

Examining the Impact of a Professional Development Program on Elementary Teachers' Views of Nature of Science and Nature of Scientific Inquiry, and Science Teaching Efficacy Beliefs

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Abstract

We examined to what extent elementary teachers' nature of science (NOS) and nature of scientific inquiry (NOSI) views, and science teaching efficacy beliefs change after a five-day professional development program designed to teach NOS and NOSI integrated with language arts. We found that elementary teachers improved their NOS and NOSI views, and one dimension of their science teaching efficacy beliefs at the end of the professional development program. Results of this study suggest that carefully designed professional development programs that provide NOS and NOSI instruction integrated with language arts may help elementary teachers improve their science teaching efficacy beliefs as well as their NOS and NOSI views.

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Introduction

Next Generation Science Standards (NGSS Lead States, 2013) focuses on a limited number of core ideas in science by adopting the notion of learning as developmental progression. In NGSS, same concepts are revisited with increasing levels of sophistication at K-2, 3-5, 6-8, and 9-12 grades. NGSS assumes that all students learn science by the time they come to the middle school. However, it is not a secret that science teaching is often neglected in favor of other subjects such as math and language arts at the elementary level (K-5). One might think that lack of science teaching at the elementary level is due to the fact that principals encourage teachers to focus on the tested subjects such as language arts and math. However, the problem is more complicated than it seems. Most elementary teachers lack appropriate science background and confidence to teach science. National Academies report *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* underscores this point.

There is a particularly strong need for elementary and middle school teachers to have a deeper education in science and mathematics. Many school children are systematically discouraged from learning science and mathematics because of their teachers' lack of preparation, or in some cases, because of their teachers' disdain for science and mathematics. In many school systems, no science at all is taught before middle school. (p.121)

Even if elementary teachers are encouraged to teach science, they may not be able to teach science effectively without support from well-designed professional development programs. Elementary teachers are generally specialists in language arts (Akerson, 2007; Pratt, 2007), and most do not have strong science backgrounds (Andersson, 1999). Capitalizing on their strengths in language arts could prove fruitful in improving their NOS, NOSI views and science teaching efficacy beliefs (Romance & Vitale, 1992). Therefore, programs focusing on improving elementary teachers' science content knowledge, NOS and SI views, and knowledge and skills in teaching science integrated with language arts are necessary.

In this study, we present a professional development program that was designed to improve elementary teachers' science teaching efficacy beliefs. We sought to increase participants' science teaching efficacy beliefs by improving their nature of science (NOS) and nature of scientific inquiry (NOSI) views. Our professional development program provided explicit-reflective instruction about NOS and NOSI. Explicit-reflective instruction should not be confused with didactic traditional methods of instruction. Explicit-reflective instructional methods used in this study were in line with constructivist teaching and learning principles and emphasized participant reflection and metacognition. Explicit-reflective instruction intentionally focuses learners' attention on relevant NOS aspects through specifically designed instruction by making NOS ideas visible to the learner. Explicit reflective instruction creates a context in which learners construct their own meanings about NOS and NOSI views with the help of the teacher. The effectiveness of explicit-reflective instruction has been demonstrated by a considerable number of studies (Abd-El-Khalick, 2001; Akerson, Abd-El-Khalick, & Lederman 2000). We capitalized on the effectiveness of explicit-reflective instruction about NOS and NOSI, but we also supported the explicit-reflective instruction with language arts connections where appropriate. We hypothesized that participants can better improve their NOS and NOSI views if they learn about these topics integrated with language arts, a subject about which they already feel comfortable. It can be thought that increased science teaching efficacy beliefs would result in more science teaching time and improved science instruction, and more science teaching time and improved science instruction would in turn increase student achievement in science (Ashton & Webb, 1986; Bleicher & Lingdren, 2002). In this study, we only explored how explicit-reflective NOS and NOSI instruction affects elementary teachers' NOS and NOSI views and science teaching efficacy beliefs. We propose to explore how science teaching efficacy beliefs are related to more science teaching time and improved science instruction in the future studies.

This project specifically examines teachers' NOS views, NOSI views, and science teaching efficacy beliefs before and after a five-day (6 hours per day) intensive professional development program that integrated NOS and NOSI instruction with language arts. The research reported in this study is based on data from beginning phase of a 2-year professional development program.

Our specific research question is as follows. To what extent do elementary teachers' NOS and NOSI views, and science teaching efficacy beliefs change after a five-day professional development program designed to teach NOS and NOSI integrated with language arts?

Theoretical Frameworks

Professional development programs have been found to be successful in helping elementary teachers improve their understandings of NOS (e.g. Akerson & Hanuscin, 2007) and their NOS teaching practice (e.g. Akerson, Cullen, & Hanson, 2009; Hanuscin, Lee, & Akerson, 2010). We sought to design a professional development program that included components previously found to be successful in aiding teachers' development of NOS conceptions, as well as adding the component of promoting improved conceptions through a content area that elementary teachers are more comfortable with, namely language arts. In designing the professional development program we thought about Bell and Gilbert's (1996) science teacher development model which emphasizes three components (a) *personal commitment* in which the teacher desires professional development to change ideas and strategies, (b) *social development* in which we sought to provide teachers with opportunities to discuss ideas with other teachers and thusly, reconceptualizing what it means to be a science teacher, and (c) *professional development* in which teachers are supported in actually implementing new strategies and into practice. Within this framework we additionally included guided inquiry activities that engaged teachers in thinking about science content, science as inquiry, and nature of science. These activities included explicit-reflective instruction as the teachers explored science content (Akerson & Hanuscin, 2007). Our explicit-reflective NOS and NOSI instruction is informed by conceptual change theory as well. We first provided some background knowledge about conceptual change theory and then described how our explicit-reflective NOS and NOSI instruction is informed by conceptual change theory below.

The conceptual change model developed by Posner, Strike, Hewson, and Gertzog (1982) tremendously influenced science teaching and science education research. According to this conceptual change model, there are four conditions required for conceptual change: (1) dissatisfaction, this condition requires that the learner fails to make sense of some event with his/her existing conception, (2) intelligibility, this condition necessitates that the learner has some understanding of the new conception, (3) plausibility, this condition is satisfied when the learner accepts the new conception, and (4) fruitfulness, this condition emphasizes that the learner should be able to use the new conception to explain novel situations as well as the situations that were formerly explained by the new conception. Despite its tremendous impact in the field of science education, the original conceptual change model was criticized by many researchers (e.g., Cobern, 1996; Pines & West, 1986; Solomon, 1987) on the grounds that the model was overly rationalistic and it failed to acknowledge affective and motivational factors in learning. Ten years later, considering these criticisms, Strike and Posner (1992) revised the model in a way that the importance of the roles of intuition, emotion, motives, and social factors were explicitly stated (Strike & Posner, 1992).

Hewson, Beeth and Thorley (1998) provided a practical interpretation of Posner et al. (1982) and Strike and Posner (1992) models. The term "conceptual ecology" (Toulmin, 1972) played a central role in both models. Hewson et al. (1998) pointed out that the concept of conceptual

ecology refers to all the knowledge that a person possess, it is composed of different types of knowledge, and these different types of knowledge interact with each other. According to Hewson et al. (1998) status of an idea is determined by its intelligibility, plausibility, and fruitfulness. Learning is defined as raising the status of desired conceptions while lowering the status of undesired conceptions within the conceptual ecology. Hewson et al. (1998) suggested four practical guidelines for conceptual change. Our explicit-reflective NOS and NOSI instruction is informed by these four practical guidelines. First, we made our and our participants' NOS and NOSI views an explicit part of classroom discourse. Second, we made the classroom discourse explicitly metacognitive meaning that our participants made their own NOS and NOSI views objects of cognition. Participants were given opportunities to compare and contrast their own views with their peers' and our views. Third, participants were given opportunities to discuss and negotiate the status of their NOS and NOSI views. This discussion allowed our participants to raise the status of their informed NOS and NOSI views and lower the status of their uninformed NOS and NOSI views. Fourth, we made the justification for ideas and status decisions explicit parts of the instruction. According to conceptual change model, learners need to understand NOS and NOSI ideas (intelligibility) before they decide whether they find those ideas plausible and fruitful. Learners also need to explain how and why they find certain ideas plausible and fruitful.

Rationale of the Study

We hypothesized that elementary teachers' NOS and NOSI views can be reasonably improved by teaching these constructs explicitly integrated with language arts. Capitalizing on elementary teachers' strengths in language arts during explicit reflective NOS and SI instruction could be fruitful in improving teachers' NOS and NOSI views. Language arts integration can provide an additional layer of support to elementary teachers in improving their NOS and NOSI views because they learn about NOS and SI in connection with a subject about which they already feel comfortable. We also hypothesized that explicit-reflective NOS and NOSI instruction can also improve elementary teachers' science teaching efficacy beliefs. Elementary teachers' science content knowledge and science teaching efficacy beliefs can be improved after a course designed to teach specific science content and inquiry methods (Jarred, 1999; McDermott & DeWater, 2000; McDermott, Shaffer, & Constantinou, 2000), but we were not able to locate a study exploring how explicit-reflective NOS and SI instruction can affect teachers' science teaching efficacy beliefs. Therefore, this study explores whether it is possible to improve elementary teachers' science teaching efficacy beliefs through explicit-reflective NOS and SI instruction. Our explicit-reflective NOS and SI instruction had two distinctive characteristics. NOS and SI were taught integrated with language arts and explicit-reflective instruction was informed by conceptual change approach (Hewson et al., 1998). It is difficult to teach about NOS and NOSI at the elementary level because there is not sufficient amount of time allocated for science teaching (Hernandez, Arrington, Whitworth, 2002; Silversten, 1993). If NOS and SI can be taught through language arts connections, this combination can help improve understanding about NOS and SI as well as knowledge of integration of science with language arts. This approach has also the potential to ensure that there is sufficient time spent on both science and language arts (Romance & Vitale, 1992).

Related Literature

In this section we review literature that is related to our research. We look at the three constructs that are mentioned in the rationale below.

Nature of science and scientific inquiry

Nature of science (NOS) refers to values and beliefs specific to scientific knowledge and its development (Lederman, 1992, 2007). It was acknowledged that there is no agreed-upon single definition of NOS among philosophers of science, historians of science, scientists, and science educators, but certain aspects of NOS are uncontroversial and relevant to K-12 education. These NOS aspects include but are not limited to conceptions that scientific knowledge is empirically-based, tentative, subjective, inferential, socially and culturally embedded, and depends upon human creativity and imagination.

The NSES (NRC, 1996) promote students' understanding about NOSI as well as promoting that students should be able to conduct various types of inquiry activities (NRC, 2000). Students' understanding about NOSI include (a) questions guide investigations, (b) multiple methods of scientific investigations, (c) multiple purposes of scientific investigations, (d) justification of scientific knowledge, (e) recognition and handling of anomalous data, (f) sources, roles of, and distinctions between data and evidence, and (g) community of practice (Schwartz, Lederman, & Lederman, 2008). It was stated that "scientific inquiry extends beyond the mere development of process skills such as observing, inferring, classifying, predicting, measuring, questioning, interpreting and analyzing data, and scientific inquiry includes the traditional science processes, but also refers to the combining of these processes with scientific knowledge, scientific reasoning and critical thinking to develop scientific knowledge" (Lederman, 2006, p.308).

We think that students and teachers should learn about NOS and NOSI because NOS and NOSI are important parts of scientific literacy. Improving students' and teachers' NOS and NOSI views can be seen as a way of increasing the number of scientifically literate citizens who have to make decisions on socio-scientific issues. In other words, sophisticated NOS and NOSI views are useful for public understanding of science. If students and teachers think that scientists faithfully follow "the Scientific Method," scientific knowledge is absolute, scientific knowledge is not influenced by scientists' bias and social and cultural factors, there is not much creativity involved in doing science, and hypothesis are educated guesses, they would not be in a good position to make informed decisions on socio-scientific issues that every modern society has to face. Unfortunately, most students and teachers at least have one or more of these inaccurate views about science (Lederman, 1992; Lederman, 2007). For this reason, it is reasonable for us to expect that teachers with uninformed NOS and NOSI views would perpetuate misconceptions about NOS and NOSI. Similarly, it is not reasonable to expect that students with inaccurate NOS and NOSI views would develop positive attitudes toward science and choose scientifically oriented careers.

Teaching about NOS and NOSI emphasized in science education policy documents (AAAS, 1993; NRC, 1996). Teaching about NOS and NOSI continues to be emphasized in more recent science education policy documents. For example, NOS and NOSI found their places in Next Generation Science Standards (NGSS Lead States, 2013). However, Lederman (2006) pointed out that these policy documents are likely to have minimal impact in the field because professional

development efforts helping teachers improve their NOS and NOSI views and their pedagogical knowledge about NOS and SI conceptions are rare.

Schwartz, Lederman, and Lederman (2008) stated that despite certain commonalities between NOS and NOSI, the distinction between NOS and NOSI is often overlooked. According to Schwartz et al. (2008) NOS aspects are more pertinent to the product of scientific inquiry and NOSI understandings are more pertinent to the process of scientific inquiry. It can be stated that NOS aspects cover the characteristics of scientific knowledge and NOSI aspects cover the characteristics of the scientific inquiry through which scientific knowledge is constructed.

It was historically documented that students and teachers generally do not hold informed NOS views (Lederman, 1992; Lederman 2007). Nowadays, most students and teachers still do not have informed NOS views. However, the research on NOS indicated that students' and teachers' NOS and NOSI views could be improved through explicit-reflective instruction. A considerable number of studies showed that explicit-reflective NOS instruction modeled after constructivist teaching and learning principles can substantially improve NOS views (e.g., Abd-El-Khalick, 2001; Akerson, Abd-El-Khalick, & Lederman 2000). Some researchers (Bell, Blair, Crawford, & Lederman, 2003; Ryder, Leach, & Driver, 1999) explored whether NOS and NOSI views could be improved by engaging students and teachers in doing science in real science settings. Although this idea is intuitively appealing, it was found that NOS and NOSI views did significantly improve after students participated in real research experiences (Bell et al., 2003; Ryder et al., 1999).

Science teaching efficacy

Teaching efficacy is considered to be subject-matter specific (Tschannen-Moran, Hoy, & Hoy, 1998). Enoch and Riggs (1990) developed an instrument to assess teachers' science teaching efficacy beliefs. This instrument included two dimensions: personal teaching efficacy (PSTE) and science teaching outcome expectancy (STOE). PSTE is related to elementary teachers' confidence in their own science teaching ability. STOE is related to teachers' belief that student learning can be influenced by effective teaching. Wheatley (2002) reported that teacher efficacy was found to predict student achievement, teacher retention, and commitment to teaching. Riggs and Enochs (1990) reported that teaching efficacy beliefs were associated with greater use of hands-on teaching methods. Although previous research favored teachers' confidence in their teaching efficacy, Wheatley (2002) drew attention to potential benefits of teachers' doubts in their teaching efficacy. Wheatley (2002) stated that teachers are more likely to learn from their doubts regarding their own personal teaching efficacy if they believe that student achievement can be improved by teaching.

It has been shown that elementary teachers do not have a robust understanding of science content (Andersson, 1999; Kruger, Palacio, & Summers, 1992), NOS and SI conceptions (Lederman, 1992; Lederman et al., 2003). For this reason, it is not surprising that elementary teachers with a weak understanding of science content, NOS and NOSI conceptions do not have much confidence in their science teaching efficacy. It has also been shown that elementary teachers' science content knowledge and science teaching efficacy beliefs can be improved after a semester long course designed to teach specific science content and inquiry methods (Jarrett, 1999; McDermott & DeWater, 2000; McDermott, Shaffer, & Constantinou, 2000). Elementary teachers'

NOS and SI views can be improved through a specifically designed explicit-reflective instruction in a semester long science teaching methods course (Abd-El-Khalick, 2001; Akerson, Abd-El-Khalick, & Lederman 2000). However, there is a lack of research exploring whether improved NOS and SI understandings are related to elementary teachers' science teaching efficacy beliefs. Some other studies showed that elementary teachers' conceptual understanding of science concepts was positively related to their science teaching efficacy beliefs (Bleicher 2002; Bleicher & Lingdren, 2002). It was also found that teacher efficacy positively correlated with student achievement (Ashton, 1985; Ashton & Webb, 1986).

Integrating science with language arts

It has been shown that in elementary classrooms (K-5) time for science is generally less than for most curriculum subjects, particularly language arts topics because elementary teachers are commonly literacy specialists (Akerson, 2007; Pratt, 2007). However, there are important parallels in language arts and science instruction that can help teachers use integrated instruction and content area reading to teach science as well as reading skills (Baker & Saul, 1994; Casteel & Isom, 1994; Rivard, 1994; Yore, Pimm & Tuan, 2007). Combining science with reading and writing in the elementary grades can help improve children's language arts and science understandings and ensure there is sufficient time spent on science as well as language arts instruction (Romance & Vitale, 1992). It can also enable elementary teachers with strengths in language arts improve their teaching of science (Akerson & Flanigan, 2000). Combining language arts with science can also help elementary students develop reading skills as well as science content skills if used with appropriate teaching strategies (Norris, Phillips, Smith, Guilbert, Stange, Baker, & Weber, 2008). Therefore, appropriate strategies for teaching science through language arts need to be developed and this development can occur through professional development programs that incorporate both language arts and science. Additionally, science can be used as a content area for improving student discourse and spoken as well as written language (Cavagnetto, Hand, & Norton-Meier, 2010). While there have been professional development programs designed to improve elementary teachers' science instruction that have combined language arts and science (e.g. Britsch & Shepardson, 2007), we have been unable to identify previous professional development programs that have used language arts as a context for teaching NOS and NOSI. We explore this context in the current study.

Methods

We used a basic pretest-posttest design approach in this study. We used a combination of qualitative and quantitative instruments and analyses procedures that will be described in the following sections. Our qualitative data analysis was informed by an interpretive qualitative data analysis (Bogdan & Biklen, 2006).

Participants

Participants were 19 elementary teachers (14 female, 5 male). Participants' age ranged from 25 to 59, with an average of 46.5 years ($SD = 12.24$). They all taught grades 1-5 in an urban public school system in the western United States. Two teachers taught first grade, 2 teachers taught second grade, 3 teachers taught third grade, 1 teacher taught fourth grade, 5 teachers taught fifth grade, 5 teachers taught grades K-5 science, and one teacher was English Language Learners (ELL) specialist.

Professional Development Program

Our professional development activities are modeled after explicit-reflective instruction. Research indicates that explicit-reflective NOS and NOSI teaching is effective in improving learners' NOS and NOSI views. The effectiveness of the explicit-reflective approach is well-documented in science education literature. (Abd-El-Khalick, 2001; Akerson, Abd-El-Khalick, & Lederman, 2000). The explicit-reflective approach intentionally draw learners' attention to relevant aspects of NOS and NOSI. Our preference for explicit-reflective instruction was informed by the research cited above. Our explicit-reflective instruction was also informed by conceptual change approach described by Hewson, Beeth, and Thorley (1998).

During the professional development program elementary teachers participated in five 6-hour long workshops. The total contact time was 30 hours. Workshops included NOS and NOSI instruction supported with language arts integrations. Language arts integrations were provided through science notebooks and relevant fiction and non-fiction readings related to NOS and NOSI aspects. We tried to incorporate reading and writing to explicit-reflective NOS and NOSI instruction wherever appropriate. We thought that using science notebooks during the professional development program would provide a genuine context for participants to express themselves in writing. For this reason, we introduced science notebooks at the beginning of the professional development program. The professional development program started with a discussion of how science notebooks can help students improve their science learning. As a result of this discussion, it was concluded that (a) science topics and activities could provide an authentic context for writing, (b) science notebooks could provide a safe venue for students to express themselves in writing without worrying about making grammatical and punctuation mistakes, and (c) writing could become an integral part of science learning through science notebooks. We thought that emphasis on using science notebooks would encourage writing during the intervention. Participants involved in activities such as "Tricky Tracks"- "Rabbit? Duck?"- "Young Woman? Old Woman?"- "The Tube" - "The Cubes," and others. These activities are explained in great detail in Lederman and Abd-El-Khalick (1998). Participants' were asked to make drawings and express their ideas and thinking in their science notebooks during the all activities. These activities were also supported with relevant readings about NOS and NOSI aspects such as McComas (1998) and NRC (2000). Some NOS conceptions were also explained through reading fiction books. For example, we read the book *Seven Blind Mice* (Young, 1993) to teach about NOS aspects such as inferential, tentative, and creative NOS aspects. This book tells the story of seven blind mice discovering different parts of an elephant and arguing about its appearance. We purposefully tried to make reading and writing an integral part of NOS and NOSI instruction where appropriate.

Participants were shown how to prepare concept maps using Inspiration software and they were asked to create a concept map of their NOS views in groups of three or four. They were given an opportunity to present their nature of science concept maps to the whole class.

Participants also involved in inquiry activities with regard to the concepts of experimental design, buoyancy, viscosity-density, and plant adaptations in a desert environment. Experimental design activity covered how to identify dependent, independent, and controlled variables in an experimental setting. Experimental design activity was supported with an oral reading of *Mr. Electronic Journal of Science Education*

Archimedes Bath (Allen, 1980). This book helped participants make connections between the story and experimental design, dependent and independent variables. The buoyancy activity asked teachers to explore whether an object weighs more or less in a glass dome with air removed compared to its weight in a glass dome filled with air or water. Participants went through a series of carefully designed activities to answer this question. The buoyancy activity was also supported with an oral reading of *Air is All Around You* (Branley & Keller, 1986). The viscosity-density exploration involved participants in a number of activities exploring whether there is a relationship between viscosity and density. The plant adaptations in a desert environment activity asked teachers to explore what type of adaptations plants might have to enable them to survive in a desert environment. Participants drew pictures and technical drawings of a variety of plants living in a desert environment in their science notebooks. They were also asked to explain in writing how certain characteristics of these plants help them to survive in desert. The plant adaptations in a desert environment activity was conducted outdoors in a certified arboretum with about 120 different desert shrubs and trees. See Table 1 for a timeline of the activities.

All these activities aimed to raise the status of desired NOS and NOSI conceptions while lowering the status of undesired NOS and NOSI conceptions within the conceptual ecology. To achieve this objective professional development program activities were modeled after the conceptual change approach (Hewson et al., 1998). This conceptual change approach suggests that students and teachers' NOS and NOSI conceptions should be made an explicit part of classroom discourse, students should critically think about their own NOS and NOSI conceptions, they should compare their NOS and NOSI views with their peers' and instructor's NOS and NOSI views, and they should discuss and justify to what extent their NOS and NOSI views change or stay the same.

Table 1

NOS activities and target NOS aspects

Day	Activity/Reading
1	Science notebooks introduction
	Reading discussion-The principal elements of the nature of science: Dispelling the myths (McComas, 1998)
	Tricky tracks (Lederman & Abd-El-Khalick, 1998)
	The tube (Lederman & Abd-El-Khalick, 1998)
	Reading-Seven blind mice (Young, 2002)
2	Exploring elementary students' science notebooks
	Reading discussion- Chapters 1 and 2 (NRC, 1996)
	Collaborative concept mapping NOS

The cubes (Lederman & Abd-El-Khalick, 1998)

Experimenting/controlling variables/

Reading-Mr. Archimede's Bath (Allen, 1980)

- 3 Guided inquiry activities related to buoyancy, floating and sinking, and viscosity-density

Reading-Air is All Around Us (Branley & Keller, 1986)

- 4 Guided inquiry activities related to plant adaptations in a desert environment

- 5 Fiction and nonfiction science books reading strategies
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Data collection

Data were collected through two open-ended questionnaires and one Likert-type instrument. The two open-ended questionnaires, the VNOS-B developed by Lederman et al. (2002) and the VOSI developed by Schwartz et al. (2008), were used to assess participants' NOS and NOSI views respectively. Lederman et al. (2002) provided extensive information about the construct validity of the VNOS-B. They showed that the VNOS-B successfully distinguishes between experts' and novices' nature of science views.

Both at the beginning and at the end of the professional development program, using a semi-structured interview approach the first author interviewed five teachers and asked them to elaborate on their written answers from both VNOS-B and VOSI questionnaires. Each interview took approximately 30 minutes. Five teachers interviewed at the beginning of the professional development program were different from five teachers interviewed at the end of the professional development program. This was done to make sure that we are validly interpreting the questionnaire data and do not misinterpret participants' answers to VNOS-B and VOSI questions during data analysis.

The STEBI-B developed by Enoch and Riggs (1990) was used to assess participants' science teaching efficacy beliefs. The STEBI consists of 23 items, each to be rated by the participant on a 1 (strongly disagree) to 5 (strongly agree) Likert scale. Riggs and Enoch (1990) validated the STEBI-B through factor analysis. Participants were videotaped throughout the professional development program. The first author also took field notes during the study. All three instruments were administered at the beginning and at the end of the professional development program in pre- and post format. Five participants were also interviewed at the beginning and at the end of the professional development program about their answers in the VNOS-B and the VOSI. Professional development activities were videotaped. The first author also took field notes and reflected on the activities every day during the professional development program.

Data analysis

Profiles of participants' NOS and NOSI views were created based on pre- and post administrations of the VNOS-B and the VOSI questionnaires. The first author interviewed a total of ten randomly selected participants (five at the beginning of the intervention and five at the end

of the intervention) based on their written answers in VNOS-B and VOSI questionnaires. These ten participants' responses in the follow-up interviews were transcribed and analyzed separately. Profiles created based on follow-up interviews were compared to the profiles generated from the written VNOS-B and VOSI questionnaire responses. These profiles were then checked against the data by looking for negative cases and then the necessary modifications were made on the analysis by arriving at a final profile which combines profiles based on written responses in questionnaires and follow-up interviews. The pre- and post-profiles for each question were compared to assess changes in participants' NOS and NOSI views. See Table 2 and Table 3.

Science teaching efficacy data were analyzed using Statistical Package for the Social Science (SPSS 14.0). Means, standard deviations, maximum and minimum scores for two subscales (PSTE and STOE) were calculated. Cronbach's alpha values for two subscales were also calculated. See Table 4. To determine whether the professional development program had any influence on participants' PSTE and STOE beliefs two paired samples t-tests were performed by using pre- and post-administration of STEBI-B scores.

Results

Participants improved their NOS understandings. Table 2 shows the number of participants holding informed and uninformed NOS views before and after the intervention. Almost all participants had already informed views about certain NOS aspects such as the tentative, empirical, and creative nature of science. However, they were able to give better examples and explanations for tentative, empirical, and creative NOS aspects after the professional development program. All participants both before and after the intervention acknowledged that scientific theories are subject to change, but prior to instruction held many misconceptions about the nature of theories. For example, they cited that Pluto being degraded as a planet is an example of a theory change. All participants also acknowledged that scientists use their creativity before, during and after data collection both at the beginning and at the end of the intervention. Participants both before and after the intervention demonstrated informed views of empirical NOS aspect by recognizing the role of evidence in justifying scientific knowledge claims. All participants at the end of the intervention compared to seven participants at the beginning of the intervention acknowledged that personal and theoretical biases of scientists influence data interpretation (subjective NOS). For example, one participant expressed her views about subjective NOS as follows.

Data can be interpreted in many ways. Scientists don't know if they have the correct answers to any questions. They use their data to provide an explanation and it depends on how one looks at the data to frame inferences. They may not always be the same results.

Twelve participants (vs. 5 participants before the intervention) held informed inferential NOS views. For example, they stated that "scientists used creativity and experiences to infer what an atom looks like." Others also acknowledged that the structure of the atom is determined by indirect evidence.

Table 2

Number of teachers holding informed and uninformed NOS views before and after the intervention

NOS aspects	Tentative NOS		Empirical NOS		Inferential NOS		Creative NOS		Subjective NOS	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Informed	17	17	12	18	6	13	17	17	9	17
Uninformed	0	0	0	0	0	3	0	0	9	0
No answer or irrelevant answer	2	2	7	1	13	3	2	2	1	2

No answer or irrelevant answer means that participants' responses did not include any specific information about the relevant NOS aspect.

Participants improved their understandings of NOSI as well. Table 3 shows the number of participants holding informed and uninformed NOSI views before and after the intervention. Nine participants began the program with the view that there is one a linear step-by-step scientific method that leads to the correct answer. However, at the end of the intervention 18 participants acknowledged that there is not a step-by-step scientific method that scientists follow to pursue scientific questions. Participants recognized that scientists use different methods while conducting scientific investigations. They also recognized that there can be various interpretations of the same data set because scientists might have different personal and theoretical orientations. Seven participants at the beginning of the intervention were not able to differentiate between an observational study and experimental study at the beginning of the intervention. However, only 2 participants did not know the difference between observational and experimental study at the end of the intervention. Seventeen participants acknowledged that both observational and experimental studies are scientific at the end of the intervention. Participants were able to justify the importance of supporting claims with evidence by using more sophisticated examples. For example, one participant stated that "Scientific knowledge is something empirically known based on observation, measurement, or objective means. An opinion is a belief that may or may not be subject to proof." Most participants already knew the difference between data and evidence. Thirteen participants at the beginning of the intervention and 14 participants at the end of the intervention were able to distinguish between data and evidence. They stated that data and evidence are not the same and data

become evidence when data are used to verify or falsify an idea or hypothesis. As one participant had put it “evidence is data, but it is data that can be used to reach a conclusion or make a decision. Evidence can support a theory or belief. Evidence can also refute a theory or belief.”

Table 3

Number of teachers holding informed and uninformed NOSI views before and after the intervention

NOSI aspects	The scientific method		Views of experiments		Interpretations of data		Data & Evidence	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Informed	9	18	11	17	9	16	13	14
Uninformed	9	1	7	2	6	3	5	5
No answer or irrelevant answer	1	0	1	0	4	0	1	0

No answer or irrelevant answer means that participants’ responses did not include any specific information about the relevant NOSI aspect.

Only the STOE beliefs of participants improved after the intervention ($t = 2.7$, $p = 0.01$). PSTE beliefs did not significantly improve after the intervention. Results of this study indicated that it is possible to improve elementary teachers NOS and NOSI views after a program specifically designed to teach about NOS and NOSI integrated with language arts. We do not claim that there is a causal relationship between improved NOS and NOSI views and science teaching efficacy beliefs. However, post-intervention STOE scores were significantly higher than pre-intervention STOE scores. This means that elementary teachers at the end of the professional development program were more likely to believe that student achievement can be changed by effective teaching. We intend to explore the reasons why participants’ post-intervention STOE scores were better than their pre-intervention STOE scores through in future studies. Similarly, future studies should also explore why PSTE scores did not change at the end of the intervention.

Table 4

Means, standard deviations, maximum and minimum scores of pre and post science teaching efficacy beliefs

Science teaching efficacy beliefs		Mean	SD	Max.	Min.	α
PSTE	Pre	51.17	3.91	60	43	0.78
	Post	51.94	4.64	59	41	0.66
STOE	Pre	35.33	3.61	45	29	0.50
	Post	37.22	3.59	44	30	0.52

Result of this study also indicated explicit-reflective NOS and NOSI instruction integrated with language arts were related to improving at least one aspect of elementary teachers' science teaching efficacy beliefs. The study described here is the initial phase of a long term study aimed to explore the relationships between NOS and NOSI views and elementary teachers' science efficacy beliefs. Although there are studies examining NOS and NOSI views and elementary teachers' science teaching efficacy beliefs in isolation, there is a lack of research of research exploring how explicit-reflective NOS and NOSI instruction can influence elementary teachers' science teaching efficacy beliefs. From this study, we can see there is some relationship, and further details of that relationship should be explored.

Discussion

Our findings indicate that participants can improve their NOS and NOSI views if NOS and NOSI are taught in connection with language arts, a subject about which they already feel comfortable. Our findings also indicate that explicit-reflective NOS and NOSI instruction supported with language arts connections can help elementary teachers improve their STOE beliefs.

Wheatley (2002) suggested that teachers are more likely to reflect on and learn from their doubts regarding their personal teaching efficacy if they believe that student achievement can be changed by effective teaching. Considering Wheatley's (2002) reasoning, it can be concluded that elementary teachers' doubts about their personal teaching efficacy and their confidence in student teaching outcome expectancy might be the right combination to foster elementary teachers' professional development. Though we recognize that relationships among NOS and NOSI understandings and science teaching efficacy beliefs could well be explored through longitudinal studies we know that short-term studies can also be informative and they can pave the way for longitudinal studies. The results of this study indicated that it is possible to improve elementary teachers' STOE beliefs by improving their NOS and NOSI understandings through specifically designed curriculum.

Professional development programs that employed explicit-reflective NOS and NOSI instruction have been shown to be effective in improving teachers' NOS and NOSI understandings (e.g. Akerson & Hanuscin, 2007). This professional development program also

used explicit-reflective NOS and NOSI instruction and explicit-reflective instruction was supported with language arts practices. NOS and NOSI lessons and activities were at the center of the professional development program. Language arts practices were used when they meaningfully supported learning about NOS and NOSI understandings. Explicit-reflective NOS and NOSI instruction supported with language arts practices not only introduces participants to informed NOS and NOSI understandings but also it introduces these conceptions through lessons and activities that are in line with conceptual change approach. In this approach, participants are given opportunities to explore their own conceptions, they are engaged in activities that are designed to expose them informed NOS and NOSI understandings, they are given opportunities to compare and contrast their initial views with NOS and NOSI understandings that are accepted by science education community, and they are encouraged to reflect on their learning experience. We believe that not only the plausibility and fruitfulness of NOS and NOSI views but also the way in which they are conveyed to the participants makes a difference in improving participants' NOS and NOSI understandings.

Another critical point is that NOS and NOSI conceptions were taught integrated with language arts. The fact that the elementary teachers were learning NOS and NOSI integrated within a subject that is their specialty (language arts) could also be a reason they improved their STOE beliefs. When science is connected to a subject they do feel comfortable teaching it could improve their efficacy for teaching science, which is generally a subject they are not comfortable teaching. In other words, connecting science, NOS and NOSI to a comfort area enabled them to develop comfort in an area they previously avoided.

Limitations of the Study

We acknowledge that the current study has certain limitations. First, number of participants (n=19) is low to conduct a powerful quantitative analysis to determine the difference between pre- and post science teaching efficacy beliefs. Second, Cronbach's alpha values for science teaching efficacy beliefs' subscales are far from ideal. Third, we did not have a control group in this study. Therefore, our findings with regard to change in elementary teachers' STOE beliefs should be read with these caveats in mind. Future studies should include a larger number of participants and a control group to more clearly identify to what extent explicit-reflective NOS and NOSI instruction supported with language arts connections can improve elementary teachers' science efficacy beliefs. Future studies should also make use of interviews to identify the meanings that teachers attribute to science teaching efficacy questions. Studies utilizing extensive classroom observations to explore how science teaching efficacy beliefs are reflected in actual classroom settings can also be extremely informative.

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