., the atomic model) expresses a copy of reality	70.6	17.3	10.2

Majority of the pre-service science teachers had uninformed view on hypotheses, theories and laws. About two-third (61.7%) believed in hypotheses being developed to become theories only, (64.45) view law as more secure than theories, and (55.1%) believe in scientific theories can be developed to become laws. The majority of the pre-service science teachers held an uninformed view of hypotheses and theories. In a written response, the respondents with the misconceptions expressed a simplistic view that with the accumulation of evidence, hypotheses are proven to become theories, laws are always stable and provide true description of phenomena, while theories just give explanations about the phenomena and laws. Further, they are of the strong conviction that theories become laws after giving explanation about phenomena such as Newton's laws being drawn from theories when proven correct with experiments, which is misleading.

Interestingly, many (71.9%) of the respondents showed an informed view on the tentativeness of scientific knowledge. They stated that scientific knowledge is not fixed and durable to withstand times as it gets changed with the advent of new ideas, interpretations, logical reasoning, and evidences.

Surprisingly, an overwhelming majority (88%) of the pre-service science teachers believed that scientific knowledge is cumulative in nature. They were of the view that scientific knowledge becomes more durable or stable with the accumulation of evidences as evidences make scientific knowledge more reliable and stable. In their standpoint, trial testing of COVID-19 vaccine takes place in several rounds to build up proofs before it becomes safe to use as the vaccine.

More than two-third (70.6%) of the respondents showed an uninformed view of scientific models. Indeed, they believed that scientist create models based on reality of the scientific phenomena. Accordingly, they assumed that atomic models are made out after scientist saw or discovered the reality. In their view, scientific knowledge and results will not be accurate or precise if scientists make model out of creativity or innovation.

The Conceptions of the NOS: Scientific Method

The Bhutanese pre-service science teachers' conceptions of the NOS concerning the scientific method are presented in Table 4.

Table 4
Conceptions of the NOS: Scientific method (n=107)

Items	Response (%)		
	Agree	Uncertain	Disagree
Item 5: The scientific method is a fixed step-by-step process	53.7	11.4	34.9
Item 6: Science and the scientific method can answer all questions	18.4	18.9	62.6
Item 7: Scientific knowledge comes from experiments only	39.1	10.2	50.7

More than one-half (53.7%) of pre-service science teachers held an uninformed conceptions of the scientific method. In support of their view, they maintained that scientists use prescribed set of phase-by-phase plans and steps in investigation. They further opined that their result will not be reliable or valid if they do not follow fixed step-by-step process. Meanwhile, more than one-third (34.9%) of the respondents expressed informed views of the scientific method while 11.4% of them had an uncertain view of the scientific method.

While 18.9% and 18.4% of the pre-service science teachers were uncertain and uninformed respectively, close to two-third (62.6%) of the respondents disagreed with the statement that "science and scientific method can answer all questions". Many of them substantiated their informed choice by stating that science is not cure for everything. They asserted that there are areas where science has no clues, as in why people dream.

More than one-half (50.7%) of pre-service science teachers held correct conceptions regarding the source of scientific knowledge. They claimed that experiments are not the only source of scientific knowledge as it also comes from creation, logical reasoning, or from societal elements such as culture and values. As opposed to the correct view, more than one-third (39.1%) of respondents held the misconceptions that the experiment is the absolute source of scientific knowledge. They maintained that without prior experiments, scientific knowledge is not valid and reliable.

The Conceptions of the NOS: Scientist's Work

The Bhutanese pre-service science teachers' conceptions of the NOS concerning scientists' work are presented in Table 5.

Table 5
Conceptions of the NOS: Scientist's work (n=107)

Items	Response (%)		
	Agree	Uncertain	Disagree
Item 10: Scientists do not use creativity and imagination in developing scientific knowledge	11	13.3	75.7
Item 11: Scientists are open-minded without any biases	54.2	23.7	22.1

The majority (75.7%) of the pre-service science teachers believed that scientists use creativity and imagination to develop scientific knowledge. They expressed an informed view about scientist's work in light of creativity and imagination. They staked a claim that scientists use creativity and imagination in their everyday life to explain phenomena or observed behavior. They viewed that the model on black holes or big bang theory are sheer examples of scientist's imagination to explain the phenomena. While 13.3% of the respondents remained undecided, 11% of them had an uninformed view on scientists using their imagination and creativity in developing scientific knowledge.

More than one-half (54.2%) of the pre-service science teachers had uninformed view and regarded scientists as open-minded and unbiased people. If scientists take things based on their own assumptions and prejudices or share their own conceptions without evidences, respondents believed that science will not have credibility or place to hold the status. However, nearly one-quarter (22.1%)

of the respondents held correct views that scientists are neither free of biases nor completely open-minded, while 23.7% of them had an unresolved view.

The Conceptions of the NOS: Scientific Enterprise

The Bhutanese science teachers' conceptions of the NOS concerning scientific enterprise are shown in Table 6.

Table 6
Conceptions of the NOS: Scientific enterprise (n=107)

Items	Response (%)		
	Agree	Uncertain	Disagree
Item 12: Science and technology are identical	61.6	11.8	26.5
Item 13: Scientific enterprise is an individual enterprise	20.5	28.9	50.6
Item 14: Society, politics, and culture do not affect the development of scientific knowledge	9.7	8	82.2

The majority (61.6%) of the pre-service science teachers held an uninformed understanding that science and technology are identical. They firmly believed that technology is a mere product of science as technology helps science to remain firm or develop further. Further, they claimed that machines or electronic products that surround us today are the by-product of science. Concurrently, more than one-quarter (26.5%) of the respondents had the contemporary view that "science and technology are not identical". In the other aspect, 11.8% of the respondents had an undecided view of whether science and technology are identical to one another.

Slightly more than one-half (50.6%) of the pre-service science teachers disagreed with the statement "scientific enterprise is an individual enterprise". Their expression was from the view that scientific endeavor is a collaborative effort or joint venture as many scientists collaborate to undertake joint inquiry into scientific domains. However, nearly one-third (28.9%) expressed an undecided view of whether the scientific enterprise is an individual enterprise, while 20.5% held an uninformed view on it.

Captivatingly, 82.2% of the pre-service science teachers expressed an informed view that "society, politics, and culture do not affect the development of scientific knowledge". In their written response they expressed that scientific knowledge is greatly influenced by social elements such as politics and culture. They further substantiated that scientific development is generally hampered by religious and cultural values while economic progress generally helps to progress the scientific development. There were 9.7% of the respondents who held misconceptions that scientific knowledge is not influenced by society, politics, and culture, while 8% of the respondents had an undecided view.

DISCUSSION

This section has structured discussion across the assessed dimensions of the NOS.

The Conceptions of the NOS: Scientific Knowledge

Majority of the pre-service science teachers held an uninformed view of hypotheses, laws, and theories. As in the case of Ornek (2014), they believed in the existence of hierarchical relationship between hypotheses, theories, and laws, whereby hypotheses are developed to become theories and theories into laws. The findings are consistent with many other similar studies. Weakest results were obtained in the aspect of scientific laws and theories (Peterson et al., 2020) indicating the biggest misunderstanding of the NOS. They stated that "The majority of the students doesn't seem to understand the relation of theories and laws: 57% assume that laws are permanently proven theories and 60.2% are of the opinion that theories would explain scientific laws" (p.8). Similarly, in

Buaraphan's (2010) study, nearly half of the pre-service teachers held an uninformed view that scientific theories are less stable than laws, and "laws are more mature theories" (p.41). Contrarily, some pre-service teachers were also found to have transitional view of the NOS particularly on the aspects of theories and laws (Dorsah, 2020).

Majority of the pre-service science teachers in this study held an informed view on the tentativeness of scientific knowledge. They mentioned that scientific knowledge is not fixed and durable to withstand times as it gets changed with the advent of new ideas, interpretations, logical reasoning, and evidences. The finding is parallel to many other studies of similar kinds. Many believed that scientific ideas can change due to advancement in technology (Dorsah, 2020), theories do change (Liu & Lederman, 2007), scientific knowledge could change with the discovery of new knowledge or more credible supporting evidences (Buaraphan, 2010). However, during the pre-test result in the study conducted by Ornek (2014) showed a contrasting view in which pre-service teachers expressed that science is not tentative as "scientific knowledge cannot change because it is absolute" (p.16). However, after intervention program, respondents have reported informed view on the tentativeness of scientific knowledge.

Almost all the pre-service science teachers in this study largely believed in Baconian induction of scientific knowledge. As in the case of Buaraphan (2010), an overwhelming majority of the pre-service science teachers believed that scientific knowledge is cumulative in nature. They were of the view that scientific knowledge becomes more durable or stable with the accumulation of evidences as evidences make scientific knowledge more reliable and stable. Further, college students misconceptions of the NOS occurs with the notion that scientific advancements cannot be made in a short time, and therefore old theories is preserved (Sumranwanich & Yuenyong, 2014).

Many of the pre-service science teachers showed an uninformed view of scientific models with a belief that scientist create real model of scientific phenomena. Accordingly, they assumed that atomic models are made out after scientist saw or discovered the reality. The findings were consistent with several other studies (Dogan & Abd-El-Khalick, 2008; Dorsah, 2020; Buaraphan, 2010). For instance, pre-service teachers believe that scientists developed model depending upon observations and experimental conclusion (Ornek, 2014). Contrary to the common misconception, science in reality is not excessively lifeless or a sequential endeavor. Hence "Scientific concepts, such as atoms, black holes, and species, are functional theoretical models rather than faithful copies of reality" (Lederman, 2007, p. 834).

The Conceptions of the NOS: Scientific Method

Many pre-service science teachers claimed that experiments are not the only source of scientific knowledge as the scientific knowledge also comes from creation, logical reasoning, or from societal elements such as culture and values. Similar views are being inferred by numerous authors (Buaraphan 2009; Dogan & Abd-El-Khalick, 2008; Peterson et al., 2020). However, more than half of the pre-service science teachers in this study held misconceptions of the scientific method. They maintained that scientists use prescribed set of phase-by-phase plans and steps in investigation as their result will not be reliable or valid if they do not follow fixed step-by-step process. Many pre-service teachers are found with an uninformed view that there is a single step-by–step method that all scientists in the world follow to establish scientific knowledge (Buaraphan, 2010; Dorsah, 2020; Liu & Lederman, 2007; Peterson et al., 2020). The prevalence of such uninformed conception can be attributed to the regular practice of fixed-step scientific methods in schools and colleges and the confirmation-type laboratory activities. This may be valid in Bhutanese context as well given that Bhutanese science curriculum in generally expounded as prescriptive or rigid in nature (Dorji et al., 2020).

More than half of the pre-service science teachers who took part in the study disagreed with the statement that "science and scientific method can answer all questions". Many of them substantiated their informed choice by stating that science is not cure for everything as there are areas where science has no clues, as in why people dream. Buaraphan's (2010) study revealed uncertain view of pre-service teachers on whether science and scientific method could provide answers for all questions.

The Conceptions of the NOS: Scientists' Work

As opposed to the transitional view by the pre-service teachers in scientists' subjectivity and creativity (Dorsah, 2020), vast majority of the pre-service science teachers in this study believed that scientists use creativity and imagination to develop scientific knowledge. Many related studies found that creativity and imagination as an important part in developing scientific knowledge (Buaraphan, 2010; Demirbas et al., 2012; Liu & Lederman, 2007). The pre-service science teachers in this study claim that scientists use creativity and imagination in their everyday life to explain phenomena or observed behaviour, which is consistent to the findings of Liang et al. (2009). They stated that "Science is a blend of logic and imagination. Scientific concepts do not emerge automatically from data or from any amount of analysis alone. Scientists use their imagination and creativity throughout their scientific investigations" (p.992). Conversely, some pre-service teachers were found to believe that scientists do not use creativity or imagination at all stages of investigation (Ornek, 2014).

In terms of subjectivity, more than one-half of pre-service science teachers' in this study had an uninformed view in regarding scientists as open-minded and unbiased people. They expressed that if scientists take things based on their own assumptions and prejudices or share their own conceptions without evidences, then science will not have credibility or place to hold the status. On the other hand, some studies claimed otherwise. While majority of the Thai pre-service teachers shared similar naive view, few pre-service teachers were of the correct view that scientists are human beings are not absolutely open-minded and unavoidably possess some biases (Buaraphan, 2010). The finding is inconsistent with Ornek's (2014) study in which science was mentioned as not objective and biased by scientist's previous experience, knowledge, background, and views.

The Conceptions of the NOS: Scientific Enterprise

As in the case of Bauraphan (2010), many pre-service science teachers held an uninformed understanding that science and technology are identical. They firmly believed that machines or electronic products that surround us today are the by-product of science. Their conceptions revolves around the notion that technology is a mere product of science and technology helps science to remain firm or develop further. In this study, many pre-service teachers believed that technology as applied science. Further, the finding is consistent with Liu and Lederman's (2007) study. The majority of participants did not exhibit adequate understanding about the empirical basis of scientific knowledge and viewed science as equivalent to technology.

While half of the pre-service science teachers viewed scientific enterprise as collaborative activity, other half disagreed with the statement "scientific enterprise is an individual enterprise". Their expression was from the view that scientific endeavor is a collaborative effort or joint venture as many scientists collaborate to undertake joint inquiry into scientific domains. Supporting the view, Bauraphan's (2010) study justified pre-service teachers view on collaboration in scientific works as favorable for additional clearer knowledge, multidisciplinary scientific research, and peer review.

Vast majority of the pre-service science teachers in this study expressed an informed view that "society, politics, and culture do not affect the development of scientific knowledge". In their written response they expressed a general view that scientific development is hindered by religious and cultural values while economic progress helps in the advancement the scientific development. The

finding is incompatible with the result of Liu and Lederman's (2007). Some of the participants in their study failed to recognize the influence of different culture and belief systems in the use of scientific knowledge and the way scientific investigations are conducted and construed scientific knowledge as universal. Golabek and Amrane-Cooper (2011) summed up the social and cultural influence attractively. They stated that "The idea that cultural values and expectations determined the work undertaken by scientists and how they approached their work also generated a strong polarisation, with the inference that the rigour of the scientific method transcends any cultural values (p.12).

CONCLUSIONS

The study indicated that the Bhutanese pre-service science teachers do not possess coherent and informed view of the NOS in many aspects. Although they held an informed view on a few areas of the NOS such as tentativeness of scientific knowledge, source of scientific knowledge, using creativity and imagination, and the socio-cultural influence on the development of scientific knowledge, many of them had naive conceptions in other aspects of the NOS. Their conceptions were inconsistent with the reality as they held hierarchical relationship between hypotheses, theories, and laws; stability of laws over theories; scientific knowledge as cumulative in nature; or scientific model as an exact replica of natural phenomena. They also had a conventional notion that the scientific method is a single universally fixed step-by-step method. Further, pre-service science teachers also held an inappropriate notion that scientist are irrefutably objective and open-minded. Moreover, they also had naive view that science and technology are single or identical entities.

LIMITATIONS

With just 107 pre-service science teachers in Bed final year and PGDE course, the findings may not represent the view of the whole pre-service science teachers. This is largely due to the fact that this study could not draw a representative sample based on a probabilistic sampling design. Therefore, generalizing the findings should be treated with caution.

To generalize findings to a larger population, future studies may be conducted using a probabilistic sampling design and inferential statistical tests. Moreover, an in-depth analysis of the modules and the content of the course for pre-service science teachers can be carried out to examine the integration of the NOS aspects and authenticate the findings from this study.

IMPLICATIONS

Teacher's inadequate understanding of the NOS is attributed to the lack of the NOS in their education courses and science programs, or not being taught on effective integration of the NOS into classroom practices (Lederman & Lederman, 2014, 2019b). Consequently, Lederman & Lederman (2019a) recommends integrating the NOS in science curricula and any science courses related to teacher preparation content or professional development programs. Furthermore, to provide science teachers with the solid understanding of the NOS, Dorji et al. (2022) and Wangdi et al. (2019) highlighted on the importance of introducing prospective science teachers to the concept of the NOS during college days. Therefore, the responsible stakeholders or relevant agencies may consider the findings from this study to enhance Bhutanese pre-science teachers' conceptual understanding of the NOS:

1. Colleges of education may design and develop an explicit teacher preparation course content that addresses the aspects of the NOS.

2. Lecturers in the colleges of educations may integrate different aspects of the NOS in the process of delivering science contents.

3. Enable prospective science teachers to immerse in hands-on practices through microteaching sessions to integrate content and pedagogical knowledge of the NOS.

4. Advocate on the clear distinction and relationship between science and technology in various college-level forums.

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