

Pre-service science teachers' conceptions of the nature of science and its relationship to classroom practice

Katherine P. Caga-anan^{1*}, Dr. John Mitchell O'Toole²

¹College of Teacher Education, University of Mindanao, Davao City, Philippines; ²School of Education, University of Newcastle, Callaghan, 2308 NSW, Australia

ARTICLE INFORMATION

Article History:

Received 18 December 2014

Received in revised form 26 February 2015

*Corresponding author: kcpkj1106@gmail.com

ABSTRACT

Certain significant tensions exist regarding relative international educational effectiveness. In the science education field such concerns churn around the extent of science understanding with which students leave school. There have been suggestions that this aspect of science literacy is related to how well teachers help students to understand the nature of science. Previous research indicates the existence of both naïve and sophisticated views of this among both teachers and students. However, little research exists regarding Filipino students preparing to teach science in a local and international fluid context, particularly how their views of the nature of science relate to their classroom teaching practices. Purposely, this qualitative study involving seven pre-service science teachers from a single institution in Mindanao, Republic of the Philippines, to better understand the relationship of teacher views of the nature of

science and the way that they are taught science during their final teaching practice. Data are gathered through non-participant class observations, document (lesson plan, CT feedback), interview, and survey analysis.

Findings reveal that:

(a) These pre-service science teachers hold a mixture of naïve and sophisticated views of the nature of science;

(b) Their views of science as empirically based (a potentially sophisticated view), were subject to strict method and producing absolute knowledge (naïve views) and transferred into their planning and delivery of practice lessons to a minor, but discernible extent;

(c) As revealed in the interview and survey their views of science were more varied and sophisticated than those appearing from the lessons planned or observed.

The implications of this study are significant because they support some indications in the literature that teacher conceptions can translate into practice. This suggests that change in the conceptions held by these teachers might lead to change in the experiences they offer to students in their classes.

Keywords

Nature of Science (NOS); Conceptions of the Nature of Science; Classroom/Teaching Practice

Introduction

Scientific literacy has been advocated by science educators, science organizations, such as the American Association for the Advancement of Science (AAAS), National Research Council (NRC), and National Science Teachers Association (NSTA), and science Education's (CHED) Memorandum Order

reform documents as a perennial goal in science education (AAAS, 1995; 1998; Achieve, 2010b; Bell, Lederman, & Adb-El-Khalick, 2000). Enhancing scientific literacy or enabling the students to approach scientific materials intelligently and to understand the world better, is emphasized by the Philippines' Commission on Higher

Number 59 (CMO No. 59) (1996), also known as the New General Education Curriculum (GED). Despite the strong emphasis on scientific literacy, poor performance in international science assessments and international studies of student achievement suggests that American (AAAS, 1995; Achieve, 2010a, b; Collins, 1997) and Filipino (Talisayan, Balbin, & De Guzman, 2006) students still experience low levels of scientific literacy such educational crisis triggered national reform efforts which prioritized scientific literacy to help the schools produce scientifically literate graduates.

Developing a well-informed understanding of the nature of science (NOS) has been seen as a central and critical component of scientific literacy and has consequently been repeatedly put forward as a goal for science education over the past several decades. Such advocacy is reasonable, as it is hard to teach something if you do not know what it is and how it develops. Emphasis on NOS as an integral component of scientific literacy has become a common theme among science reform efforts and reform documents such as those produced by the American Association for the Advancement of Science and the National Research Council (Abd-El-Khalick, 2001; Kattuala, Verma, & Martin-Hansen, 2009; Lederman 1999; Schwartz & Lederman 2002; Wang, 2001). Helping students develop well-informed conceptions of the nature of science is an essential goal of science education (Bell, Lederman, and Abd-El-Khalick, 2000), but research reveals that many science pre-service and in-service teachers and students have low, naive, uninformed and inadequate NOS views of many aspects of the nature of science inconsistent with the conceptions promoted by science education reforms (Posnanski, 2010; Akerson, Cullen, & Hanson, 2009).

AAAS (1998) strongly suggests that students be frequently given opportunities to actively explore natural phenomena to help them become scientifically literate. This responsibility lies in the hands of efficient teachers properly trained and prepared to carry out the various important roles and

functions of a teacher (CHED, 2004). What the teachers should know and be able to do is of primary importance to the education process (Bybee & Champagne, 2000). Thus, science teacher preparation programs should enable prospective teachers to construct science concepts with understanding and reflect on the history and nature of science (NSTA, 2005). However, many teacher preparation programs, such as the Philippine Bachelor of Secondary Education (BSED) - major in Biological Science do not include a course on NOS much less emphasize concepts about the nature of science.

What the teacher is teaching and how she teaches it are likely to be influenced by the nature of the subject and by the teacher's explicit and implicit beliefs about that subject. Science teachers may teach their subject according to how they understand the nature of scientific knowledge (Shah, 2009). Thus, to effectively teach students sophisticated views of the nature of science consistent with modern policy and research, teachers must themselves possess well-informed conceptions of the nature of scientific enterprise. Otherwise she certainly cannot effectively teach it (Schwartz & Lederman, 2002).

In the Philippines (where this study was conducted), a low level of scientific literacy is evident in the students' poor performance in the Trends in International Mathematics and Science Study (TIMSS) in which the country ranked last third for student achievement in science in 1999: 36th out of 38 participating countries (National Centre for Education Statistics (NCES), 2001; Talisayan, Balbin, & De Guzman, 2006) and 4th last in 2003: 42nd out of 45 participating nations (NCES, 2004). Science educators in the Philippines are very interested in determining the predictors of student achievement discernible from the TIMSS results so that measures can be undertaken to improve education (Talisayan, Balbin & De Guzman, 2006). Furthermore, a similarly low level of scientific literacy among Filipino students can be perceived at the national level from the National Achievement Test (NAT) results which revealed that for four consecutive school years (2004-2008) and in

2011-2012, student performance in science was the lowest when compared to the other four core subjects included in the NAT (Department of Education - DepEd, 2009; 2013). This situation suggests the need to upgrade science teaching and learning process and enhance students' scientific literacy.

The University of Mindanao Tagum Campus, the setting for this project, offers a Bachelor of Secondary Education (BSED) degree, with a major in Biological Science. The curriculum in this program does not include a course on NOS nor emphasis is given on the concepts about the nature of science (although the nature of science is included in BSED major in Physical Science). The BSED program accommodates students who aspire to become science teachers in secondary schools, aiming to produce scientifically literate graduates who are capable of carrying out the various important roles and functions of a teacher in accordance with the Philippines' Commission on Higher Education (CHED) Memorandum Order Number 59 (CMO No. 59) (CHED, 1996). This study investigated whether the pre-service science teachers of UM Tagum College have well-informed or naive conceptions of the nature of science and if these conceptions were actually revealed in their practice teaching experiences.

Research Questions

This study explored pre-service science teachers' conceptions of the nature of science and whether these conceptions were revealed in their practice teaching experience.

Sub-questions:

- What are the pre-service science teachers' conceptions of the nature of science?
- How are the pre-service teachers' conceptions of the NOS revealed in their practice teaching experience?

Definitions

Nature of Science

This phrase commonly refers to the "epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge" (Abd-El-Khalick & Lederman, 2000, p. 665).

Conception of the Nature of Science

This refers to the way in which the nature of science is perceived by different individuals.

Conceptual Framework of the Study

Science enterprise is a multifaceted and dynamic endeavour (Abd-El-Khalick, 2001; Bianchini & Solomon, 2003; Lederman et al 2002; Schwartz & Lederman, 2002) and so is the conception of the nature of science (Lederman et al., 2002; Schwartz et al., 2002). This characteristic of science may be the likely reason for the continuing disagreements among philosophers, historians, sociologists in science, researchers, and science educators on the single and specific definition of the nature of science (Abd-El-Khalick, 2001; Akarsu, 2007; Akerson et al., 2009; Halai & Hodson, 2004; Kattoula et al., 2009; Lederman, 1999; Lederman et al 2002; Lotter et al., 2009; Schwartz & Lederman, 2002). The topic of study keeps changing. Lederman et al. (2002) doubt the existence of a single and specific meaning for NOS. However, for present purposes the most commonly used definition of the 'nature of science' was identified as the common theme of the varied uses of this phrase. It commonly refers to the "epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge" (Abd-El-Khalick & Lederman, 2000, p. 665). The noncontroversial aspects of NOS (Lederman et al. 2002), as recommended by NSTA, describe what tenets of the nature of science teachers must be able to teach to their students (Akerson et al., 2009).

Among the premises of the scientific enterprise important to the understanding of the NOS is that **scientific knowledge**:

- (a) is both reliable and tentative (Abd-El-Khalick, 2001; Akerson et al., 2009; Halai & Hodson, 2004; Kattoula et al., 2009; Lederman et al. 2002; Liang et al. 2010; Lotter et al., 2009; NSTA, 2000; Posnanski, 2010; Sahin, Deniz, & Gorgen, 2006);
- (b) is empirically based (Abd-El-Khalick, 2001; Lederman et al. 2002; Lotter et al., 2009; Posnanski, 2010; Sahin, Deniz, & Gorgen, 2006; Schwartz & Lederman, 2002);
- (c) is subjective or theory-laden (Abd-El-Khalick, 2001; Akarsu, 2007; Akcay, 2006; Akerson et al., 2000; Lederman, 1999; Lederman et al. 2002; Lederman, Schwartz, Abd-El-Khalick, & Bell, 2001; Liang et al. 2010; Lotter et al., 2009; Posnanski, 2010; Sahin et al., 2006; Schwartz & Lederman, 2002);
- (d) necessarily “involves human inference, imagination, and creativity” (Akarsu, 2007, p. 2, see also Abd-El-Khalick, 2001; Akcay, 2006; Akerson et al., 2009; Halai & Hodson, 2004; Lederman, 1999; Lederman et al. 2002; Lederman et al., 2001; Liang et al. 2010; Lotter et al., 2009; NSTA, 2000; Posnanski, 2010; Sahin et al., 2006; Schwartz & Lederman, 2002);
- (e) is “socially and culturally embedded” (Akarsu, 2007, p. 2,; see also Akcay, 2006; Akerson et al., 2000; Akerson et al., 2009; Lederman, 1999; Lederman et al. 2002; Lederman et al., 2001; Liang et al. 2010; Lotter et al., 2009; Posnanski, 2010; Sahin et al., 2006; Schwartz & Lederman, 2002);
- (f) does not arise from application of a universal step-by-step method (no single scientific method) (Akerson et al., 2009, p.1092, see also Halai & Hodson, 2004; Lederman et al. 2002; Liang et al. 2010; NSTA, 2000);

(g) necessarily involves a combination of observations and inferences (Abd-El-Khalick, 2001; Akarsu, 2007; Akcay, 2006; Lederman, 1999; Liang et al. 2010); and

(h) involves the formation of theories and laws, terms with distinct functional roles in the development of scientific knowledge (Abd-El-Khalick, 2001; Akarsu, 2007; Akcay, 2006; Akerson et al., 2000; Halai & Hodson, 2004; Kattoula et al., 2000; Lederman et al., 2001; Lederman et al. 2002; Liang et al. 2010; Lotter et al., 2009; NSTA, 2000; Posnanski, 2010; Sahin et al., 2006; Schwartz & Lederman, 2002).

In this paper, ‘**well-informed conceptions**’ refer to the views that are in agreement with this description of the various aspects of the nature of science while ‘**naive conceptions**’ mean views that do not touch on these eight points, which provide the conceptual framework for this study.

Literature Review

Scientific literacy, as emphasized in reform documents, is a primary goal in science education (AAAS, 1995, 1998; Achieve, 2010b; Bell et al., 2000). Science literacy becomes evident when a person can understand science processes (Posnanski, 2010) and apply it in daily undertakings (Collins, 1997). This is the ‘public understanding of science’ component of a broader notion of literacy. A low level of such scientific literacy is apparent in poor student performance in international science assessments and international studies of student achievement, such as the on-going Trends in Mathematics and Science Study (AAAS, 1995; Achieve, 2010a, b; Collins, 1997; Talisayan et al., 2006). Low performance in such tests has triggered national reforms intended to improve scientific literacy and produce scientifically literate graduates and raise national TIMSS averages (AAAS, 1995; Collins, 1997).

Developing well-informed conceptions of the nature of science is a

central and a critical component of scientific literacy (Achieve, 2010b; Holbrook & Rannikmae, 2007; Posnanski, 2010; Rutledge, 2005). A scientifically literate person necessarily holds accurate and clear understanding of the nature of science (Akçay, 2006; Kucuk, 2008). Since the nature of science remains one of the major concerns emphasized in science reform documents (Abd-El-Khalick, 2001; Kattoula, Verma, & Martin-Hansen, 2009; Lederman 1999; Schwartz & Lederman 2002; Wang, 2001), teachers are encouraged to teach NOS to their students (Bianchini & Solomon, 2003). However, regardless of the emphasis on NOS as a critical component of scientific literacy, much research reveals that teachers and students themselves generally have naive conceptions of several aspects of the nature of science (Abd-El-Khalick & Akerson, 2004; Akarsu, 2007; Akerson, Abd-El-Khalick, & Lederman, 2000; Cochrane, 2003; Hanuscin, Akerson, & Phillipson-Mower, 2006; Kucuk, 2008; McDonald, 2008; Ogunniyi et al, 1995; Sahin, Deniz, & Gorgen, 2006; Shah, 2009; Thye & Kwen, 2004) and scientific literacy remains a struggle for science educators (Meyer & Avery, 2009).

Although no consensus has been reached about a single definition of NOS (see Abd-El-Khalick, 2001; Akarsu, 2007; Akerson et al., 2009; Halai & Hodson, 2004; Kattoula, Verna, & Martin-Hansen, 2000; Lederman, 1999; Lederman et al., 2002; Lotter, Singer, & Godley, 2009; Schwartz & Lederman, 2002), there is agreement as to the aspects of the nature of science (Abd-El-Khalick, 2001; Bianchini & Solomon, 2003; Lederman, 1999; Lederman et al. 2002; Schwartz & Lederman, 2002) relevant to K-12 students (Akarsu, 2007; Halai & Hodson, 2004; Lederman et al. 2002; Posnanski, 2010; Schwartz & Lederman, 2002) and important for them to learn (Lederman, 1999; Lotter, Singer, & Godley, 2009). Teaching NOS requires the teacher to have well-informed conceptions of the nature of science (Akarsu, 2007; Akerson et al., 2009; NSTA, 2000); otherwise, she cannot effectively teach it (Schwartz & Lederman, 2002).

However, having well-informed conceptions of the NOS does not guarantee

that a teacher will be able to teach NOS effectively. The translation of one's NOS views into classroom practice is so complex that the issue persists under debate, as evidenced in the existence of two groups of literature, one group claiming that teachers' conceptions of the nature of science affects and is translated into their classroom practice (Ackay, 2006; Lunn, 2002), and the other group asserting that teachers' NOS views do not necessarily translate into classroom practice (Akçay, 2006; Bell et al. 2000; Hipkins & Barker 2005; Lederman, 1999; Mellado, Bermejo, Blanco, & Ruiz, 2007; Shah, 2009).

Given the vital role that a well-informed NOS understanding plays in developing science literacy (Achieve, 2010b; Holbrook & Rannikmae, 2007; Posnanski, 2010; Rutledge, 2005), it is not surprising that there have been on-going attempts to enhance students' and teachers' conceptions of the nature of science (Lederman, et al., 2002). Science educators and researchers implemented interventions to enhance students' and teachers' NOS views (e.g. Akerson et al., 2009; Rutledge, 2005; Schwartz et al., 2002). Among these efforts to address NOS in the classroom, the explicit-reflective approach to teaching NOS has been found to be most effective in enhancing teachers' and/or students' NOS understanding (Abd-El-Khalick, 2001; Abd-El-Khalick & Akerson, 2004; Abd-El-Khalick & Lederman, 2000; Akerson et al., 2000; Cochrane, 2003; Hanuscin, Akerson, & Phillipson-Mower, 2006; Koksall, 2009; Kucuk, 2008; Lotter, Singer, & Godley, 2009; McDonald, 2008; Meyer & Avery, 2009; Posnanski, 2010).

Method

Research Design

A qualitative case study design was employed by the researcher in investigating the pre-service science teachers' conceptions of the nature of science and its relationship to classroom practice. Specifically, the "instrumental case study" (Creswell, 2008, p. 476; Punch, 2005, p. 144) was employed, since the investigation focused on gaining insight on a particular issue (NOS

understanding and classroom practice) by studying the participants in their natural setting (their school). This was done by collecting multiple forms of data as sources of evidence through an open-ended questionnaire, semi-structured individual interview, non-participant classroom observations, analysis of lesson plans and cooperating teachers' (CT) feedback. The data gathered were analyzed by describing, elucidating, and interpreting the themes generated from the individual and shared patterns of NOS conceptions and instructional practices among the participants. The findings were presented in a written form that stresses description and interpretation (Punch, 2005) in light of the eight aspects of the nature of science.

Site and Subjects

This project was conducted particularly at the College of Teachers Education University of Mindanao Tagum Campus, located at the heart of Tagum City, Davao del Norte, Mindanao, Philippines. It offers an education program (BSED major in Biological Science) that aims to produce scientifically literate teachers who will practice their profession at various private and public schools in Mindanao and other parts of the Philippines.

"Purposeful sampling" (Creswell, 2008, p. 214) was employed in selecting the participants and the site for this study. It selects 'information-rich' cases" for in-depth study to be able to develop a thorough understanding of the issues under investigation. Information-rich cases are those cases from which one can learn a great deal about issues of central importance to the purpose of inquiry" (Patton, 2002, p. 230). The pre-service science teachers of UM Tagum Campus were considered by the researcher as 'information-rich', since they were exposed to science subjects for an extended period (approximately 3 years), as they enroll and undergo their science major subjects. Among the strategies under this sampling technique, the "homogeneous sampling" strategy was used wherein the researcher samples individuals based on their

membership in a sub-group (Creswell, 2008, p. 216) with the aim of describing this particular sub-group in depth. In this study, this subgroup referred to all seven pre-service science teachers of UM Tagum Campus who had their practicum in the second semester of the school year 2010-2011.

Data Collection Strategies

Triangulation is utilized in this study to enhance the validity (Mathison, 1988) and accuracy of the findings drawn from the text data gathered through four data sources. Cum an adapted open-ended questionnaire (the VNOS-C), semi-structured individual interview, non-participant classroom observations, and documents (participants' lesson plans and CT comments and/or suggestions).

Open-ended Questionnaire

The open-ended nature of the VNOS-C questionnaire allowed the participants to elucidate their views regarding the target NOS aspects using their own words (Krosnick, 1999; Lederman et al., 2002) thus capture diversity in the responses (Jackson & Trochim, 2002). Previous studies of Lederman et al. (2002) showed that the NOS items generated responses that distinguished naive from well-informed NOS conceptions and provided insights into the participants' understanding about the target NOS aspect. Data generated from VNOS questionnaires elucidated the participants' actual thinking about the NOS and the reasons behind their thinking. These studies also supported the validity of the VNOS-C in assessing NOS understanding in a wide variety of respondents including pre-service secondary science teachers (Lederman, et al., 2002). Many researchers have adapted and used the VNOS-C in their study to determine the teachers' and/or students' NOS views (including Cochrane, 2003; Kucuk, 2008; Lederman et al., 2001; Martin-Dunlop, 2004; Posnanski, 2010; Schwartz & Lederman, 2002; Schwartz et al., 2002; Thye & Kwen, 2004).

This questionnaire was administered after conducting the classroom observations to avoid biasing such observations with the researcher's prior idea about the participants' NOS views and in response to the limited remaining time of the practicum. It took 45-75 minutes for the participants to complete the questionnaire. The participants' responses were reviewed and organized to determine which answers needed to be elucidated more or ambiguous ones to be clarified and later incorporated in the subsequent individual interview.

Semi-structured Individual Interview

The semi-structured individual interview was intended to validate and clarify the participants' responses to VNOS-C items, to help assess their ascribed meanings to key terms and phrases associated with the nature of science (Lederman et al., 2002), and to gather more data about the participants' views of the NOS. This practice was also done in earlier research projects (e.g. Kucuk, 2008; Lederman et al., 2001; Posnanski, 2010; Schwartz & Lederman, 2002). A follow-up interview following the administration of the VNOS-C was considered as a principal source of validity for this questionnaire since it gave an opportunity to directly check and clarify the participants' understanding of each item in the questionnaire as well as the researchers' interpretation of the responses, thus avoid misunderstanding and misinterpretations (Lederman et al., 2002). The interviews, which lasted for about 45-75 minutes per participant, were audio-recorded using a voice tracer.

Classroom Observations

Non-participant classroom observations were undertaken to gather first-hand information (Creswell, 2008) about the participants' classroom practice and to determine if their conceptions of the nature of science were revealed in their practice teaching experience. They were used to identify links between the participants' understanding of NOS and their classroom practice during their practice teaching. Using

qualitative or unstructured approach to observation the researcher did not use predetermined categories or classifications during the observation to allow more focus on the holistic events inside the classroom (Punch, 2005). However, despite being unstructured, classroom observations and field note taking were still guided by the research questions and the purpose of the observation.

The researcher used the "*ad libitum*" sampling in conducting classroom observations wherein "the observer simply recorded whatever was of interest" or significant to the present study (Kellehear, 1993, p. 130). In this research, attention centered on activities, actions, or attempts that explicitly or implicitly related to the teaching of NOS. The observations also involved an element of "scan sampling" since it used simple recording and noting of the absence or presence (Kellehear, 1993, p. 130) of any attempts toward NOS integration or NOS teaching. Recording of observations came in the form of written notes with less emphasis on strict descriptions and using few abbreviations to make recording easier and faster to avoid losing observation time due to intensive writing (Kellehear, 1993). Field notes include both descriptive and reflective entries. "Descriptive field notes" captured the description of events, activities, and people while "reflective field notes" included the researcher's personal thoughts in relation to the observed events, activities, and people (Creswell, 2008, p. 225). Any interaction and/or activities that bear upon or possibly relates (explicitly or implicitly) to the nature of science were written as a single episode.

Lesson plans and Cooperating Teachers' comments and/or suggestions

Instructional materials such as the participants' lesson plans and their CT feedback in the form of comments and/or suggestions, for the whole duration of the practice teaching, were photocopied and collected as data sources to supplement, support and/or challenge the data gathered through classroom observations. These instructional materials were triangulated with

classroom observations to help the researcher gain more understanding of the participants' classroom practice. The data drawn from these documents were used by the researcher to contextualize the data gathered through classroom observations. Documents are "unobtrusive" and "non-reactive"; they are not affected by the research process (Bowen, 2009). The participants' lesson plans were not made for the purpose of the research and they were already prepared by the participants before their actual teaching and before observing their classes. Thus, these documents were unaffected by the researcher's presence inside the classroom.

Analysis of Data

Preparation for Analysis

The researcher organized all the text data from the participants (Tesch, 1990). The responses in the VNOS-C questionnaire were typed into a computer file, the audio recorded interviews transcribed verbatim, the field notes from classroom observations were also transcribed, and the lesson plans and CT comments/suggestions photocopied.

Analysis

Text data were analyzed individually (each participant was identified by letter) since there was a need to determine each of the 7 participants' conceptions of the NOS and to find evidences of alignment that would show whether their conceptions of NOS were revealed in their practice teaching experience. After which, final comparative analysis was undertaken, that is collectively, by comparing the individual analysis results and finding overall alignment between NOS conceptions and classroom practice among the 7 participants.

VNOS-C responses, interview transcripts, and classroom observation field notes

The analysis was done manually by the researcher using Microsoft Word. In the preliminary exploratory analysis, all the raw

text data were read several times, explored and examined individually (per participant) to have a general sense of the data (Creswell, 2008) in its context. Memos, or ideas that came to mind while reading the text data, (Creswell, 2008; Punch, 2005), were written in the margins of the VNOS-C responses and the interview and field note transcripts as comments and/or footnotes. Such memos were essential in the analysis process, since they suggest higher level coding through recognition of patterns in the data, elaborate concepts, and/or relate concepts to each other (Punch, 2005). Following the preliminary exploration was the coding of the text data. Done in an inductive manner, the analysis started with specific or detailed codes and then subsumed these codes into broad or general themes in the later stages of the analysis process (Coffey & Atkinson, 1996; Creswell, 2008). Coding is central in the analysis of this study since there is a need to find regularities and patterns in the text data (Punch, 2005). In the initial or first-level coding process, texts were segmented and labeled with specific or detailed codes. These initial codes were "descriptive codes or low-inference codes" and were the basis for later higher-order coding (Punch, 2005, p. 200). Some of these codes were stated using the participants' own words (in vivo codes), while others used the researcher's own language. Text segments were then carved out of their context ('segmenting' and 'de-contextualizing': Tesch, 1990, p. 115) and grouped together, using the initial codes by tabulating together or subsuming all responses under the same initial code to make the initially coded data more accessible for further analysis.

In the second-level coding, the initial/descriptive codes were then reexamined further and those found overlapping or redundant codes were collapsed into pattern codes (Punch, 2005) or categories (Coffey & Atkinson, 1996) or "repeating ideas" (Auerbach & Silverstein, 2003, p. 37) by grouping together related segments or passages of the text data. Subsequently, the categories or repeating ideas were subsumed into broad themes (Auerbach & Silverstein, 2003; Creswell, 2008). Themes were then interconnected, subsuming minor themes into broader

themes. A “theme is an implicit topic that organizes a group of repeating ideas” (Auerbach & Silverstein, 2003, p.62), or an aggregate of similar codes that forms a major idea (Creswell, 2008).

Furthermore, the data were “recoded” (Saldaña, 2009, p. 45) as codes, repeating ideas/categories, and themes were refined and re-grouped as the coding progressed. The themes that emerged from data analysis were elucidated in relation to the research questions. Such themes were reviewed in light of the eight aspects of the nature of science identified in the NOS literature, then summarized and elucidated into narratives that answered each of the research questions.

Documents (Lesson plans and CT comments and/or suggestions)

Documents, in the form of participants’ lesson plans and their CT’s feedback, were collected and analyzed in this study to be able to verify the findings, corroborate or challenge evidence gathered from classroom observations. Document analysis in this study involved an “iterative process” which combines elements of “content analysis” and “thematic analysis” (Bowen, 2009, p. 32). During content analysis, the researcher organized the information in the documents into categories related to the research purpose of determining if the participants’ NOS conceptions were revealed in their practice teaching experience. This was done by identifying meaningful and relevant passages or text in the documents pertinent to NOS. The subsequent thematic analysis involved recognizing patterns within the selected relevant text or data from the documents done through careful, more focused re-reading, and coding the selected relevant data. The codes were used to build categories and themes pertinent to (the inclusion or exclusion of) NOS (in) teaching. These themes were then elucidated together with the themes taken from field note analysis to identify alignment between the participant’s NOS conceptions and his/her classroom practice during practice teaching.

Results and Discussion

A. Discussions on Conceptions of the Nature of Science (NOS)

In the subsequent sections, the participants’ views about the nature of science are presented and discussed in line with the eight identified NOS aspects emphasized in the literature. The individual participants were represented by letters (A-G) to maintain their anonymity.

Scientific Knowledge is both Reliable and Tentative

Five of the seven participants (A, C, D, F, & G) indicated that scientific theories are not permanent. “Scientific theories do change” (A-VNOS-C) when new evidences that support it are acquired through further investigations. Additionally, four participants (A, C, D, & F) suggested that

“a theory will become a law if proven with evidences” (C-interview).

These participant views on scientific theories could be taken to reflect the tentative nature of scientific knowledge (Abd-El-Khalick, 2001). However, on closer examination, these views about the tentativeness of theories arise from the participants’ naive conception about the nature of scientific theories and its relationship to scientific laws. The participants asserted that theories do change not because they believed that scientific knowledge is tentative but because they held naive conceptions about the nature of theories as yet to be confirmed laws. Therefore, this finding cannot be considered as a well-informed view about the tentativeness of scientific knowledge.

Scientific Knowledge involves the Formation of Theories and Laws, terms with distinct functional roles in the Development of Scientific Knowledge

Most of the participants did not perceive theories and laws to be equally legitimate as scientific knowledge, since most

of them think that theories are inferior to law because theories are not proven yet and are still under further investigations (A, C, D, E, & F) while laws are already proven with evidences and are universally accepted (A, B, C, D, E, & F). Furthermore, the majority of the participants perceived theories not as legitimate scientific knowledge, but as intermediary steps toward formulating scientific laws, as they asserted that theories and laws have hierarchical relationship in which theories will become laws when proven with empirical evidences (A, C, D, E, & F).

“For me, scientific theory is just a person’s theory without specific evidence. It is not proven yet, it is not a law yet.” (C-interview)

“Theories are those things that are not proven yet, like the Origin of Mankind, so it’s just a theory, scientific theory...” (D-interview)

Participants failed to recognize that scientific theories are well established, highly substantiated, and internally consistent explanations of scientific concepts. “Laws are descriptive statements of relationships among observable phenomena while theories are inferred explanations for observable phenomena or regularities in those phenomena” (Lederman et al., 2002, p. 500): theories and laws are both legitimate scientific knowledge and one does not become the other. Thus, the above-mentioned views of participants about scientific theories and scientific laws are considered naive.

Scientific Knowledge is Empirically-based

Four of the seven participants (A, B, C, and G) believed that science is based on empirical evidence and five of them (A, B, D, F, and G) indicated that

“Science is a set facts and theories based on experiments, investigations and research” (D-interview).

These facts are proven true with empirical evidences. All of the seven

participants asserted that experiments are necessary to test hypotheses, to prove and/or verify existing science concepts, and to solve problems. Experiments are done following the scientific method to make it organized and logical (A, B, C, F, and G). Moreover, in relation to the perceived essential role of experiments in science, most of the participants (A, B, C, D, F, and G) asserted that

“Experimental approach is the best way of teaching science because it will boost students’ interest as they learn while doing” (D-interview).

In this method, students are given opportunities to discover and experience concepts on their own, thus helping them to learn better. In relation to this, teachers should be skilful in conducting laboratory experiments (F). These findings revealed that the participants recognized the empirical nature of science. However, this also means that they perceived scientific knowledge as solely based on experimental data and observations of the natural world, and is facts based, with the exclusion of other subjective human factors such as beliefs and opinions (Abd-El-Khalick, 2001). Notably, however, scientists do not have access to all natural phenomena and that experiment results are not absolutely objective since laboratory instruments are always mediated by the set of assumptions underlying their functions (Lederman et al., 2002).

The absence of a universal step-by-step method in doing Science

The majority of the participants (A, B, C, and D) suggested that ‘scientific method’ is the only way, and the best way (C), of doing science.

“Do you think there are other ways of doing science aside from scientific method?”

D: *“As far as I know, none, only the scientific method.”* (D-interview)

This method is systematic since it has logical steps to be followed (B, C, D, E, F, and G).

"In scientific method, there are steps to be followed in doing an experiment. So you need to identify your problem, gather information about the problem, formulate your hypothesis [pause] conduct investigation or experimentation, interprets data, and so on...." (E-interview).

The belief that there is one recipe like procedure to follow in doing science is one of the most widely held naive conceptions about the nature of science (Lederman et al., 2002). "There is no single scientific method that would guarantee the development of infallible knowledge" (Lederman et al., 2002, p. 501).

By contrast, participants B, F, and G expressed that scientific method is flexible, not rigid, and can be modified depending on the nature of the experiment or the problem under investigation.

"I believe that scientific method is dynamic. It will depend on the need of a certain experiment. It is not that fixed, it is dynamic. It is flexible, but still logical." (G-interview)

This informed view about the scientific method agrees with the nature of scientific knowledge that although scientists observe, hypothesize, speculate, test, and so on, there is no single sequence of doing such activities that will lead to the solution of a problem (Lederman et al., 2002).

Science involves a combination of Observations and Inferences

"To see is to believe" (F-interview), a person should see something first to be sure of it. This is the idea of the majority of the participants (B, C, D, E, F, and G) when asked about the certainty of the atomic structure.

"I don't know how to teach my students that an atom is composed of protons, neutrons and electrons, because even I myself do not purely believe that atoms are composed of these particles, because one of my principles in life is "to see is to believe". I don't even see atoms; therefore, I am hesitant

to believe that it is composed of protons, electrons and neutrons." (F-VNOS-C)

These participants failed to recognize the distinction between inference and observation: not all concepts in science are directly observable by the human senses, thus scientists use inferences in explaining concepts that are not directly accessible to the senses (e.g. atoms, and gravitational force) (Lederman et al., 2002).

Scientific knowledge is Subjective or Theory-laden.

"If I will be presented with a set of data, my perception is definitely different from other person's perceptions which will result in our different interpretations of the same data." (A-interview)

The participants indicated that interpretation is an essential component of science (A, B, and E) (three of the seven). However, it should be noted that interpretation **per se** or pure interpretation is not science (F), it is the interpretation of empirical data that is considered science (G). In addition, interpretations and perceptions alone are not as accurate as facts unless the objects of the interpretation are actually observed through experimentation (C and D). How a person interprets data is affected by how he perceives it (A, B, C, D, and G) (five of the seven). The participants asserted that a person's unique individuality, frame of mind, imagination, observation, ideas, intelligence, prior knowledge, personality, and understanding of the data all affect how a person interprets and deals with empirical data.

"We arrived at different conclusions from the same data because we have different perceptions about that data, so we interpret it differently" (B-interview).

In this premise of the nature of science that the participants expressed their informed conceptions. These findings reveal that the participants recognized the theory laden nature of scientific knowledge. Scientists' individuality and mindset greatly

influence their work and how they perceive and interpret empirical data (Lederman et al., 2002).

Scientific Knowledge necessarily involves Human Inference

“I guess imagination and creativity are applicable to all the stages of investigations. In planning, you need to imagine what is going to happen and you must be creative enough to do such. Same in designing, imagine first what will be the experiment like, and be creative. In data collection, imagination is being applied in the process of thinking of ways and means to gather data and creativity in organizing the collected data, and so on...” (G-VNOS-C)

Most of the participants (A, B, C, D, F, and G) indicated that scientists use their creativity and imagination in all stages of investigation, from planning, designing, conducting experiment, collecting data, presenting data, interpreting data, presenting of the results, and formulating theories and recommendations. This resembles the result obtained from the study of Abd-El-Khalick, Bell, & Lederman (1998) in which all participants ascribed to the idea that creativity and imagination are integral components of scientific investigations.

Scientific Knowledge is Socially and Culturally-embedded

In the questions related to this aspect of the nature of science the participants showed many ambiguous responses. Most of them would take a stand, but could not provide an example to illustrate the idea. However, the preceding statement presented the general view based on the themes that emerged from the analysis of the participants' responses. “Science is affected by the society's social and cultural values in which it is practiced” (A, C, D, and G). People's beliefs, activities, and their cultural backgrounds affect how they view science or their attitude toward science. People's philosophical views serve as guide in their discoveries. In addition, investigations involving humans as

participants are affected by the participants' cultural values (A). In contrast, two participants articulated that the society's cultural values are also influenced by science and technology (E and G). Science is reflected on people's culture. Thus the relationship between science and culture is two-way, one affects the other and vice versa. On the other hand, it should be noted that two participants (B and F) asserted that science is universal, since science concepts are the same worldwide.

Summary of the Discussions on Conceptions of the Nature of Science (NOS)

It can be deduced from the above findings that generally, the majority of the participants held naive views of many of the identified aspects of NOS. They failed to recognize that scientific knowledge is tentative, theories and laws are both legitimate scientific knowledge, there are no recipe like procedures in doing science, and that scientific knowledge combines inferences and observations. This finding is consistent with the other previous studies (Abd-El-Khalick & Akerson, 2004; Akarsu, 2007; Akerson et al., 2000; Cochrane, 2003; Hanuscin et al., 2006; Kucuk, 2008; McDonald, 2008; Ogunniyi et al, 1995; Sahin et al., 2006; Shah, 2009; Thye & Kwen, 2004). Nevertheless, in congruence with earlier studies of Bell et al., (2000), Lederman et al., (2001), and Wang, (2001). Some participants' in this study expressed informed views on the empirical, subjective and theory-laden, creative and imaginative, and the social and cultural embeddedness nature of scientific enterprise.

B. Discussions on the Nature of Science and Practice Teaching Experience

Despite unfamiliarity with the concepts of the nature of science, the pre-service science teacher participants suggested that they tried to implicitly include some characteristics of science, to which they referred as the nature of science, and they articulated willingness to incorporate NOS in their future classes. Findings of this study

revealed that some of the participants' views about the nature of science, both informed and naive were implicitly included in their classroom instruction during their practice teaching experience.

Implicit NOS inclusion in Classroom Instruction

The Classroom observation field notes, lesson plans, and CT comments and/or suggestions indicated that all of the participating pre-service teachers dealt with the empirical nature of science, four of the seven included that science knowledge was theory-laden (B, E, F, and G) and socially and cultural embedded (B, C, E, and F) implicitly included in the planned lessons as well as in the classroom instruction. The empirical nature of science was addressed by the pre-service teachers when they reinforced the lessons discussed in the classroom with laboratory experiments or hands-on activities (e.g. experiment on changes in matter following the discussion of physical and chemical change) to prove the concepts and to let the students experience what they learned. However, it should be noted that the decision of the pre-service teachers to conduct experiments is also influenced by their cooperating teachers, as evidenced in one of the CT's comments suggesting that the pre-service teacher should "prepare hands-on activities for students" (B's CT comment in lesson plans).

The theory-laden nature of science is apparent in the practice of almost half of the participants as they asked students' prior knowledge about the lesson and used it as springboard for the discussion. This shows that they acknowledged the students' previous knowledge, individuality, and mindset in presenting the lesson (Lederman et al., 2002). Besides, the pre-service teachers fairly emphasized the social and cultural embeddedness of science, as they helped students relate the lesson to the real world or to students' own experiences. For example, application of radiation in medicine (F), Carbon Oxygen cycle and global warming (B). These results agree with other research which showed that the teacher's views about science are consistent with their teaching practices

(Lunn, 2002) thus can affect their classroom instruction as well as their choice of teaching strategies (Ackay, 2006).

Contrastingly, some naive conceptions were also implicitly integrated in the participants' classroom teaching. These include the treatment of scientific knowledge as fixed instead of tentative by most of the participants (B, C, D, E, F, and G), as shown in the participants' emphasis on fixed values (e.g. value of the color bands in resistors) and in the way they treat and present science concepts as if these concepts are very certain and permanent. Furthermore, the logical steps followed during experiments indicated the naive conceptions of the participants about the absence of recipe-like scientific method in doing science (for example, classroom observation field notes for a number of lessons delivered by G indicate that the teacher conducted orientation about the procedures to be followed, before the students perform the laboratory experiment, but did so in such a way as suggested that there was only one way the activity could be performed). These participants also presented fixed steps and patterns in solving science problems (e.g. binding energy), and rules or steps to be followed in writing chemical equations. The pre-service teachers did not mention that there are other ways of solving the sample problems and writing the sample chemical equations, that students might have their own ways of doing it, or that the way being presented was a product of historical processes that could have worked out otherwise.

Summary of the Discussions on the Nature of Science and Practice Teaching Experience

Generally, the participants implicitly addressed only three NOS aspects, two of which are naive, in their classroom instruction during their practice teaching: the empirical nature of scientific knowledge, the existence of a single scientific method or stepwise procedures to be followed in acquiring infallible scientific knowledge, and the absolute nature of scientific knowledge. Classroom observation field notes, participant lesson plans and CT comments/suggestions indicate that these NOS aspects, only one of

which matches either policy or current understanding, were sometimes translated into their classroom practice. Thus, only few of these participants' conceptions of the nature of science, either informed or naive, were transferred into their practice teaching experience. This finding is consistent with other investigation results that teacher conceptions about the nature of science do not significantly influence their classroom practice (Abd-El-Khalick, Bell, & Lederman, 1998; Bell et al., 2000; Hipkins & Barker 2005; Lederman & Zeidler cited in Akcay, 2006; Mellado et al., 2008; Shah, 2009).

Seemingly, these pre-service science teachers did little well, in terms of building student understanding of the nature of science, but that they did little actual direct harm. NOS issues had so little presence that impact cannot be expected. However, the fact that they were not challenging widely held public misconceptions of the nature of science (some of which they held themselves) meant that an opportunity to productively influence the students in their science classes was lost.

Implications for Teaching

The implications of this study are significant, because they support some indications in the literature that wider teacher conceptions can translate into practice. This suggests that change in the conceptions held by these teachers might lead to change in the experiences they offer to students in their classes.

Considering the absence of any course or emphasis on concepts of the nature of science in their field and the participants' unfamiliarity about NOS, it is fairly anticipated that the participants held naive views about some aspects of the nature of science. Indeed, they expressed uninformed views about many aspects of the NOS. However, discussions during the interviews suggested that with proper exposure, training, and support, the participants had great potential in changing their naive views of the other aspects of NOS.

The findings of this study should make the participants raise their awareness of their own views of the nature of science, both

informed and naive. It will also provide evidence for the in-service teachers regarding their students' naive and informed views about the nature of science. This information could guide and might encourage the pre-service teacher participants and the in-service teachers of participating institution to enhance such naive views and to reinforce their informed views of NOS taking into account the essential role of well-informed conceptions of the nature of science in scientific literacy.

The fact that a restricted NOS repertoire was expressed in science classes suggests that better prepared pre-service teachers might implement a fuller range of NOS understandings. They could go beyond three aspects of the nature of science that emerged from these classes (one informed: the empirical nature of scientific knowledge; and two naive: the existence of a single scientific method or stepwise procedures to be followed in acquiring absolute scientific knowledge).

The nature of science was not treated explicitly in the curriculum where the participants of this study were enrolled. The findings of this study provided data to suggest that the curriculum needs to change. NOS concepts should be incorporated in the program during the regular syllabi review process.

Finally, the results of this study provided relevant information and data regarding the NOS aspects on which to focus, as the researcher plans and implements interventions and/or seminar-workshops on enhancing science teacher views of the nature of science.

Conclusion

The participants held naive as well as informed views of some aspects of the nature of science. Most of them participants believed that scientific theories will change and become laws once proven with empirical evidences, which illustrates that they perceived theories as inferior to law. The participants also indicated that science is

purely based on empirical evidences gathered through experimentation following the logical steps of the scientific method which is the only way of doing science. Furthermore, some participants perceived science to be objective, thus allowing no room for creativity and imagination in dealing with empirical data. These statements are at odds with well-informed views of the nature of scientific knowledge emphasized in the literature.

By contrast, most participants expressed informed views on the empirical nature of science, the role of interpretation in science, the effect of individuality and mindset in dealing with empirical data, and the creative and imaginative nature of science. Few participants recognized the flexibility of the scientific method as well as the equal legitimacy of theories and laws as scientific knowledge.

The participants articulated unfamiliarity with the NOS, but expressed willingness to incorporate the concepts of the nature of science to their future classes.

Only few of the participants' conceptions of the nature of science were transferred into their practice teaching experience. The participants implicitly addressed only three NOS aspects in their classroom instruction during their practice teaching. One is well-informed: the empirical nature of scientific knowledge; and two are naïve: the existence of a single scientific method or stepwise procedures to be followed in acquiring infallible scientific knowledge, and the absolute nature of scientific knowledge.

Recommendations

- (a) The research process piloted in this small study could be scaled up to make a useful contribution to science education as the nation for which it was contextualized moves into a period of rapid curriculum change.
- (b) Pre-service (and in-service) science teachers should be provided with opportunities to enhance their naïve

views and reinforce their well-informed conceptions of the identified NOS aspects important to science teaching and scientific literacy.

- (c) The NOS concepts should be incorporated and treated explicitly in the new BSED-Biological Science curriculum.
- (d) Interventions and or seminar/workshops on enhancing science teacher views of the nature of science should be designed and implemented to assist participants in enhancing their NOS views.

References

- AAAS (1995). Project 2061. Science literacy for a changing future: A decade of reform. Washington D.C.
- AAAS (1998). Project 2061. Science literacy for a changing future: Update 1998-1999. Washington D.C.
- Abd-El-Khalick, F. (2001). Embedding nature of science instruction in pre-service elementary science courses: Abandoning scientism, but... *Journal of Science Teacher Education*, 12(3), 215-233.
- Abd-El-Khalick, F., & Akerson, V. (2004). Learning as conceptual change: Factors mediating the development of pre-service elementary teachers' views of nature of science. *Science Teacher Education*, 88, 785-810.
- Abd-El-Khalick, F., & Lederman, N. (2000). Improving science teachers' conceptions of nature of science: A critical review of the literature. *International Journal of Science Education*, 22(7), 665-701.
- Abd-El-Khalick, F., Bell, R., & Lederman, N. (1998). The nature of science and instructional practice: **Making the unnatural natural.** *Science Education*, 82, 417-436.

- Achieve (2010a). What states should know about international standards in science: highlights from Achieve's analysis. US: Achieve, Inc.
- Achieve (2010b). International science benchmarking report. Taking the lead in science education: forging next generation science standards. US: Achieve, Inc.
- Akarsu, B., (2007). What are the effects of teaching experience on in-service elementary science teachers' conceptions of the nature of science? Proceedings from the Association for Science Teacher Education (ASTE) Conference, (pp. 1-15).
- Akçay, B. (2006). The analysis of how to improve student understanding of the nature of science: a role of teacher. *Asia-Pacific Forum on Science Learning and Teaching*, 7(2), 1-13.
- Akerson, V., Abd-El-Khalick, F., & Lederman, N. (2000). Influence of a reflective explicit activity-based approach on elementary teachers' conception of nature of science. *Journal of Research in Science Teaching*, 37(4), 295-317.
- Akerson, V., Cullen, T., & Hanson, D. (2009). Fostering a community of practice through a professional development program to improve elementary teachers' views of NOS and teaching practice. *Journal of Research in Science Teaching*, 46(10), 1090-1113.
- Auerbach, C., & Silverstein, L. (2003). *Qualitative data: An introduction to coding and analysis*. New York: New York University Press.
- Bell, R., Lederman, N., Abd-El-Khalick, F. (2000). Developing and acting upon one's conception of the nature of science: A follow-up study. *Journal of Research in Science Teaching*, 37(6), 563-581.
- Bianchini, J., & Solomon, E. (2003). Constructing views of science tied to issues of equity and diversity: A study of beginning science teachers. *Journal of Research in Science Teaching*, 40(1), 53-76.
- Bowen, G. (2009). Document analysis as a qualitative research method. *Qualitative Research Journal*, 9(2), 27-40.
- Bybee, R., & Champagne, A., (2000). The national science education standards. **The Science Teacher**, 67(1), 54-55.
- CHED Memorandum Order No. 30 (2004). Revised Policies and Standards for Undergraduate Teacher Education Curriculum. Retrieved April 29, 2010, from <http://www.ched.gov.ph/policies/CMO2004/CMO%2030%20S.%202004.pdf>
- CHED Memorandum Order No. 59 (1996). New General Education Curriculum. Retrieved April 29, 2010, from <http://www.ched.gov.ph/policies/index.html>
- Cochrane, B. (2003). Developing pre-service teachers' views of the nature of science: Examining the effectiveness of intervention types. Paper presented at the Annual Meeting of the Association for the Education of Teachers of Science, (Proceedings pp. 1-10).
- Coffey, A., & Atkinson, P. (1996). *Making sense of qualitative data*. Thousand Oaks: Sage.
- Collins, A., (1997). National science education standards: looking backward and forward. *The Elementary School Journal*, 97(4), 299-313.
- Creswell, J. (2008). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research*

- (3rd ed.). New Jersey: Pearson Education Inc.
- Department of Education (DepEd) (2009). Basic Education Statistics Fact Sheet. Retrieved June 16, 2010, from <http://www.deped.gov.ph/cpanel/uploads/issuancelmg/Factsheet2009%20Sept%2022.pdf>
- Department of Education (NETRC) (2013). NAT Overview and 2012 Test Results. Retrieved August 10, 2014 from <http://www.depedqc.ph/announcements/2013-NAT-GUIDELINES/2013%20NAT%20Overview%20-%20QC.pdf>
- Halai, N., & Hodson, D., (2004). Munazza's story: Shedding light on a science teacher's conceptions of the nature of science through a life history study. *Canadian Journal of Science and Technology Education*, 4(2), 193-208.
- Hanuscin, D., Akerson, V., & Phillipson-Mower, T. (2006). Integrating nature of science instruction into a physical science content course for pre-service elementary teachers. **Science Teacher Education**, 90, 912-935.
- Hipkins, R., & Barker, M. (2005). Teaching the 'nature of science': *Modest adaptations or radical reconceptions?* *International Journal of Science Education*, 27(2), 243-254.
- Holbrook, J., & Rannikmae, M. (2007). The nature of science education for *enhancing scientific literacy*. *International Journal of Science Education*, 29(11), 1347-1362.
- Jackson, K., & Trochim, W. (2002). Concept mapping as an alternative approach for the analysis of open-ended survey responses. *Organization Research Methods*, 5(4), 307-336.
- Kattoula, E., Verma, G., & Martin-Hansen, L., (2009). Fostering pre-service teachers' "nature of science" understandings in a Physics course. *Journal of College Science Teaching*, 18-26.
- Kellehear, A. (1993). The unobtrusive researcher: a guide to methods. Crow's Nest NSW: Allen and Unwin
- Koksal, M. S. (2009). An instructional design model to teach nature of science. *Asia-Pacific Forum on Science Learning and Teaching*, 10(2), 1-18.
- Krosnick, J. (1999). Survey research. *Annual Reviews Psychology*, 50, 537-567.
- Kucuk, M. (2008). Improving pre-service elementary teachers' views of the nature of science using explicit-reflective teaching in a science, technology and society course. *Australian Journal of Teacher Education*, 33(2), 16-40.
- Lederman, N. (1999). Teachers' understanding of the nature of science and classroom practice: Factors that facilitate or impede the relationship. *Journal of Research in Science Teaching*, 36(8), 916-929.
- Lederman, N., Abd-El-Khalick, F., Bell, R., & Schwartz, R. (2002). Views of the nature of science questionnaire: toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching*, 39(6), 497-521.
- Lederman, N., Schwartz, R., Abd-El-Khalick, F., & Bell, R. (2001). Pre-service teachers' understanding and teaching of nature of science: an intervention study. *Canadian Journal of Science, Mathematics & Technology Education*, 1(2), 135-160.
- Liang, J. C., Lee, M. H., & Tsai, C. C. (2010). The relations between scientific epistemological beliefs and approaches to learning science among science-major undergraduates

- in Taiwan. *The Asia-Pacific Education Researcher*, 19(1), 43-59.
- Lotter, C., Singer, J., & Godley, J. (2009). The influence of repeated teaching and reflection on pre-service teachers' views of inquiry and nature of science. *Journal of Science Teacher Education*, 20, 553-582.
- Lunn, S. (2002). What we think we can safely say: Primary teachers' views of the nature of science. *British Educational Research Journal*, 28(5), 649-672.
- Martin-Dunlop, C. (2004). Perception of the learning environment, attitudes towards science, and understanding of the nature of science among prospective elementary teachers in an innovative science course. Unpublished doctoral thesis, Curtin University of Technology, Australia.
- Mathison, S. (1988). Why triangulate? *Educational Researcher*, 17(2), 13-17.
- McDonald, C. V. (2008). Exploring the influence of science content course incorporating explicit nature of science and argumentation instruction on pre-service primary teachers' views of nature of science. Unpublished doctoral thesis, Queensland University of Technology, Australia.
- Mellado, V., Bermejo, M., Blanco, L., & Ruiz, C. (2007). The classroom practice of prospective secondary biology teacher and his conception of the nature of science and of teaching and learning science. *International Journal of Science and Mathematics Education*, 6(1), 37-62.
- Meyer, D., & Avery, L. (2009). The flow lab: a simple activity for generating NOS principles. **School Science and Mathematics**, 109(8), 484-495.
- NCES (2001). Highlights from the Third International Mathematics and Science Study-Repeat (TIMSS-R). Retrieved July 20, 2011, from <http://nces.ed.gov/pubs2001/2001027.pdf>
- NCES (2004). Highlights from the Trends in Third International Mathematics and Science Study (TIMSS) 2003. Retrieved July 20, 2011, from <http://nces.ed.gov/pubs2005/2005005.pdf>
- NSTA Board of Directors (2000). NSTA Position Statement: The Nature of Science. Retrieved April 29, 2010, from <http://www.nsta.org/about/positions/natureofscience.aspx>
- NSTA Board of Directors (2005). NSTA Position Statement. Retrieved April 29, 2010, from <http://www.nsta.org/about/positions/natureofscience.aspx>
- Ogunniyi, M., Jegede, O., Ogawa, M., Yandila, C., & Oladele, F. (1995). Nature of worldview presuppositions among science teachers in Botswana, Indonesia, Japan, Nigeria, and the Philippines. *Journal of Research in Science Teaching*, 32(8), 817-831.
- Patton, M. Q., (2002). *Qualitative Research and Evaluation Methods*. Retrieved August 12, 2011, from <http://www.google.com/books?hl=tl&lr=&id=FjBw2oi8E14C&oi=fnd&pg=PP23&dq=qualitative+research+and+evaluation+methods&ots=bum0cBNjyM&sig=Ce6rRhglpatiDkNm65wDkVSc0c#v=onepage&q&f=false>
- Posnanski, T., (2010). Developing understanding of the nature of science within the professional development program for in-service elementary teachers: Project nature of elementary science teaching. *Journal of Science Teacher Education*, 21, 589-621.
- Punch, K. (2005). Introduction to social research: Quantitative and qualitative

approaches (2nd ed.). London: Sage Publication Ltd.

- Rutledge, M. (2005). Making the nature of science relevant: Effectiveness of an activity that stresses critical thinking skills. **The American Biology Teacher**, 67(6), 329-333.
- Sahin, N., Deniz, S., & Gorgen, I. (2006). Student teachers' attitudes concerning understanding the nature of science in Turkey. *International Education Journal*, 7(1), 51-55.
- Saldaña, J. (2009). The coding manual for qualitative researchers. London: Sage
- Schwartz, R. & Lederman, N., (2002). "It's the nature of the beast": The influence of knowledge and intentions on learning and teaching nature of science. *Journal of Research in Science Teaching*, 39(3), 205-236.
- Schwartz, R., Lederman, N., Rola, K., Lederman, J., Sweeney, J., Lee, M. et al., (2002). Explicit / reflective instructional attention to nature of science and scientific inquiry: Impact on student learning. Proceedings of the Annual International Conference of the Association for the Education of Teachers in Science, (pp. 1-23).
- Shah, M. Z. (2009). Exploring the conceptions of a science teacher from Karachi about the nature of science. *Eurasia Journal of Mathematics, Science & Technology Education*, 5(3), 305-315.
- Talisayan, V., Balbin, C., & De Guzman, F. (2006). Predictors of Student Achievement in TIMSS 1999 and Philippine Results. Retrieved July 12, 2011 from http://www.google.com.ph/books?hl=en&lr=&id=moKQJZdZfc8C&oi=fnd&pg=PA225&dq=Philippines+performance+on+TIMSS&ots=bmnkNIO6hy&sig=0MzpmiepOcqridNxIhMVZGSmrj8&redir_esc=y#v=onepage&q=Philippines%20performance%20on%20TIMSS&f=false
- Tesch, R. (1990). *Qualitative research: Analytic types and software tools*. Lewis: Falmer Press.
- Thye, T. L., & Kwen, B. H. (2004). Assessing the nature of science views of Singaporean pre-service teachers. *Australian Journal of Teacher Education*, 29(2), 1-10.
- Wang, J. R. (2001). Improving elementary teachers' understanding of the nature of science and instructional practice. Paper presented at the Annual Meeting of the National Association for Research in Science teaching, (Proceedings: pp. 1-31).