The Influence of Explicit Nature of Science and Argumentation Instruction on Preservice Primary Teachers' Views of Nature of Science

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Abstract: There exists a general consensus in the science education literature around the goal of enhancing learners' views of nature of science (NOS). An extensive body of research in the field has highlighted the effectiveness of explicit NOS instructional approaches in improving learners' NOS views. Emerging research has suggested that engaging learners in argumentation may aid in the development of their NOS views, although this claim lacks empirical support. This study assessed the influence of a science content course incorporating explicit NOS and argumentation instruction on five preservice primary teachers' views of NOS using multiple sources of data including questionnaires and surveys, interviews, audio- and video-taped class sessions, and written artifacts. Results indicated that the science content course was effective in enabling four of the five participants' views of NOS to be improved. A critical analysis of the effectiveness of the various course components led to the identification of three factors that mediated the development of participants' NOS views during the intervention: (a) contextual factors (context of argumentation, mode of argumentation), (b) task-specific factors (argumentation scaffolds, epistemological probes, consideration of alternative data and explanations), and (c) personal factors (perceived previous knowledge about NOS, appreciation of the importance and utility value of NOS, durability and persistence of pre-existing beliefs). The results of this study provide evidence to support the inclusion of explicit NOS and argumentation instruction as a context for learning about NOS, and promote consideration of this instructional approach in future studies which aim to enhance learners' views of NOS.

There exists a general consensus in the science education literature around the goal of enhancing learners' views of nature of science (NOS). Indeed this goal has been documented in the literature for at least the past 85 years (Abd-El-Khalick, Bell, & Lederman, 1998), and has been the focus of numerous research efforts for over 50 years (Abd-El-Khalick & Lederman, 2000a; Lederman, 1992). Many reasons have been cited by science education researchers and reform organizations for developing learners' views of NOS, with perhaps the most fundamental reason positing that an understanding of NOS is necessary for achieving scientific literacy (American Association for the Advancement of Science (AAAS), 1990, 1993; Tytler, 2007). Although no universally agreed upon definition exists, NOS is commonly defined as the epistemology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development (Lederman, 1992). Despite the extensive amount of research conducted in the field and the prominence of this important component of scientific literacy in the reform documents, the development of informed NOS views has been shown to be a difficult goal to achieve, with many studies reporting difficulties in changing learners' NOS views (Duschl, 1990; Lederman, 1992).

Importantly, a recent line of research has highlighted the effectiveness of explicit NOS instructional approaches in improving learners' views of NOS. An explicit NOS instructional approach deliberately focuses learners' attention on various aspects of NOS during classroom instruction, discussion, and questioning. This type of instructional approach is based on the assumption that NOS instruction should be planned for and implemented in the science classroom as a central component of learning, not as an auxiliary learning outcome. Findings reported in many reviewed studies (e.g., Abd-El-Khalick & Lederman, 2000b; Hanuscin, Akerson, & Phillipson-Mower, 2006; Khishfe & Abd-El-Khalick, 2002) provide evidence of the effectiveness of explicit approaches to NOS instruction. Conversely implicit NOS instructional approaches are underpinned by the view that an understanding of NOS will result from engaging students in inquiry- based activities, without the addition of deliberately focused (explicit) NOS instruction, with results from many reviewed studies (e.g., Sandoval & Morrison, 2003; Schwartz, Lederman, & Thompson, 2001) indicating that implicit approaches are generally not successful in developing learners' NOS views. Importantly, studies continue to show that the implementation of explicit NOS instructional approaches do not result in improved NOS views for all learners (e.g., Abd-El-Khalick &

Akerson, 2004). Emerging research in the field of argumentation has provided some evidence to suggest that engaging learners in argumentation may aid in the development of more informed understandings of NOS (Bell & Linn, 2000; Ogunniyi, 2006; Yerrick, 2000).

Argumentation

The inclusion of argumentation in the curricula is an important component of contemporary science education in many countries. The ability to make informed decisions about both personal and global issues is a key component of scientific literacy explicated in reform documents worldwide, thus emphasizing the importance of engaging learners in argumentative practices (Tytler, 2007). Precise definitions of the terms ‘‘argument’’ and ‘‘argumentation’’ do not exist in the literature, although a commonly utilized definition of argument is provided by Toulmin (1958) as an assertion and its accompanying justification. Jimenez- Aleixandre and Erduran (2007) support a dual meaning of the term argument from both an individual and social perspective. From an individual perspective, argument can refer to any item of reasoned discourse, thus as an individual proposes a perspective on an issue, they can be thought of as developing an argument. From a social perspective, an argument refers to ‘‘a dispute or debate between people opposing each other with contrasting sides to an issue’’ (2007, p. 12).

An examination of previous argumentation studies conducted in the field of science education indicates students generally have poor argumentation skills, with specific difficulties such as ignoring data and warrants, introducing inferences and re-interpretations, jumping to conclusions, and an inability to evaluate counter-evidence commonly reported (e.g., Chinn & Brewer, 1998; Driver, Newton, & Osborne, 2000). Research indicates that most classrooms are teacher dominated, with students given few opportunities to learn about, or engage in argumentation, and teachers generally do not possess adequate skills to teach argumentation to their students (Newton, Driver, & Osborne, 1999). Attempts to remedy the dominance of teacher discourse in the classroom have occurred over the past 20 years (e.g., Ratcliffe, 1996; Solomon, 1992), with many researchers recommending a shift towards promoting student-oriented dialog and argumentation, and the provision of adequate training and support to enable teachers to implement effective argumentative instruction in their classrooms.

A recent line of research in argumentation focuses on the incorporation of explicit argumentation instruction (i.e., the direct teaching of various aspects of argumentation including instruction pertaining to the various definitions, structure, function, and application of arguments, and the criteria used to assess the validity of arguments) in an attempt to improve learners’ skills and / or quality of argumentation. Studies conducted in scientific contexts (e.g., Bell & Linn, 2000; Yerrick, 2000; Zohar & Nemet, 2002) have reported favorable improvements in learners’ skills and / or quality of argumentation when explicit argumentation instruction is provided. Scientific contexts for argumentation are concerned with the application of scientific reasoning to enable an understanding of the justification for hypotheses, the validity and limitations of scientific evidence, and the evaluation of competing models and theories (Giere, 1979). Interestingly, recent studies conducted in socioscientific contexts have reported improvements in learners’ skills and/or quality of argumentation without the addition of explicit argumentation instruction (e.g., Jimenez-Aleixandre & Pereiro-Munoz, 2002; Patronis, Potari, & Spiliotopoulou, 1999). These contexts for argumentation are concerned with the application of scientific ideas and reasoning to an issue, and also invoke a consideration of moral, ethical, and social concerns (Osborne, Erduran, & Simon, 2004a).

Thus, a consideration of the context of argumentation and the incorporation of explicit argumentation instruction (particularly in scientific contexts) are important factors to consider in studies which aim to develop learners’ skills and / or quality of argumentation. Importantly, ensuring learners participate in argumentation is a vital final step in the process, and a number of factors have been found to influence learners’ engagement in argumentation, including classroom culture (e.g., Kovalainen, Kumpulainen, & Vasama, 2002), and personal characteristics including a reluctance to criticize peers' ideas (e.g., Nussbaum, Hartley, Sinatra, Reynolds, & Bendixen, 2002).

NOS and Argumentation

More recently, some scholars have proposed that learners' NOS views may influence their engagement in argumentation (e.g., Nussbaum, Sinatra, & Poliquin, 2008; Sandoval & Millwood, 2007). They state that learners with less developed epistemological views may not realize claims are open to challenge and refutation, requiring the support of empirical evidence, thus limiting their participation in argumentation (Sampson & Clark, 2006). Kuhn and Reiser (2006) assert that if learners hold naïve views of scientific knowledge as a body of absolute facts, they are unlikely see the need to engage in debates about scientific issues. This assertion was first proposed by Kuhn (1992) in her seminal work on argumentation. From her study assessing 160 participants' argumentation, she proposed that naive epistemological views may influence people's engagement in argumentation, stating that people are unlikely to engage in argumentation if they do not appreciate its value. Conversely, people displaying more developed epistemological views carefully consider evidence and contrast this evidence with alternative viewpoints, using argument to verify claims. Taken together, this research indicates that improving learners' argumentation may involve developing their NOS views, and designing and implementing pedagogical practices that support and promote argumentation in the classroom.

An examination of the literature (encompassing papers published in major science education journals, e.g., Journal of Research in Science Teaching, Science Education, International Journal of Science Education; and unpublished papers presented at major science education/education conferences, e.g., NARST, AERA, ESERA; up to and including the year 2008) revealed 11 studies which have examined NOS and argumentation. One line of research explores the influence of learners' NOS views on their argumentation, and the impetus for studies in this area relates to problems with engaging learners in argumentation. A second line of research explores the influence of argumentation on learners' NOS views, and an assumption underpinning this line of research is that engaging learners in the process of argumentation may improve their understandings of NOS (refer to McDonald & McRobbie, in press, for a detailed review of these studies).

Influence of NOS Views on Argumentation

Studies examining the influence of learners' NOS views on their argumentation have been conducted in socioscientific and scientific contexts. A summary of these studies is provided in Table 1.

Research conducted in socioscientific contexts has highlighted possible links between learners' NOS views and their engagement in argumentation. Zeidler, Walker, Ackett, and Simmons (2002) found that, in a few cases, students' views of NOS were reflected in the arguments they presented on a moral and ethical issue, although many participants' responses were based on personal opinions and failed to integrate relevant scientific evidence. A similar study was conducted by Sadler, Chambers, and Zeidler (2004) with results indicating that students' views of the social NOS considerably influenced their reasoning and argumentation whilst investigating global warming. Findings from a study conducted by Walker and Zeidler (2004) reported that students' views of NOS developed over the duration of an intervention incorporating explicit NOS and argumentation instruction, although NOS was not explicitly referred to in their arguments. Conversely, Bell and Lederman (2003) investigated the role of NOS in university professors and research scientists' decision- making about socioscientific issues and found that participants' NOS views were not a significant contributing factor in the decisions reached by the participants, with reasoning patterns tending to focus on personal, social, and political aspects of the issue. Importantly, recommendations stemming from the four studies reviewed in socioscientific contexts stress the importance of providing both explicit NOS instruction and explicit argumentation instruction to aid in the development of learners' skills and / or quality of argumentation, their NOS views, and their engagement in argumentation. Although mixed results were reported with respect to the influence of learners' NOS views on their reasoning, the authors of all four studies emphasize the importance of providing guidance to learners in applying their NOS understandings to socioscientific issues.

Researchers working in scientific contexts propose that engaging learners in inquiry tasks such as constructing, developing, defending, and evaluating scientific arguments and explanations requires the application of epistemological understandings to support epistemic decisions. Sandoval and Millwood (2005) investigated high school students' selection and use of data in their scientific explanations, with results indicating that students had difficulties citing sufficient data and providing warrants for claims. Implications from this research suggest that students who display na¨ıve views of NOS may not provide explanations or warrants for their claims, thus influencing their ability to engage in scientific argumentation effectively. Findings from a more recent study conducted by the same authors (Sandoval & Millwood, 2007) with primary school students indicated that the majority of students were able to articulate claims, but most students did not warrant their claims. The authors propose that the students may not have been motivated to provide explicit evidence (in the form of warrants) as the audience for the students' written arguments was their teacher, and that their primary role was in providing the correct answer. Nussbaum et al. (2008) examined the influence of undergraduate students' epistemic beliefs, and exposure to argumentation instruction, on the quality of their arguments. Results indicated that participants with more developed epistemic views rarely displayed inconsistent reasoning, and tended to engage in more critical argumentation than participants with less developed epistemic views. The incorporation of explicit argumentation instruction was also found to improve participants' quality of argumentation. Recent research conducted by Kenyon and Reiser (2006) utilized an instructional approach where argumentation was used as a context to ‘‘create a need'' for students to apply their epistemological understandings to develop and evaluate scientific explanations. Students were asked to develop their own epistemological criteria to build and evaluate their scientific explanations, with results indicating that utilizing the epistemological criteria facilitated engagement in argumentation.

Influence of Argumentation on NOS Views

Few studies have explored the influence of argumentation on NOS views with three studies identified in the literature. A summary of these studies is provided in Table 2.

Yerrick (2000) assessed changes in high school students' abilities to construct arguments within scientific contexts, with results indicating that students' views of some aspects of NOS developed over the duration of the study. These aspects of NOS were also reflected in their arguments, with some improvements in their skills of argument also evident. The results of this study provide some support for the notion that engaging students in scientific argument and inquiry may result in improvements in their views of some aspects of NOS, although this was not a specific aim of the study. Similarly, Bell and Linn (2000) assessed middle school students' argument constructions during a Knowledge Integration Environment (KIE) debate project, with results indicating that more complex arguments were constructed by students with more informed views of NOS. Other findings indicated that students' NOS views and skills of argumentation improved over the duration of the study. Interestingly, although neither of these studies incorporated explicit NOS instruction, participants' views of NOS improved over the duration of the studies. These findings suggest that developing learners' NOS views may not require the integration of explicit NOS instruction in scientific contexts where explicit argumentation instruction is provided. As this assertion is contrary to a large body of research in the field of NOS that supports the notion that explicit NOS instruction is necessary to aid in developing learners' views of NOS, further studies are needed to provide empirical evidence to support or refute this claim. A recent study by Ogunniyi (2006) examined the effectiveness of an argumentation-based, NOS course on inservice science teachers' views of NOS. In contrast to the previous two studies conducted in scientific contexts, this study was situated in a historical context emphasizing the historical, philosophical, and sociological aspects of science. Preliminary results indicated an improvement in teachers' views of NOS, with the author concluding that this improvement provides evidence of the effectiveness of a course emphasizing explicit argumentation instruction, and a consideration of historical, philosophical, and sociological aspects of science.

Summary and Aim of the Study

Implications drawn from the small body of research exploring NOS and argumentation highlight the following five premises: (1) learners' NOS views influence their engagement in argumentation in scientific contexts (mixed findings reported in socioscientific contexts); (2) the provision of explicit NOS instruction and explicit argumentation instruction is recommended to aid in the development of learners' skills and / or quality of argumentation, their NOS views, and their engagement in argumentation; (3) guidance is needed to ensure learners recognize the relevancy and application of NOS views to their arguments via appropriate pedagogical strategies; (4) engaging learners in scientific argumentation may improve their NOS views without the addition of explicit NOS instruction; and (5) engaging learners in explicit argumentation instruction and explicit NOS instruction leads to improvements in their NOS views.

A consideration of these findings informed the design of the present study. As stated earlier, improving learners' NOS views via an explicit NOS instructional approach enjoys widespread empirical support in the field of science education (although this approach is not fail safe). Emerging research presented in the previous section suggests that engaging learners in argumentation and / or the incorporation of explicit argumentation instruction, may lead to improvements in their NOS views, although this claim lacks strong empirical support. Thus, this exploratory study sought to incorporate both explicit NOS instruction AND explicit argumentation instruction in the learning environment with the aim of maximizing opportunities for developing learners' NOS views. Learners must also be provided with opportunities to engage in argumentation and guidance in applying their NOS views to their arguments via appropriate pedagogical strategies. They also need to recognize the relevancy of these views to ensure that the arguments they develop are informed by epistemological considerations. Thus, this study will also seek to identify effective pedagogical strategies to promote engagement in argumentation, and the application of learners' NOS views to their arguments.

Specifically, this study explored the influence of a science content course incorporating explicit NOS and argumentation instruction on preservice primary teachers' views of NOS. Eight aspects of NOS were examined in this study: (1) the empirical NOS, (2) the methods of science, (3) the functions and relationships of theories and laws, (4) the tentative NOS, (5) the inferential and theoretical NOS, (6) the subjective and theory-laden NOS, (7) the social and cultural NOS, and (8) the creative and imaginative NOS. The research questions guiding this study were: (1a) What are preservice primary teachers' initial views of the examined aspects of NOS? (1b) How do their views of these aspects of NOS change over the course of the intervention? (2) What is the influence of the various course components implemented during the study, on preservice primary teachers' views of the examined aspects of NOS? (3) What factors mediated the development of preservice primary teachers' views of the examined aspects of NOS?

Method

A constructivist perspective (Denzin & Lincoln, 2000) was chosen to guide this study to enable an in- depth investigation to take place, and to provide rich descriptions of the study's findings using a variety of qualitative methods including questionnaires, surveys, interviews, audio- and video-taped class sessions, and written artifacts.

Validity and Ethical Considerations: The Perspective and Role of the Researcher

A constructivist perspective recognizes that a researcher's beliefs and ideologies influence all aspects of the research process, from the design of the research questions, through to the interpretations that are drawn from the analysis of data. As such, the researcher must ensure that any biases he / she holds are made explicit to the readers of the written study. As stated earlier, an underlying assumption guiding this study was that the incorporation of both explicit argumentation instruction and explicit NOS instruction in the learning environment would maximize opportunities for developing learners' NOS views. Importantly, I recognized that this was an empirically untested assumption, and although this assumption provided an empirical and methodological framework for the study, I sought to identify and explore the possible inter-relationships between NOS and argumentation. I did not make participants explicitly aware of this underlying assumption during the study, but did explicitly emphasize the importance of developing informed understandings of NOS, and developing skills of argumentation during the study.

It is also vitally important to describe the role of the researcher to enable readers of the study to understand the relationship between the researcher and the participants. Constructivist researchers recognize that it is not possible to eliminate the influence of the researcher, and instead aim to understand and document this influence. It is particularly important to describe my role in the present study as I designed and implemented all major phases of the study. I conducted all interviews with participants, and was the course lecturer in the classroom intervention phase of the study. I also marked and graded participants' assessment items in the course. These factors all raise validity issues for the study.

A number of techniques were implemented to allow the adequacy of this study to be ascertained, including the application of trustworthiness criteria (Guba & Lincoln, 1989), and methodological triangulation protocols (Denzin, 1984). For example, prolonged engagement was achieved by engaging in a substantial involvement in the setting in which the study was based, to ensure a sense of rapport and trust was established with participants. This involvement allowed me to gain a greater appreciation of the culture of the context, and minimized any possible distortion of information from the study's participants. Rapport was well established, as contact with both the context site and its participants, was frequent and substantial. Peer debriefing with two science educators was utilized to ensure that the results and analyses of the study were clarified and viewed through multiple perspectives. This process enabled any biases in the reporting of the study to be identified and re-evaluated. Thick description was also used in the reporting of the study to allow the reader to make their own transferability judgments about the study. A dependability audit was incorporated that allowed the implementation of the study to be tracked and evaluated by outside parties. Importantly, confirmability was established by ensuring that constructions emerging during the study were able to be traced back to their original sources. Classroom discourse and interviews were fully transcribed, and results of the study incorporated verbatim quotes from participants' transcripts, in addition to my interpretations of this discourse. The employment of methodological triangulation protocols via multiple methods and multiple data sources maximized opportunities to identify possible influences on the data, thus increasing confidence in the validity of the study.

In addition, there is a recognition that the role of the researcher as ''data collector'' presents some validity issues. Fontana and Frey (1998, p. 646) state ''increasingly, qualitative researchers are realizing that interviews are not neutral tools of data gathering but active interactions between two (or more) people leading to negotiated, contextually based results.'' This is an important point, although it should be stressed that the initial interview was conducted before the commencement of the main intervention, and the final interview was conducted after the assessment for the course had been marked and graded. These measures were taken to minimize the influence of my perspectives on the participants' interview discourse.

Participants

This study was conducted with preservice primary teachers enrolled in a science content course conducted at a large urban university in Queensland, Australia. The majority of the preservice teachers entered the course having studied science to upper secondary levels with varying degrees of success, and were predominantly of Caucasian descent, and middle class socioeconomic status. Sixteen of the 17 preservice teachers enrolled in the course consented to participate in the study. Five of these 16 preservice teachers were purposively selected for intensive investigation, and became participants in the present study. The following criteria were utilized to select the five participants: (1) completion of all data collection task requirements in the study, (2) regular class attendance, (3) freely availed themselves for interviews and informal discussions, and (4) fully participated in all classroom activities. As such, rich information was able to be obtained from these participants to aid in addressing the research questions guiding this study, although it is important to note that the results of this study are applicable to the five participants selected for investigation in this study. Profiles of the five participants are outlined in Table 3.

The remaining 11 preservice teachers completed the majority of the interviews, questionnaires, and classroom tasks implemented as possible sources of data in the study, although all of these 11 preservice teachers failed to complete one or more of the data collection tasks implemented in the study. As such a complete data set was unable to be obtained from these preservice teachers.

Context

The science content course is one of a set of three science electives recommended for preservice primary teachers who wish to specialize in science teaching at the end of their degrees. The course teaches basic chemistry concepts and was designed with the underlying assumption that preservice teachers entering the course would generally possess limited conceptual knowledge of chemistry. Classes were held weekly in 3-hour sessions, and covered an 11-week teaching period. Each teaching session generally consisted of a theory section addressing basic chemistry concepts, and an inquiry-based section that allowed participants to apply and develop their evolving conceptual knowledge. In addition to these sections, a set of six course components were specifically embedded in the course to provide opportunities for developing participants' NOS views, and their skills of argumentation; and to provide opportunities for participants to engage in argumentation and apply their views of NOS to their arguments: (a) explicit NOS instruction, (b) explicit argumentation instruction, (c) argumentation scenarios, (d) global warming task, (e) superconductors survey, and (f) laboratory project. It is important to note that participants did not necessarily engage in argumentation during the implementation of all of these course components, nor did they engage in explicit NOS instruction during the implementation of all of the course components. An overview of the specific focus and details of each individual course component is provided in the following subsections (refer to McDonald, 2008 for further details). It is also important to note that some of these course components have been utilized as assessment tools in previous studies (e.g., global warming task, Sadler et al., 2004; superconductors survey, Leach, Millar, Ryder, & Sere, 2000; Ryder & Leach, 2000). The rationale for their inclusion in this study was to provide opportunities for participants to develop and apply their skills of argumentation in differing contexts, in addition to assessing their views of specific NOS aspects. As such, these components were utilized as both assessment and intervention tasks.

Explicit NOS Instruction. Participants were engaged in explicit NOS instruction during both inquiry- based classroom sessions and theory-based classroom sessions. The eight examined NOS aspects were introduced, discussed, and reflected upon, at contextually relevant stages throughout the intervention. This embedding of NOS aspects within relevant science content during the intervention was designed to enable participants to examine and link their views of NOS to specific science conceptual ideas discussed in the course, thus allowing contextualized NOS instruction to occur. Relevant examples from the history of science (HOS) were also discussed during the intervention. Similar to Khishfe and Abd-El-Khalick (2002), I sought to implement an instructional approach which ''emphasizes student awareness of certain NOS aspects in relation to the science-based activities in which they are engaged, and student reflection on these activities from within a framework comprising these NOS aspects'' (p. 555). This section will detail some episodes of planned explicit NOS instruction that took place during weekly class sessions. Importantly, many informal, unplanned opportunities for explicit NOS instruction also occurred during class sessions, due to the contextualized nature of the course.

In the first teaching week participants took part in a practical activity designed to allow them to experience observing and theorizing about the solubility and behavior of a group of inorganic substances. During a whole class discussion of why some groups had differing results, the distinction between observations and inferences was emphasized, with groups encouraged to re-examine their results after considering this information. Another whole class discussion was then conducted where participants were explicitly engaged in discourse centered on the subjective and theory-laden NOS, and the social and cultural NOS, which stressed that the results of experiments are subject to interpretation and are influenced by a scientist's background and experiences. Participants completed a practical activity exploring some of the principles of separation in the second teaching week. In a whole class discussion held at the end of the activity, participants were engaged in discourse focused on the notion of the ‘‘scientific method,’’ and were prompted to consider whether experiments always followed a strict, stepwise procedure. Stimulus material was used as a springboard for a class discussion about the methods of scientific investigation, and participants were asked to reflect on their views on the processes of scientific experimentation after a consideration of this information. During this whole class discussion, participants were asked to consider their understandings of the concepts of hypothesis, theory, and law. In particular, participants were prompted to consider whether laws are absolute. After proposing their views about scientific laws, participants were explicitly engaged in discourse centered on the tentative nature of all scientific knowledge, which emphasized that theories and laws are subject to revision over time. At the end of this teaching session, a general introduction to the various aspects of NOS to be explored in the course was shared with participants, where the eight target aspects of NOS were introduced and briefly discussed. The purpose of this introduction was to enable participants to situate their developing understandings of the various aspects of NOS examined in the course, into the wider context of the scientific enterprise.

In another teaching session conducted towards the middle of semester, participants were engaged in concept development about atoms and molecules. General properties and structures of atoms, molecules, elements, and compounds were taught in this session, and a discussion about the history of atomic theory also took place. During this session participants were explicitly engaged in discourse centered on the creative and imaginative NOS, and inferential and theoretical nature of atomic structure, as participants were introduced to the notion that an atom is a model created by scientists to explain the behavior of certain substances. Participants were provided with an overview of the various models of atoms developed over time, and asked to consider why the models had changed. After proposing their views about atomic models, participants were explicitly engaged in discourse highlighting the tentative NOS, emphasizing that each interpretation was an attempt to provide the best possible explanation of the theory based on the experimental evidence available at the time. In summary, the discussion of the history of atomic theory introduced and re-emphasized the notions of the tentative NOS, the creative and imaginative NOS, the inferential and theoretical NOS, and an understanding of scientific theories.

The historical development of the periodic table was introduced towards the end of semester. During a whole class discussion focusing on the gaps in the periodic table where Mendeleev hypothesized elements existed but had yet to be discovered by scientists, I highlighted how these elements were later discovered but some of them did not fit with the original groupings. Participants were asked to consider possible solutions to the problem, and to discuss their ideas in small groups. After putting forward their ideas in a whole class discussion, participants were explicitly engaged in discourse focusing on the nature of scientific laws and the difference between theories and laws after considering that Mendeleev had to change his original ideas about the structure of the periodic table to accommodate these discrepancies. The discovery of new synthetic elements that are continually being added to the periodic table was used as a springboard for discussion at the end of the session, using the example of American and Russian scientists who had both discovered and individually named element 104. During this discussion participants were explicitly engaged in discourse focusing on the social and cultural NOS, subjective and theory-laden NOS, and tentative NOS. In addition to participating in explicit NOS instructional activities during classroom sessions, participants were provided with opportunities to apply their evolving views of NOS to their arguments during the implementation of the argumentation scenarios (discussed later in this section).

Explicit Argumentation Instruction. Argumentation instruction was explicitly implemented during classroom teaching sessions by incorporating teaching materials developed from the Ideas, Evidence and Argument in Science (IDEAS) Project (Osborne, Erduran, & Simon, 2004b). These materials were specifically designed to support the teaching of ideas, evidence, and argument in school science education, and placed a primary emphasis on the development of scientific reasoning. This section will detail some episodes of explicit argumentation instruction that took place during weekly class sessions. For example, in an early teaching session participants were engaged in an activity highlighting the importance of evaluating sources and quality of evidence. Examples of primary sources of data, such as peer-reviewed academic journals were contrasted with secondary or tertiary sources of data, such as popular culture magazines, and many Internet sites and articles. In another teaching session the importance of considering counterarguments was discussed, with the difference between counterclaims and counter-arguments highlighted. ‘‘Writing frames’’ (Osborne et al., 2004b) were also introduced to enable participants to practice structuring their arguments more effectively. In a later teaching session, Toulmin’s (1958) model of argument was introduced, and a class discussion was held to explore the various aspects of the model, including claims, data, warrants, qualifiers, backings, and rebuttals. This model of argumentation was introduced as it is a widely utilized model in science education used to examine the structure of an argument, and a useful starting point for introducing learners to the components of arguments. Participants were then introduced to a multi-level framework for evaluating the quality of arguments (Osborne et al., 2004a), and engaged in a teaching session where they attempted to apply the framework to a sample argument. Participants were provided with opportunities to practice their evolving skills of argumentation introduced during these explicit argumentation sessions, and also whilst engaging in the argumentation scenarios discussed in the following section.

Argumentation Scenarios. Participants engaged in a set of five argumentation scenarios during the intervention. The rationale for the inclusion of the argumentation scenarios was to provide opportunities for participants to engage in argumentation, practice their skills of argumentation, and apply their evolving views of NOS to their arguments during the implementation of the scenarios. The argumentation scenarios utilized written and verbal prompts to encourage participants to engage in argumentation, but did not utilize written or verbal prompts to orient participants’ attention to relevant NOS aspects applicable to the scenarios. Two of these argumentation scenarios were situated in scientific contexts, and three of the scenarios were situated in socioscientific contexts. Originally, a third scientific argumentation scenario was to be included but due to unforseen time constraints, this scenario was not incorporated in the class sessions.

The two scientific argumentation scenarios were sourced from the ‘‘IDEAS’’ curriculum materials (Osborne et al., 2004b) are were contextually linked to relevant scientific concepts addressed in the course. The first scenario ‘‘Mixtures, Elements, and Compounds’’ implemented in the second week of teaching coincided with the teaching of properties of matter. The scenario investigated various scientific concepts related to elements, mixtures, and compounds, and participants were required to work in groups to provide evidence for a set of statements, and to construct arguments and counterarguments to support their statements. Relevant aspects of NOS applicable to this scenario included the empirical NOS, and the subjective and theory-laden NOS. The second scenario ‘‘Snowmen’’ implemented in the fifth week of teaching was linked to scientific concepts concerning heat transfer. The aim of the scenario was to generate scientific argument around competing theories of what will happen to two snowmen, one who is wearing a coat, and another who is not wearing a coat. Participants were asked to predict which snowman would melt first, and were required to work in groups to construct written arguments using writing frames to support one of the claims, and counter the other claim. Relevant aspects of NOS applicable to this scenario included the empirical NOS, subjective and theory-laden NOS, and creative and imaginative NOS.

The three socioscientific scenarios were sourced from a set of four scenarios, and associated questions developed by Bell and Lederman (2003). The Decision Making Questionnaire ‘‘DMQ’’ was designed to obtain information about participants’ reasoning in a variety of socioscientific contexts, and the scenarios were contextually linked to relevant scientific concepts addressed in the course. The first scenario ‘‘Diet, exercise, and cancer’’ was implemented in the fourth week of teaching. Participants worked in groups and practiced constructing arguments and counterarguments focused on the possible role of diet in initiating cancer, and the potential benefits of exercise in reducing the risk of cancer. The second scenario ‘‘Cigarette smoking and cancer’’ was implemented towards the end of the intervention and coincided with the teaching of organic chemistry, with a focus on the organic compounds in cigarettes. The scenario provides evidence to support a positive relationship between smoking and cancer, and participants were required to work in groups to develop arguments and counterarguments in relation to this scenario, and to identify the various components of argumentation utilized in Toulmin's framework. The final scenario ''Fetal tissue transplantation'' was implemented at the end of the intervention and was conceptually linked to a discussion of drugs and medicines. The scenario is concerned with an experimental operation that utilizes fetal tissue to treat Parkinson's disease. Groups of participants were asked to develop arguments and counterarguments in relation to this scenario, and were also asked to evaluate the arguments they created by utilizing a framework created by Osborne et al. (2004a). Relevant aspects of NOS applicable to the socioscientific scenarios included the empirical NOS, tentative NOS, subjective and theory-laden NOS, social and cultural NOS, and creative and imaginative NOS.

Global Warming Task. The global warming task was implemented towards the end of the intervention with the aim of aiding the development of participants' views of NOS; providing opportunities for participants to develop and apply their skills of argumentation in a socioscientific context; providing opportunities for participants to apply their views of NOS to their reasoning about the task; and enabling a comparison of participants' views of two specific NOS aspects in socioscientific contexts, to their views of these aspects of NOS expressed in the Views of Nature of Science Questionnaire ''VNOS-C'' (Abd-El- Khalick, 1998). The global warming task consisted of two inter-related parts, the global warming survey and the global warming essay. The global warming survey was distributed to participants at the beginning of the intervention. The survey was accompanied by two ''science briefs'' developed by Sadler et al. (2004) on the issue of global warming, and had previously been used to investigate high school students' views of NOS in response to a socioscientific issue. The science briefs detail fictitious accounts based on the views of two groups of environmental scientists holding opposing views on the issue of global warming. Participants were required to read both science briefs, and then respond to five open-ended questions designed to elicit their views of data use and interpretation, social and cultural influences on the development of scientific ideas, the subjective and theory-laden nature of scientific ideas, and the factors that influenced their reasoning on the issue. Thus, the global warming survey utilized written prompts to orient participants' attention to relevant NOS aspects applicable to the scenarios.

Participants were required to conduct research about global warming, and align themselves with one of the two science briefs. Written and verbal prompts were used to encourage participants to engage in argumentation. They were required to collect supporting evidence for their position, as well as providing counterarguments to rebut the position held by the other group of scientists, and present this information in a written essay. Participants also presented their arguments in a seminar format towards the end of the intervention, and were required to critique the two position statements in their presentations by addressing the five open-ended survey questions. Information obtained from the global warming task provided evidence to aid in addressing the second research question.

Superconductors Survey. The superconductors survey was implemented in the study to provide opportunities for participants to apply their understandings of aspects of NOS to their reasoning in a scientific context. The survey enabled an assessment of participants' views of the examined NOS aspects to be determined at the commencement and conclusion of the study, and findings from this assessment enabled changes in participants' views of the examined aspects of NOS to be ascertained. The survey also allowed a comparison of participants' views of NOS as expressed in the superconductors survey (scientific context), to their views of similar aspects of NOS expressed in the VNOS-C. Participants provided written responses to the survey during the pre- and post-intervention phases of the study, and also took part in follow-up interviews to clarify and further probe their responses.

The superconductors survey was sourced from a larger survey designed to investigate students' views about science, and was originally implemented in a comprehensive study that examined the role of lab-work in science across several European countries (Leach et al., 2000). In the survey, participants are presented with a data interpretation context in which theoretical models have a central role, and detail a fictitious conference where groups of scientists are investigating different models to explain the changes in the electrical resistance of a superconductor. Participants are required to demonstrate their understanding of the role of data and theoretical models in the interpretation of the data by responding to various questions (Ryder & Leach, 2000). The survey did not require conceptual or technical knowledge of the topic, therefore allowing participants to make judgments about the models presented on the basis of the information contained in the survey alone. Information obtained from the survey provided evidence to aid in addressing the second research question.

Laboratory Project. The laboratory project was implemented in the study to provide opportunities for participants to develop and apply their skills of argumentation in a scientific context, and also apply their understandings of NOS to their reasoning about the task. Participants were required to design and implement an inquiry-based laboratory project concerned with determining the most efficient substance for melting ice. The laboratory project was an adaptation of a science fair project by Bochinski (1991), originally designed for middle and high school students. In this study the original idea was modified and presented as an open-ended problem for participants to attempt to solve (refer to the Appendix for further details) and participants were required to work in groups to plan and conduct their experiments, and analyze their findings. They were also required to collect data, justify the use of their data, and deal with the ambiguity of their data during analysis. The project was designed to allow participants to research and test a range of chemicals to determine the most suitable chemical to solve the problem, thus providing a context for participants to engage in scientific argumentation by evaluating information, providing justifications for their choices, and offering rebuttals and counterarguments. It is important to note that the project did not utilize written or verbal prompts to encourage participants to engage in argumentation, nor did it utilize written or verbal prompts to orient participants' attention to relevant NOS aspects applicable to the project. Relevant aspects of NOS applicable to the project included the empirical NOS, methods of science, inferential and theoretical NOS, subjective and theory- laden NOS, social and cultural NOS, and creative and imaginative NOS.

Groups carried out their laboratory projects over a 4-week period towards the end of semester. In the final week of teaching each group informally reported their findings to the class, and groups were then required to present their findings in a written laboratory report. Information obtained from the written laboratory report provided evidence to aid in addressing the second research question.

Data Sources

I utilized four sources of data to provide evidence to address the research questions guiding this study: questionnaires and surveys, interviews, audio- and video-taped class sessions, and written artifacts.

Questionnaires and Surveys. Participants completed the VNOS-C, global warming survey, and superconductors survey. The global warming survey and superconductors survey were discussed in the previous section.

VIEWS OF NATURE OF SCIENCE QUESTIONNAIRE (VNOS-C). The ''VNOS-C'' (Abd-El-Khalick, 1998) and associated semi-structured interviews were utilized to assess participants' NOS views, and to provide information to aid in addressing the first research question. I administered the VNOS-C during the pre-intervention and post-intervention phases of the study, with follow-up interviews also being conducted at these times. The VNOS-C took approximately 30–45 minutes to complete, and after the administration of the written questionnaire, I individually interviewed all participants to clarify their responses to the questionnaire items. The interview schedule developed by Abd-El-Khalick (1998) was often utilized to clarify any ambiguities present in their written responses and also probe and explore relevant meanings and findings. The follow-up interviews took approximately 30 minutes to complete, and all interviews were audio-taped and fully transcribed for analysis.

Interviews. Participants took part in an initial and final interview. The initial interview was conducted at the commencement of the study, where I sought background information from the participants regarding their previous science education and experience, their feelings about science, any previous exposure to NOS or argumentation instruction, and general demographical information (e.g., age, socioeconomic background, gender, etc.). Participants were also interviewed about their responses to the pre-intervention VNOS-C, and the pre-intervention superconductors survey at this time. At the conclusion of the study, I conducted a final interview with the participants designed to provide an overview of the learning that occurred throughout the course. The final interview was semi-structured, and consisted of 16 questions designed to provide information about participants' perceptions of the course including: whether they felt they had learnt about NOS and argumentation, whether they found learning about NOS and argumentation useful, whether they could refer to specific instances in the course where they learnt about NOS and argumentation, and whether they could provide a definition or explanation of NOS or argumentation. Participants were also interviewed about their responses to the post-intervention VNOS-C, and the post-intervention superconductors survey during the final interview. Information obtained from the initial and final interviews provided evidence to aid in addressing the first and second research questions.

Audio- and Video-Taped Class Sessions. All weekly classroom teaching sessions conducted during the intervention were audio- and / or video-taped. Participants' engagement in explicit NOS instruction, explicit argumentation instruction, the argumentation scenarios, and the oral presentation of the global warming survey provided information about the effectiveness of the various course components implemented during the study, thus aiding in addressing the second research question.

Written Artifacts. Two written artifacts were examined in this study, the global warming essay and written laboratory project. Information obtained from the written artifacts provided evidence to aid in addressing the second research question. Details of these artifacts were discussed in the previous section.

Data Analysis

Data analysis was conducted at the conclusion of the study. As discussed earlier, a variety of validity and ethical protocols were considered during the analysis to ensure the findings and interpretations emerging from the data were valid.

Questionnaires and Surveys

VNOS-C. The first stage of analyzing the VNOS-C involved generating separate NOS profiles from each participant's questionnaire and interview data, and comparing these two data sources to ensure the views expressed in each source were comparable. This initial analysis indicated that the two sources were indeed comparable, and a single NOS profile was developed for each participant. Many previous studies that have implemented the VNOS-C have coded participants' responses to the questionnaire as either naïve or informed. Initial data analysis uncovered some difficulties in coding participants' responses into two distinct categories, as many of the responses indicated intermediate positions. Four categories of response were developed in this study to enable a detailed, differential classification of participants' views of the examined NOS aspects. These categories were modified from the original descriptions and elaborations of each NOS aspect developed by Abd-El-Khalick (1998). It is important to note that other researchers (e.g., Abd-El- Khalick & Akerson, 2004; Khishfe, 2008) have utilized similar terms for coding participants' NOS views with subtle differences in emphasis. Participants' views of the examined aspects of NOS in this study were coded on a continuum, as either naïve, limited, partially informed, or informed; where naive or limited views of NOS represented less desirable understandings, and partially informed or informed views of NOS represented more desirable understandings. Full details of the coding for each of the examined NOS aspects are provided in McDonald (2008). A sample of the data generated from the VNOS-C (50%) was also coded by an experienced science educator who had previous experience in NOS research, to assess the reliability of the coding scheme. After discussions of the generated codes, consensus was reached across all examined NOS aspects. Eight broad aspects of NOS (empirical, methods of science, theories and laws, tentative, inferential, subjective and theory-laden, social and cultural, and creative and imaginative) were assessed in this study, with some aspects comprising one or more sub-aspects. Participants' responses to the VNOS-C questionnaire and follow-up interview were coded under each of these eight aspects of NOS at both the pre-intervention and post-intervention phases of the study. Participants' NOS profiles generated at these stages were then able to be compared to allow an assessment of the possible development of their NOS views over the duration of the intervention.

GLOBAL WARMING SURVEY. Two of the five questions on the global warming survey were selected for data analysis as they provided information about participants' views of the social and cultural NOS [Question 2— Do societal factors (issues not directly related to science) influence either position? If so, describe how these factors influence each argument? If not, describe why these factors would not influence each argument], and the subjective and theory-laden NOS [Question 3— Why do the two articles, which are both written by scientists discussing the same material, have such different conclusions?]. As these aspects of NOS were part of the set of eight aspects chosen for examination in this study (as assessed by the VNOS-C), information obtained from participants' responses to these items enabled a comparison of their views of these aspects of NOS in the global warming survey (socioscientific context) to their views of these aspects of NOS as expressed in the VNOS-C. Participants' views of the two examined aspects of NOS were coded on a continuum, as either naïve, limited, partially informed, or informed; utilizing the same coding scheme developed to analyze participants' VNOS-C responses. This first stage of data analysis enabled an assessment of participants' views of the social and cultural NOS, and the subjective and theory-laden NOS, as expressed in the global warming survey, to be ascertained. The second stage of data analysis involved comparing participants' views of these aspects of NOS, to their views of the same aspects of NOS, as expressed in the VNOS-C.

SUPERCONDUCTORS SURVEY. Initial data analysis involved comparing participants' written responses to the survey questions to their oral responses expressed in the follow-up interviews. Previous studies that have utilized this survey (Leach et al., 2000; Ryder & Leach, 2000) found that participants' written responses often did not correlate with their oral responses. In this study, transcripts of discourse from the follow-up interviews were compared with participants' written responses, and where discrepancies arose between the two data sources, the interview data were taken to be the more accurate interpretation of the participants' position. A profile of participants' expressed views of NOS in response to the superconductors survey was generated at both the pre-intervention and post-intervention phases of the study. Following the coding scheme developed by Ryder and Leach (2000), participants' responses to each of the three sections of the survey were coded as data focused views, model focused views, or relativist focused views. In this study, participants who exhibited predominantly data focused views across the three sections of the survey represented less desirable understandings of NOS, and participants who exhibited predominantly model focused or relativist focused views across the three sections of the survey represented more desirable understandings of NOS. Descriptions of these views of NOS are provided in Table 4.

A sample of the data generated from the survey (50%) was also coded by an experienced science educator who had previous experience in NOS research, to assess the reliability of the coding scheme. After discussions of the generated codes, consensus was reached across all examined aspects. Coded responses to each of the three sections of the survey were amalgamated to provide an assessment of each participants overall view of NOS. A comparison of participant's pre- and post-intervention views of the examined aspects of NOS enabled an assessment of the development (or lack thereof) of participants' views of the examined NOS aspects over the duration of the study. Participants' views of the examined NOS aspects as assessed by the superconductors survey were then compared to their views of similar aspects of NOS as expressed on the VNOS-C. The empirical NOS and the subjective and theory-laden NOS were identified as similar aspects of NOS across both instruments, and participants' views of NOS as assessed by the superconductors survey were compared to their views of the empirical NOS, and the subjective and theory-laden NOS as assessed by the VNOS-C. It is important to note that the use of different coding schemes across these two instruments limits a direct comparison of views of NOS, although it does allow an assessment of general trends in NOS views across contexts.

Interviews. Participants' responses to the initial and final interview questions were fully transcribed for analysis. These transcripts provided evidence of participants' self-perceptions of the course, and provided important information regarding perceived changes in their views, and the attributions for these changes.

Audio- and Video-Taped Class Sessions. Audio- and video-recordings of weekly classroom teaching sessions conducted during the intervention were fully transcribed for analysis. Transcripts of participants' engagement in explicit NOS instruction, explicit argumentation instruction, the argumentation scenarios, and the oral presentation of the global warming survey were searched for evidence of engagement in argumentation, and explicit reference to the examined NOS aspects. Any identified NOS aspects were highlighted and compared to participants' views of NOS as assessed by the VNOS-C. Identified instances of engagement in oral argumentation were searched for explicit references to NOS aspects in participants' discourse.

Written Artifacts. Participants' global warming essays and written laboratory projects were searched for explicit references to the examined NOS aspects, and evidence of engagement in argumentation (an analysis of the quality of participants' written argumentation is provided in McDonald, 2009). Any identified NOS aspects were highlighted and compared to participants' views of NOS as assessed by the VNOS-C.

Results

Research Question 1: Views of NOS

A summary of individual participants' pre- and post-intervention views of each of the examined NOS aspects is provided in Table 5 (further details are provided in McDonald, 2008).

All of the participants expressed naive or limited views of six or more of the eight examined NOS aspects at the commencement of the study. Many positive changes were evident in participants' NOS views at the end of the study, with four of the five participants' views of NOS developing from predominantly naive or limited understandings of NOS, to predominantly partially informed or informed understandings of NOS over the duration of the intervention. Rachel and Monica exhibited development in six of the eight examined aspects, and Tom and Sarah showed development in five of the eight examined aspects. Participants' views of the subjective and theory-laden NOS, the social and cultural NOS, and the creative and imaginative NOS improved substantially over the duration of the intervention, although little development was evident in participants' views of theories and laws. David failed to exhibit substantial development in any of the examined NOS aspects and continued to express naïve or limited views of all eight examined NOS aspects at the conclusion of the study.

Trends in the Data

Alignment of NOS Views Between VNOS-C and Interview Transcripts. An examination of participants' definitions of NOS expressed in the final interview corresponded positively to the aspects of NOS that developed most substantially as assessed by the VNOS-C. When asked to describe or define NOS in their own words, all of the participants made reference to either the subjective and theory-laden NOS, and/or the social and cultural NOS, in their responses. An interesting response was given by David when asked to define or describe NOS in his own words:

> Long pause (laughs) Aspects? What's an example of the NOS? That's a bit over my head, that one.
> . . . To me, the characteristics that describe what science is. The NOS is the characteristics of science and all that it encompasses. . . . Long pause . . . Social ramifications, ethical implications, commercial applications, theological connections. (Final interview)

David's lack of ability to articulate his own definition of NOS, without prompts, is evident in the above quote. This is not an unexpected finding as David's views of the examined NOS aspects as assessed by the VNOS-C showed no overall development, remaining largely limited at the conclusion of the study.

Impact of Perceived Previous Knowledge about NOS. During the final interview participants were asked whether they had learnt about NOS during the course. Tom stated that he had ''not so much learned, a lot was refreshed on what's been brought up to me in the past'' (Final interview) at the beginning of the final interview, attributing his understanding of NOS to his previous science studies and work experience. Interestingly, his confidence in his pre-existing ideas about NOS was mediated towards the end of the final interview when he was asked whether his view of NOS had changed from the beginning of the course:
''Oh, it's changed a little bit, I think I've learnt something, yeah. It was hard, when I was writing, to put a pinpoint on it'' (Final interview). An examination of David and Sarah's initial interview transcripts revealed that David and Sarah expressed that they had not heard of NOS before, although in their final interviews they provided responses to the contrary. In the final interview, David expressed that he already knew about NOS and nothing in the course was an introduction of a new idea or aspect. Sarah stated that she already knew about many of the aspects of NOS introduced in the course, but did mediate this response in the final interview by noting that she had learnt additional information about NOS in the course. Conversely, Rachel and Monica expressed that they had ''definitely'' learnt about NOS during the course.

Recognition of the Importance or Usefulness of NOS. All of the participants cited that they had enjoyed learning about NOS in the final interview. Rachel, Monica, Tom, and Sarah stated that the inclusion of NOS and argumentation enhanced the learning of the other course content, whereas David expressed uncertainty:

> Didn't take away from it, pause, I don't know whether it enhanced it for me, but I learnt a lot. And I liked what I learnt. So, I suppose it put a different slant on science for me, because I thought science was basically what you did at high school, and that those deep and meaningful discussions that we had just made it more interesting and put a different slant on what could otherwise be a dry subject. (Final interview)

When David was asked whether he would have enjoyed the course more with or without the inclusion of NOS and argumentation, he commented: ''Oh, definitely not. I would much prefer the way we did it. If you would have done the chalk and talk on atoms and all that it would have been more difficult for you and less enjoyable for us'' (Final interview). Thus, although he enjoyed learning about NOS, he did not fully recognize the importance or utility value of learning about NOS. Sarah also expressed uncertainty when asked whether she would have enjoyed the course more or less with or without the inclusion of NOS and argumentation:
''probably less because I think you do need to have it in there somewhere'' (Final interview).

Research Question 2: Influence of Course Components

This section will present both empirical data derived from the implementation of the various course components, and transcripts of participants' perceptions of the intervention, sourced from the final interview. It is important to note that participants' perceptions are self-reported, and their role in this study is to provide possible explanations for trends identified through the data analysis process. In addition, as this was an exploratory study that did not utilize a comparison group, causal claims about the relative effectiveness of one course component over another are not able to be made.

Explicit NOS Instruction. Participants' final interview transcripts were searched for any references to explicit NOS instructional activities. Only two specific references to explicit NOS instructional activities were found, although three of the participants referred to the classroom ''discussions'' when asked to recall any specific instances of NOS in the course. Rachel expressed the class discussions and questioning aided her in developing her understandings of NOS: ''I think it was more just a theme, and it didn't just come up in one big block, it came through everything we talked about'' (Final interview). Monica and David both cited explicit NOS instructional activities when asked whether they could recall any specific aspects or instances of NOS during the course. These findings provide evidence to suggest that the inclusion of explicit NOS instruction aided some of the participants' understandings of a couple of the examined NOS aspects, although specific references to this course component were infrequently cited.

Explicit Argumentation Instruction. Participants' final interview transcripts were searched for any references to explicit argumentation instructional activities. The infrequent citing of explicit argumentation instruction by participants was not unexpected as this course component was primarily designed and implemented in the study with the aim of familiarizing participants with descriptions of the various components of an argument, and to facilitate participants' engagement in the argumentative aspects of the other course components.

Argumentation Scenarios. Two sources of data were examined to assess the influence of the argumentation scenarios on participants' views of NOS. First, transcripts from audio-taped class sessions were searched for evidence of engagement in argumentation, and explicit references to NOS aspects as participants engaged in the argumentation scenarios. Second, participants' final interview transcripts were searched for any references to the argumentation scenarios. All participants engaged in argumentation during the scenarios, although there were no explicit references to NOS in participants' oral discourse in either of the scientific argumentation scenarios by any of the participants. There were also no explicit references to NOS in participants' oral discourse in any of the three socioscientific argumentation scenarios by either Rachel or Monica. Tom and David each made a single explicit reference to NOS, and Sarah made two explicit references to NOS in their oral discourse during the socioscientific argumentation scenarios. These findings suggest that participants' views of NOS were generally not reflected in their oral argumentative discourse in either scientific or socioscientific contexts in this study.

Participants' final interview transcripts were searched for references to the argumentation scenarios. Three of the participants (Rachel, David, and Sarah) specifically referred to the argumentation scenarios when asked whether they could recall any specific aspects or instances of NOS during the course. Rachel referred to the socioscientific argumentation scenarios in her response: ''. . . probably the ethics behind everything, it's not just clear cut, we can't make a decision based on it can be done so we will do it, there are ethical issues involved in it and they have to be considered'' (Final interview). David also referred to a socioscientific scenario in his response, and Sarah referred to the argumentation scenarios in general, stressing the subjective and theory-laden NOS in her response: ''I think all of the little scenarios about how it was presented as 'this is a problem that's open to debate,' it's open for everyone to provide their perspectives on, that science is something that everyone's got opinions about, debate and discuss'' (Final interview). These findings indicate that the argumentation scenarios provided a context for learning about aspects of NOS for some participants.

The argumentation scenarios were cited as one of the most enjoyable aspects of the course by Tom, David, and Monica, although Rachel and Sarah stated that they had not enjoyed engaging in the scenarios. Sarah stated that she disliked participating in oral argumentation in the classroom, and expressed a lack of confidence in her perceived scientific knowledge compared to Tom. Rachel also expressed some discomfort with engaging in the argumentation scenarios due to a perceived lack of sufficient scientific content knowledge and insufficient skills of argumentation. Other participants also referred to the influence of group dynamics on engagement in argumentation in the scenarios. For example, Monica stated that she disliked some of the other class members' personalities, and Tom expressed that he found it difficult to talk to some of the younger students. In addition, Monica, Tom, and David expressed positive views of the usefulness of argumentation to teaching and learning science, whereas Rachel and Sarah expressed uncertainty. For example, Sarah commented that she found it unusual to learn about argumentation in a science course:

''I feel that it's more of an English kind of realm, like debating, more of an English, drama kind of slant on science'' (Final interview).

Global Warming Task

GLOBAL WARMING SURVEY. Four of the participants (Rachel, Monica, Tom, and Sarah) expressed partially informed or informed views of the two examined NOS aspects (social and cultural NOS, and subjective and theory-laden NOS) on the survey. These participants' views of the examined aspects of NOS aligned with their post-intervention VNOS-C responses. Similarly, David expressed limited views of the two examined NOS aspects on the survey which also aligned with his post-intervention VNOS-C responses. These findings suggest that participants' views of the social and cultural NOS and the subjective and theory-laden NOS expressed in the post-intervention VNOS-C were similar to their views of NOS expressed in the global warming survey.

GLOBAL WARMING ESSAY. Participants' global warming essays were searched for explicit references to NOS aspects, and evidence of engagement in argumentation. Participants' final interview transcripts were also searched for references to the global warming task. Engagement in argumentation was evident throughout all five participants' global warming essays. All of the participants provided arguments, counterarguments, and rebuttals supported with multiple justifications and an extended argument structure; and coordinated their claims with available evidence. Four of the five participants also incorporated specific and accurate scientific knowledge into their developed arguments (refer to McDonald, 2009, for further details). References to aspects of NOS were prevalent throughout the essays with all five participants referencing the subjective and theory-laden NOS, and empirical NOS in their essays. Numerous references to the social and cultural NOS were also prevalent, and a couple of references were also cited for the well- supported nature of scientific theories, and the tentative NOS. Table 6 provides a summary of examples of explicit NOS references sourced from the participants essays.

Some participants made reference to the essay as one of the enjoyable aspects of the course, and all of the participants referred to the above-cited aspects of NOS when they were asked to define NOS during the final interview, suggesting that the global warming task highlighted the application of specific NOS aspects. These findings suggest that the global warming essay provided an effective context to enable participants to apply their views and understandings of many aspects of NOS to their reasoning in the task.

Superconductors Survey. All of the participants exhibited broadly data focused views of the three parts of the superconductors survey at the commencement of the study. Participants' responses typically focused on the primacy of data, and the reduction or elimination of experimental error to help solve the problem. Rachel and Monica expressed overall relativist views during the post-intervention administration of the survey, although Rachel's views were coded as ''weakly'' relativist. Tom, David, and Sarah expressed overall data focused views with little change noted between the pre- and post-intervention administration of the survey. A summary of participants' responses to the superconductors survey is provided in Table 7.

COMPARISON OF NOS VIEWS ACROSS ASSESSMENTS. Participants generally expressed limited views of the empirical and subjective and theory-laden NOS as assessed by the VNOS-C, at the commencement of the study. These views aligned closely with participants' data focused views expressed in the pre-intervention superconductors survey. Rachel and Monica expressed partially informed and/or informed views of the empirical NOS and subjective and theory-laden NOS as assessed by the post-intervention VNOS-C, which were aligned with their broadly relativist focused views in the post-intervention administration of the superconductors survey. David's views of the examined NOS aspects were also aligned across both instruments, as he expressed limited views of the empirical and subjective and theory-laden NOS as assessed by the VNOS-C, and data focused views in the superconductors survey, during the post-intervention phase of the study. Conversely, Tom and Sarah's post-intervention views of the examined NOS aspects were not aligned across the two instruments. For example, although Tom and Sarah expressed partially informed views of the subjective and theory-laden NOS as assessed by the VNOS-C, they expressed data focused views of these aspects in the superconductors survey. Table 8 provides examples of expressed views of the subjective and theory-laden NOS across the two instruments.

TRENDS IN THE DATA. During the final interview, Rachel, Monica, and David expressed that they found the survey difficult to understand, in terms of interpreting the graphs, and understanding the wording of some of the closed stem responses. On the other hand, Tom and Sarah expressed confidence in their abilities to interpret the survey, attributing this confidence to their background scientific knowledge. On numerous occasions during the study, Tom made reference to his extensive scientific knowledge: ''. . . in a lot of circumstances I was listening and I was thinking maybe I need to dumb down what I know . . . well from what I've done in the past, it is a little bit over the top'' (Final interview). Sarah also referred to her previous scientific knowledge during the study, stating she had previously learnt about the science content covered in the course, and in previous science courses she had undertaken during her degree.

Laboratory Project. Participants' written laboratory reports were searched for explicit references to NOS aspects, and evidence of engagement in argumentation. Participants' final interview transcripts were also searched for references to the laboratory project. No engagement in argumentation was evident in four of the five participants' written laboratory reports. Tom was the only participant who engaged in argumentation, and developed a high-quality argument for his choice of chemical by providing arguments, counter- arguments, and rebuttals supported with multiple justifications and an extended argument structure; the incorporation of specific and accurate scientific knowledge; and evidence of the coordination of claims with all available evidence. The other four participants were not deemed to be engaging in argumentation, as although they provided a claim for their choice of chemical supported by justification, they did not provide counterarguments examining other alternative chemicals, or rebuttals to refute the possible selection of these chemicals (refer to McDonald, 2009, for further details). There were no explicit references to aspects of NOS in any of the participants' written laboratory reports. None of the participants referred to the laboratory project as influencing their views of NOS, and no references to this course component were evident in any of the participants' responses during the final interview.

Discussion

The importance of enhancing learners' views of NOS is a central goal of studies conducted in the field of NOS, and this study sought to incorporate explicit NOS and argumentation instruction in a science content course to aid in developing preservice primary teachers' views of NOS. Consistent with previous research (e.g., Akerson, Abd-El-Khalick, & Lederman, 2000; Akerson, Morrison, & Roth McDuffie, 2006), all of the participants expressed predominantly naive or limited views of the majority of the examined NOS aspects at the commencement of this study. Over the duration of the study participants engaged in a variety of course components specifically designed to facilitate the development of their views of NOS and/or their engagement in argumentation. Many positive changes were evident at the end of the study with four of the five participants expressing partially informed or informed views of the majority of the examined NOS aspects. Similar results were reported by Ogunniyi (2006) who examined the effectiveness of an argumentation- based, NOS course situated in a historical context. Thus, the results of this study provide some evidence to support the claim that integrating explicit NOS and argumentation instruction in a science content course incorporating scientific and socioscientific contexts for argumentation, and providing opportunities for participants to apply their views of NOS to their reasoning, leads to desirable developments in participants' NOS views. The following subsections will discuss the variety of factors found to mediate the development of participants' NOS views in this study, thus addressing the third research question. The identified factors will include factors that directly mediated participants' views of NOS, and also factors that indirectly mediated participants' views of NOS by influencing their engagement in argumentation. Intuitively, a necessary pre- requisite for applying views of NOS to reasoning recognizes that one must first be engaged in argumentation.

Contextual Factors

Context of Argumentation. Findings from this study indicated that participants' expressed views of aspects of NOS in socioscientific contexts were aligned with their expressed views of similar aspects of NOS in the VNOS-C. This was not necessarily the case in scientific contexts, as results indicated some participants' expressed views of aspects of NOS in these contexts were not aligned with their expressed views of similar aspects of NOS in the VNOS-C. Possible explanations for these findings may relate to the presence of multiple epistemologies. Previous research has indicated that participants possess both general epistemologies of knowledge, and specific scientific epistemologies. Bell and Lederman (2003) proposed that the decisions made by participants in their study on a selection of socioscientific issues may have reflected their general epistemologies of knowledge, rather than their specific scientific epistemologies. In this study, Tom and Sarah possessed relatively stronger background scientific knowledge than Rachel, Monica, and David. They appeared to draw on their specific science epistemological knowledge when responding to the superconductors survey situated in a scientific context but were able to apply their general epistemologies of knowledge when responding to course components situated in socioscientific contexts (e.g., global warming task). Conversely, Rachel, Monica, and David did not appear to draw on specific science epistemologies. These participants applied their general epistemologies of knowledge across scientific and socioscientific contexts, providing an explanation for the alignment of their expressed views of NOS over all of the assessments. These findings are consistent with those of Leach et al. (2000) who proposed that participants can draw on multiple forms of epistemological reasoning in differing contexts, and the application of particular forms of epistemological reasoning may be more or less appropriate depending on the given context. In this study, the prominence of data focused epistemological views expressed by Tom, Sarah, and David, in response to questions regarding data analysis and interpretation during the superconductors survey, reflect an inappropriate application of epistemological reasoning in this context.

Another finding from this study indicated that all participants developed written arguments in the global warming essay but only one participant developed a written argument in the laboratory report, suggesting that engagement in argumentation in scientific contexts is more difficult than engagement in argumentation in socioscientific contexts. Osborne et al. (2004a) support this proposition, stating that argumentation in scientific contexts requires the application of relevant scientific knowledge to enable participants to support and justify their arguments. In this study, most participants lacked background chemical science knowledge which may have inhibited their ability to select appropriate chemicals to test during the laboratory project. On the other hand, participants were provided with scientific evidence to aid in supporting and justifying their positions during the global warming task, via the science briefs. This factor may have contributed to participants' ease of engagement in written argumentation in socioscientific contexts. In addition, argumentation in socioscientific contexts does not place the same conceptual demands on participants, as they can apply informal knowledge gained through previous life experiences to support and justify their arguments. However, it is important to emphasize the role of scientific evidence in socioscientific contexts, in addition to a consideration of informal knowledge, and moral and ethical values, to ensure relevant scientific evidence is not dismissed when engaged in these contexts.

Mode of Argumentation. Two modes of argumentation, oral and written, were utilized in this study. Engaging in oral argumentation presented some difficulties for Rachel and Sarah who expressed a lack of confidence in their scientific knowledge compared to other members of the class. Similar to previous studies (e.g., Kuhn, 1993) these findings suggest that a perceived lack of scientific content knowledge may hinder participants' engagement in argumentation tasks. Another possible explanation for a lack of engagement in oral argumentation has been suggested by Nussbaum et al. (2002) who reported that learners often resist criticizing or challenging each other's ideas, and tend to avoid engaging in argumentation. In a similar vein, Clark and Sampson (2006) state that some participants may feel marginalized during oral argumentation, due to the dominance of other participants. In this study, Tom and David dominated oral argumentation discourse, and both expressed that they enjoyed ''winning arguments.'' An additional finding reported in this study indicated that Rachel did not feel she possessed sufficient skills of argumentation to participate in oral argumentation, but did feel confident to engage in written argumentation. An analysis of participants' written arguments provided in the global warming essays revealed numerous explicit references to NOS aspects examined in the study, indicating that the global warming essay may have provided a context for reflection about NOS ideas. Conversely, there were very few explicit references to NOS aspects in the oral argumentation scenarios, lending support for the importance of including written argumentation tasks in this study.

Task-Specific Factors

Argumentation Scaffolds. Findings from this study highlight the importance of providing argumenta- tion scaffolds to facilitate engagement in argumentation contexts. An argumentation scaffold is a written or verbal prompt that encourages participants to engage in argumentation (McDonald, 2008). Argumentation scaffolds should be used in conjunction with explicit argumentation instruction to ensure participants are familiar with the various definitions and meanings of argumentation components, such as data, claims, warrants, rebuttals, etc. Participants were provided with argumentation scaffolds during the argumentation scenarios, and engaged in the scenarios after sessions of explicit argumentation instruction. They were encouraged to utilize this information and were verbally prompted to consider relevant argumentation aspects (e.g., claims, data, warrants, qualifiers, etc.) during the scenarios. Argumentation scaffolds were also provided in the global warming task, via written assessment criteria that explicitly asked participants to develop an argument and counterargument to support and justify their position on the issue. These argumentation scaffolds were successful in enabling participants to engage in argumentation in both of these tasks.

Conversely, no argumentation scaffolds were utilized in the laboratory project. Written assessment criteria did not explicitly ask participants to develop an argument and counterargument to support and justify their position. Results indicated that many of the participants simply presented empirical data with minimal scientific interpretation, and there was little attempt to convince the reader of why one chemical was more effective than another chemical. Similar findings have been reported by Kuhn and Reiser (2006). Sandoval and Millwood (2005) propose that learners may believe data are self-evident, not requiring interpretation, or justification; or alternatively they may believe the teacher/ instructor already know why the data are important, and therefore it only matters to include the data. Thus, engagement in argumentation in this task may have been influenced by whether participants perceived a need to explain their data.

Epistemological Probes. An analysis of the findings of this study indicate that the inclusion of epistemological probes was influential to the development of participants' views of some aspects of NOS. An epistemological probe is a written or verbal prompt that orients the participants' attention to relevant NOS aspects highlighted in a task, or focuses the participants' attention on a question designed to draw on their epistemological knowledge or reasoning (McDonald, 2008). Epistemological probes should be used in conjunction with explicit NOS instruction to ensure participants are familiar with the definitions and meanings of various aspects of NOS, such as the creative and imaginative NOS, the social and cultural NOS, etc. Epistemological probes were included in the global warming survey which utilized a set of guiding questions that explicitly drew participants' attention to two aspects of NOS examined in this study: the subjective and theory-laden NOS, and the social and cultural NOS. An analysis of the results from the global warming survey indicated that the survey was effective in providing opportunities for participants to apply their understandings of these specific aspects of NOS to their reasoning in a socioscientific context. The same specific NOS aspects, amongst others, were explicitly referred to in participants' written global warming essays, providing evidence of the effectiveness of these epistemological probes in orienting participants' attention to relevant NOS aspects highlighted in a task. On the other hand, epistemological probes were not utilized in the argumentation scenarios. Participants' attention was not explicitly drawn to relevant aspects of NOS during the scenarios, and although results indicated that some of the participants explicitly cited the argumentation scenarios as a context for learning about NOS, very few explicit references to NOS aspects were reflected in their argumentative discourse as they engaged in the scenarios. These findings suggest that the non-inclusion of epistemological probes hindered participants' abilities to apply their NOS views to their reasoning during the argumentation scenarios.

Consideration of Alternative Data and Explanations. As discussed previously, possible explanations for participants' lack of engagement in the argumentative nature of the laboratory project include a lack of relevant scientific content knowledge, and the non-inclusion of argumentation scaffolds in the task. A third factor identified that may have facilitated participants' engagement in argumentation was the non-inclusion of alternative data and explanations. A closer analysis of participants' written laboratory reports indicated that Rachel and Sarah only chose to test one chemical. These findings suggest that unless participants are explicitly instructed to research and test a range or quantity of chemicals, they may make decisions about the most effective chemical without considering suitable alternatives. On the other hand, Monica and David chose to test three chemicals but failed to consider data obtained from testing these chemicals in their final choice of chemical. This failure to consider, test and evaluate possible alternatives, limits participants' abilities to engage in the argumentative nature of the task, and has been reported previous studies (e.g., Bell & Linn, 2000; Kuhn, 1991, 1993). Conversely, in the global warming task, participants were presented with two opposing views of the phenomenon, which forced them to evaluate multiple perspectives on the issue. Thesefindings suggest that participants may have engaged in the argumentative nature of the laboratory project if it had been designed to allow competing ideas to be tested.

Personal Factors

Perceived Previous Knowledge about NOS. Findings from this study suggest that perceived previous knowledge about NOS hindered the development of participants' NOS views. Although all of the participants expressed similar views of NOS at the commencement of the study, there were differential gains noted in the development of individual participants' NOS views. Rachel and Monica did not show confidence in their pre-existing views of NOS, and exhibited the most substantial development in their views of the examined NOS aspects. Tom and Sarah expressed that they already knew about NOS at the commencement of the study, although at the end of the study they did express that they had learnt some new ideas. These participants exhibited development in their views of many of the examined NOS aspects, but this development was less pronounced than the development exhibited by Rachel and Monica. David also expressed that he already knew about NOS at the commencement of the study, but stated that he had not learnt any new ideas about NOS in the course, and subsequently did not exhibit any substantial development in his views. These findings indicate that there was not as much incentive for David, and to a lesser extent, Tom and Sarah, to be receptive to learning more about NOS, as they did not initially recognize a need to change their pre-existing views. Similar findings have been reported by Schwartz, Lederman, and Crawford (2004).

Findings from this study suggest that cognitive dissonance was generated for all of the participants except David during the study. Schwartz and Lederman (2002) suggest that the generation of cognitive dissonance is a vital first step in enabling the development of NOS views, regardless of the confidence in pre- existing views of NOS expressed by the participant. This dissonance between participants' naive or limited views of NOS expressed at the commencement of the study, and the more informed views of NOS explicitly introduced during the study, was recognized early in the study by Rachel and Monica. Tom and Sarah's perceived previous knowledge about NOS impeded the generation of cognitive dissonance early in the course, but as they engaged in the various course components and began to recognize the deficiencies in many of their NOS views, they were able to accommodate more informed views of NOS. Conversely, it was not until the very end of the final interview where evidence was furnished that David had finally recognized dissonance between his pre-existing views of NOS, and the views of NOS presented in the course: ''. . . maybe these two interviews and everything we did in the subject is now starting to make me think that up till now I've just been agreeing with science blindly'' (VNOS-Post, Q3). This generation of cognitive dissonance at the end of study occurred after the administration of the post-intervention VNOS-C, highlighting the importance of providing contexts for reflection about NOS views.

Appreciation of the Importance and Utility Value of NOS. Other findings from this study suggest that a lack of appreciation of the importance and utility value of learning about NOS may hinder the development of participants' NOS views. Rachel, Monica, Tom, and to a lesser degree, Sarah, all recognized the importance and usefulness of learning about NOS in the course. These participants expressed that learning about NOS enhanced their learning of the other course content. Conversely, although David stated that he had enjoyed learning about NOS in the course, he did not appreciate the importance or utility value of learning about NOS, viewing the inclusion of NOS simply as a novel teaching approach designed to make learning science more interesting. Thus, he was not motivated to change his pre-existing views, as he failed to recognize the importance of internalizing more informed understandings of NOS to facilitate effective learning and teaching of science. Similar findings were reported by Abd-El-Khalick and Akerson (2004).

Durability and Persistence of Pre-Existing Beliefs. Previous research has highlighted the durability of participants' views and beliefs, and the difficulties experienced in attempting to change pre-existing views (Akerson et al., 2000; Kuhn, 1991). At 46 years of age, David was the oldest participant in the study. His views of NOS had developed over the duration of his school education, and also over nearly 30 years of post-school experiences. As such, it may be unrealistic to expect him to substantially change his largely unchallenged views of the examined aspects of NOS over the relatively short time frame of a single university semester. The tenacity with which participants' hold on to their pre-existing views of NOS has been documented by Akerson et al. (2000), and they recommend that participants are made explicitly aware of the inadequacies of their views of NOS at the beginning of interventions designed to develop their NOS views. Unlike the other four participants who did become aware of some of the inadequacies of their views of NOS throughout the study, David did not become aware of the inadequacies of his NOS views until the end of the study. His lack of development in NOS views can also be explained by examining the phenomenon of belief persistence (Kuhn, 1991), which recognizes that participant's beliefs persist for an extended time after evidence has been furnished that discredits the original belief. Examples of belief persistence were evident in David's VNOS-C responses, and during the implementation of the various course components. A notable example was expressed during the pre-intervention VNOS-C, in response to a question about atomic structure:

> I have put my faith in the honesty of the scientists. This observation is the only one I am aware of and no-one has ever disputed it to my knowledge, so it must be true. . . . I'd put my faith in the fact that we've been taught that ever since I was a boy or since high school anyway that that's what made up an atom, I put my faith in the honesty of the scientists . . . (VNOS-Pre, Q6)

Little change was noted in David's response to the same question during the post-intervention VNOS-C:

> Well, that's one of those silly things that I can't explain . . . Right now I've never seen one, I put my faith in science . . .

> I suppose it's part of my personality, my psyche, I'm just scientifically inclined. And I blindly believe the scientists. (VNOS-Post, Q1)

Thus, the persistence of David's pre-existing beliefs influenced his ability to disavow himself of his pre-existing position, and subsequently accommodate a new perspective.

Limitations of the Study

The results of this exploratory study are applicable to the five participants selected for investigation in this study. Accordingly, the identification of factors mediating the development of participants' NOS views was determined from data obtained from these five participants. As such, these factors are directly applicable to these participants, and further research is needed to determine whether they apply to other participant groups. In addition, similarly to Abd-El-Khalick and Akerson (2004), information regarding how the identified factors interacted with each other is difficult to determine.

Implications and Recommendations for Research

This study has made a unique contribution to the field in that it is the first empirical study identified in the literature that has investigated NOS and argumentation in both scientific and socioscientific contexts, and has implemented explicit NOS and argumentation instruction in both of these contexts. Implications from this study indicate that future studies that aim to incorporate explicit NOS and argumentation instruction as a context for learning about NOS should consider the possible influence of various contextual, task-specific, and personal factors on the development of their participants' views of NOS. As learners may draw on multiple forms of epistemological reasoning in varying contexts, it is important to provide explicit teacher guidance to enable them to apply appropriate epistemological reasoning in given argumentation contexts, with the addition of specific scientific knowledge in scientific contexts to aid in facilitating their engagement in argumentation. As various factors may limit learners' engagement in oral argumentation, it is important to provide additional argumentation skills instruction, relevant scientific knowledge support, and group working skills where needed. Written modes of argumentation may not present these same challenges, and have the added advantage of providing a context for reflection about NOS ideas. The inclusion of argumentation scaffolds in tasks, used in conjunction with explicit argumentation instruction; and the provision of alternative data and explanations in tasks, are recommended to facilitate learners' engagement in argumentation. Importantly, tasks need to be carefully designed to ensure learners recognize the need to explain their data. The inclusion of epistemological probes, used in conjunction with explicit NOS instruction, is vital to explicitly draw learners' attention to specific NOS aspects, and to facilitate the application of their views of NOS to their reasoning during argumentation. A consideration of the possible influence of factors such as perceived previous knowledge about NOS, appreciation of the importance and usefulness of learning about NOS, and the durability and persistence of pre-existing beliefs are critical in studies that aim to develop learners' NOS views. Opportunities to generate cognitive dissonance must be provided early to allow learners to recognize the deficiencies in their NOS views (especially for learners with substantial life experience), thus enabling them to seek alternative views congruent with informed views of NOS. An explicit rationale should also be provided to ensure learners are made aware of the importance and utility value of learning about NOS.

The findings from this study contribute to the emerging body of research exploring NOS and argumentation. Although this study has provided some evidence to support the incorporation of explicit NOS and argumentation instruction to aid in developing preservice primary teachers' NOS views, would this approach be effective with primary, middle, and/or high school students? In addition, research is needed to ascertain whether preservice teachers experiencing this type of course actually implement NOS and argumentation instruction in their own classrooms. Although the participants in this study expressed that they had enjoyed learning about NOS and argumentation, the question remains as to whether they would prioritize the implementation of NOS and argumentation instructional approaches in their own classrooms.

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Table 1
Empirical studies investigating the influence of NOS views on argumentation

Study	Aim	Context	Participants	Results
Bell and Lederman (2003)	Investigate the role of NOS in decision-making about socioscientific issues	Socioscientific	University professors and research scientists (N ¼ 21)	NOS views did not influence reasoning on issues
Sadler et al. (2004)	Examine views of NOS in response to a socioscientific issue	Socioscientific	High school students (N ¼ 84)	Views of some aspects of NOS reflected in arguments Some aspects of NOS influenced students' reasoning on the issue
Walker and Zeidler (2004)	Investigate the role of NOS in decision-making	Socioscientific	High school students (N ¼ 36)	NOS views did not influence their reasoning on the issue Views of NOS improved
Zeidler et al. (2002)	Examine the relationship between NOS views and evidence that challenged beliefs about a socioscientific issue	Socioscientific	High school students to preservice elementary teachers (N ¼ 248) (n ¼ 82)	Views of some aspects of NOS reflected in arguments
Kenyon and Reiser (2006)	Investigate the application of epistemological views to develop and evaluate explanation	Scientific	Middle school students (N ¼ 64)	Applying epistemological criteria facilitated evaluation and engagement in argumentation
Nussbaum et al. (2008)	Examine the influence of epistemic beliefs, and exposure to argumentation instruction, on the quality of argumentation	Scientific	College undergraduates (N ¼ 88)	More informed epistemological views promoted critical engagement in argumentation
Sandoval and Millwood (2005)	Examine the influence of epistemological views about argumentation on inquiry practices	Scientific	High school students (N ¼ 87)	Naïve views of NOS constrained engagement in argumentation
Sandoval and Millwood (2007)	Examine students' epistemological views about warranting claims	Scientific	Primary school students (N ¼ 33)	Students held naive epistemological views and did not provide warrants for claims

Table 2
Empirical studies investigating the influence of argumentation on NOS views

Study	Aim	Context	Participants	NOS Instruction	Argumentation Instruction	Results
Bell and Linn (2000)	Investigate relationship between students' NOS views and their arguments	Scientific	Middle school students (N ¼ 172)	No	Yes	Argumentation and NOS improved
Yerrick (2000)	Assess students' skills of argumentation	Scientific	High school students (N ¼ 5)	No	Yes	Argumentation and NOS improved. Views of some aspects of NOS reflected in arguments
Ogunniyi (2006)	Examine the effectiveness of an argument-based, reflective NOS course on NOS views	Historical	Inservice science teachers (N ¼ 3)	Yes	Yes	NOS improved

Table 3
Profiles of participants

Name	Biographical Information	Educational Background	Nature of Science (NOS) and Argumentation[a]	Classroom Interactions[b]	Course Grade (7-Point Scale)
Rachel	Female, 19 years	General science to year 12	Had not heard of NOS. Learnt about argumentation in high school social studies	Quiet, industrious participant. Participated in small group and whole class discussions	5
Monica	Female, 21 years	Biology and general science to year 12	Had not heard of NOS. Engaged in argumentation activities in high school	Outgoing participant. Participated in small group and whole class discussions	5
Tom	Male, 30 years	Biology, chemistry, and physics to year 12, Bachelor of Engineering	Had previously learnt about NOS and argumentation. Learnt about argumentation during tertiary studies and work experience	Confident, outgoing participant. Dominated small group and whole class discussions	6
David	Male, 46 years	Biology to year 12 (returned to complete year 12 after many years in the workforce)	Had not heard of NOS. Not specifically asked about argumentation	Outgoing participant. Major contributor during small group and whole class discussions	5
Sarah	Female, 20 years	Physics and biology to year 12. Honors student	Had not heard of NOS. Had previously learnt about argumentation in high school English	Quiet, confident, and industrious participant. Dominated small group discussions. Participated in whole class discussions	6

[a]Views expressed during initial interviews.
[b]Based on audio and/or video-recordings of classroom teaching sessions.

Table 4
Descriptions of epistemological views (Leach et al., 2000; Ryder & Leach, 2000)

Data Focused Views	Model Focused Views	Relativist Focused Views
Data focused views reflect a belief in the primacy of data. The processes of measurement and data collection are viewed as simply involving ‘‘copying’’ from reality, and the process of drawing conclusions is a simple one of stating what happened in an experiment. Scientific knowledge claims are viewed as descriptions of the material world, and differences of interpretation can be resolved by collecting enough data of an appropriate form	Model focused views recognize the importance of considering underlying models when interpreting data. Understands the distinction between models, predictions, and data. Recognition that data treatment should be informed by underlying models, and that models are based on theoretical ideas and data collected through experimental measurements	Relativist focused views reflect the view that there are limited grounds for assessing the truth of knowledge claims in science. Multiple interpretations of the same data are possible. Data interpretation is subjective and theory-laden, is influenced by factors such as a scientists' theoretical orientations, beliefs, previous knowledge, experiences, and expectations. Appreciates the role of data as providing empirical evidence to support the chosen position

Table 5
Pre- and post-intervention nature of science (NOS) views

	Rachel			Monica			Tom			David			Sarah		
NOS Aspect	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change
Empirical	+	++	D	-	+	D	-	+	D	-	-	U	-	-	U
Methods of science	-	+	D	-	+	D	-	+	D	- -	-	D	- -	-	D
Theories and laws	-	-	U	-	-	U	-	-	U	-	-	U	-	+	D
Tentative	+	+	U	-	++	SD	+	+	U	-	-	U	-	-	U
Inference and theoretical entities	-	+	D	- -	-	D	+	+	U	- -	- -	U	+	++	D
Subjective and theory-laden	-	++	SD	+	++	D	-	+	D	-	-	U	-	+	D
Social and cultural	-	++	D	+	+	U	-	+	D	-	-	U	-	+	D
Creative and imaginative	-	+	D	-	+	D	-	+	D	-	-	U	+	+	U
Total + or ++	2	7		2	6		2	7		0	0		2	5	
Total D or SD			6			6			5			1			5

Note: , Naïve view of NOS aspect; , limited view of NOS aspect; þ, partially informed view of NOS aspect; þþ, informed view of NOS aspect; U, view of NOS aspect largely unchanged; D, view of NOS aspect developed; SD, view of NOS aspect substantially developed.

Table 6
Examples of expressed NOS views in the global warming essay

Aspect of NOS	Global Warming Essay
Subjective and theory-laden NOS	No human endeavor, even that of science, is isolated from personal biases, beliefs and interpretation. This is evident in the use of the increase of temperatures by 0.5−0.88C from both arguments but with different emphases on the repercussions of this data. These personal beliefs are also evident in the priority of importance given to different elements of the global warming issue. (Rachel, GW Essay, pp. 10−11
Empirical NOS	As well as this, several of this side's arguments are based on emotive beliefs and unconfirmed evidence .. . Where as, ''The Against'' side provides validated and reviewed research to back up their claims .. . (Monica, GW Essay, p. 8)
Social and cultural NOS	Both arguments are supported by scientific evidence (often the one source of evidence) being interpreted by scientists who are employed / supported by lobby groups or by elements with a vested interest in the debate (governments, multinationals, oil companies, Greenpeace, Planet Ark, etc.). (Tom, GW Essay, p. 3)
Well-supported nature of scientific theorie	For a scientific theory to be worthy of merit it must provide valid and authentic evidence to support it. (Sarah, GW Essay, pp. 10 – 11)
Tentative NOS	Due to the uncertainties that still remain about global warming, it would be unwise to act as if we do? Ultimately, we have to use our best judgment guided by the current state of science to determine what the most appropriate response to global warming should be. (Monica, GW Essay, p. 8)

Table 7
Summary of participants' responses to the superconductors survey

Survey	Rachel		Monica		Tom		David		Sarah	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Part 1	IR	wRF	wDF	RF	DF	DF	DF	DF	DF	DF
Part 2	DF	wRF	DF	wRF	DF	DF	DF	DF	DF	DF
Part 3	DF	DF	IR	RF	DF	wRF	DF	DF	DF	wDF
Overall	DF	wRF	DF	RF	DF	DF	DF	DF	DF	DF

Note: DF, data focused response; RF, relativist focused response; IR, invalid response; wDF, weakly data focused response; wRF, weakly relativist focused response.

Table 8
Examples of expressed NOS views on VNOS-C and superconductors survey (subjective and theory-laden NOS)

Participant	VNOS-C	Superconductors Survey	Alignment of Views
Monica	Different conclusions are possible from the same set of data, as different scientists have differing backgrounds, values, beliefs and training. These all contribute to the way they draw conclusions from data. (Post-VNOS, Q8)	I think there is no right or wrong. If both groups came up with nearly identical data results, then individual scientists will come up with their own idea where the line should go through. A computer generated line would do only what an individual scientist had programmed or taught it to go. As long as within the error margins, it can't be said that the line is wrong. (Post-Super, Part 3)	Aligned
Tom	I think it's more their background .. . in the background they've been brought up to believe, if they're more of a volcanologist leaning or astrological leaning, I think that has a lot to influence, and themselves what they've personally experienced, if they've gone out and seen volcanic layers, debris they'd be more tending to believe that way whereas if they've gone out and been on more impact sites and checked .. . (Post-VNOS, Q8)	Have them meet, identify similarities and differences and then see if they can come up with a composite theory. Well if they couldn't get any more data, which would be the ultimate thing, they need to come together .. . (Post-Super, Part 2)	Not aligned

Appendix: Laboratory Project Brief (Adapted from Bochinski, 1991)

The captain of a fishing trawler has approached your research group with a problem. He has a build-up of ice approximately 2 cm thick on the bottom of an aluminum ice box used to store fresh fish. He needs to be able to melt the build up of ice without damaging the aluminum. Your task is to determine what would be the most effective substance to carry out this process. You will need to consider factors such as speed, cost, and efficiency in your recommendation.

The following conditions are noted:

(1) Outside air temperature is in the range of 18−258C.
(2) No outside heat sources may be used (it is assumed there is no electricity available on the trawler). (3) No mechanical agitation of the ice is permitted (e.g., grinding, breaking up, agitating, etc.).
(4) All groups will be provided with six aluminum baking pans and will have access to a very limited amount of freezer space.