

Exploring the relationships among epistemological beliefs, metacognitive awareness and nature of science

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This study aims to investigate the relationships among epistemological beliefs, metacognitive awareness, and nature of science (NOS). Participants were 45 preservice science teachers (PSTs) enrolled in two sections of Laboratory Application in Science II course in a university in Turkey. All of the participants were juniors with the same science major background. Participants in both groups were engaged with explicit-reflective and inquiry-based NOS instruction under conceptual change theory. This study is considered as a mixed methods concurrent embedded design model. After the intervention, all of the PSTs demonstrated developments about many of the NOS aspects. It can be concluded that inquiry-based laboratory instruction informed by the conceptual change theory provided PSTs' improve their NOS understanding. This study revealed statistically significant relationships among the some aspects of NOS, epistemological beliefs, and metacognitive awareness. The relationships were discussed in respect to current science education literature.

Keywords: epistemological beliefs, metacognitive awareness, nature of science

Introduction

There have been many studies about how to promote students' learning in science. To achieve this aim, science educators applied several epistemological approaches. In particular, last four decades researchers designed their studies under 'constructivist' approach (Taber, 2009; Tobin, 2000; White, 1998). Contemporary science reforms focused on constructivism as a main view and they highlighted many concepts. As related to the current study, some of these are inquiry-based instruction, epistemological beliefs, metacognitive awareness, and nature of science concepts (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996).

One of the most consistent messages in science association reforms is that, developing students' conceptions of nature of science (NOS) (AAAS, 1993; NRC, 1996). There is no agreed upon a single definition of NOS, because it has been defined in various ways (Driver, Leach, Millar, & Scott, 1996). However, there is consensus about it is related to epistemology and values and beliefs for scientific knowledge. Abd-el-Khalick, Bell, and Lederman (1998) defined "typically, the nature of science has been used to refer to epistemology of science, science a way of knowing, or the values and beliefs inherent to the development of scientific knowledge" (p.418).

In addition, NOS was accepted as one of the important component of scientific literacy (Abd-El-Khalick & Lederman, 2000; Bybee, 1997). If it is expected from every citizen to make appropriate decisions about social-political issues in real life, policy makers should consider scientific literacy that includes NOS aspects. The close relationship between NOS and epistemological beliefs was addressed that, NOS refers to the epistemology of science (Lederman, 1992).

Epistemology was defined as “the origin, nature, limits, methods, and justification of human knowledge” (Hofer 2002, p. 4). After 1990s, some studies were done different perspective from previous research about epistemology, personal epistemology, and epistemological beliefs (Schommer, 1990; Hofer & Pintrich, 1997). Hofer (2002) delineated epistemological beliefs as one’s beliefs about knowing and knowledge. Schommer (1990) tried to answer two questions in her study, what are the students’ beliefs about the nature of knowledge, and how do these beliefs affect comprehension? Hofer and Pintrich (1997) envisioned epistemological beliefs as a domain-specific multidimensional construct. They stressed two general areas represent the core structure of learner’s epistemological theories; these are nature of knowledge and nature of knowing. Hofer and Pintrich (1997) suggested two dimensions for each area, under nature of knowledge; certainty of knowledge and simplicity of knowledge were suggested. Moreover, for nature of knowing area; source of knowledge and justification for knowing were suggested. At the end of the study the researchers emphasized that constructivist approach will undoubtedly continue to affect research in this area. Recent studies showed that, not only epistemological beliefs but also other factors can affect NOS understanding, one of the important factor described as metacognitive awareness (Abd-El-Khalick & Akerson, 2004).

Metacognition includes some important cognitive processes, which are important for any forms of learning. Schraw and Dennison (1994) defined metacognition as a referring to the ability to reflect upon, understand and control one’s one learning. Schraw and Dennison (1994) described two major components of metacognition; knowledge about cognition and regulation of cognition. They explained knowledge about cognition represents reflective aspect of metacognition and includes three dimensions; declarative knowledge, procedural knowledge, and conditional knowledge. Regulation of cognition refers to knowledge about facilitate the control aspect of learning, including planning, strategies, monitoring, and evaluating. The purpose of this study was to investigate the relationships among epistemological beliefs, metacognitive awareness, and nature of science views for prospective science teachers.

Theoretical Background

The nature of knowledge has several epistemological approaches, which are different philosophical views to understand scientific knowledge. Some of them are very important and they influence the development of curriculum from elementary school through university and influence the type of instructions. These are positivism, constructivism, realism, and rationalism (Matson & Parsons, 2006). The current study was conducted within a constructivist approach of scientific knowledge.

In the past, some educators and psychologists developed important learning theories, which try to explain learning. One of the most famous is Piaget, who developed his cognitive development theory through some observations and interviews with children. Piaget’s theory leads to constructivist theories related to how new information is assimilated. Another famous psychologists is Ausubel, his meaningful learning theory emphasized the importance of advance organizers for information processing. Ausubel made much of importance to prior knowledge, he asserted that “If I had to reduce all of educational psychology to one principle, I would say this: the most important single factor influencing learning is what the learner already knows. Ascertain

this and teach him accordingly”, in his book (Ausubel, 1968, p.18). We know that students already have alternative explanations; they do not come class with empty minds. Generally, students’ alternative conceptions are different from the scientific conceptions taught in class. This situation is similar for students’ views of NOS (Lederman, 1992).

Conceptual change is accepted a way of meaningful learning science from constructivist approach (Duit & Traegust, 2003). Studies in science education showed that students do not come into science classes without any pre-instructional knowledge about the subjects to be taught. Students come together their conceptions and ideas that are not in consistence with the science views or generally they contrast to them (Duit & Traegust, 2003). Similar situation was seen for the some studies, which especially focused students’ conceptions at the content level to understand their learning about views of nature of science and views of learning. Therefore, science educators and researchers focused conceptual change studies.

The conceptual change model was developed by Posner, Strike, Hewson, and Gertzog (1982), and used as a way of thinking about the learning of disciplinary content such as physics and biology. In this model, learning includes changing a learner’s conceptions in addition to an interaction between new and existing conceptions (Hewson, 1992). Although, many criticisms made about the model two major components remain central to learning as conceptual change. These are “concept status” and “conceptual ecology” (Hewson, 1992). Abd-El-Khalick and Akerson (2004) used “learning ecology” instead of “conceptual ecology, because they asserted that “learning ecology” is expanded to include elements from the cognitive, affective, motivational, contextual, social, and cultural domains. There are four conditions were identified in the conceptual change model. First, learners confronted with a new condition use their existing knowledge (their learning ecology) to determine whether is different or not, if it is different dissatisfaction condition is occurred. Second, whether the new condition is intelligible (knowing what it means) or not. Third, whether the new condition is plausible (believing it to be true) or not. Fourth, whether the new condition is fruitful (finding it useful) or not (Hewson, 1992).

After some criticisms, the latest revision of the conceptual change model by Hewson, Beeth, and Thorley (1998) went some way in addressing some concerns. The main criticism about role of cognitive conflict was modified (Abd-El-Khalick & Akerson, 2004). Hewson et al. (1998) emphasized that teaching for conceptual change refers to teaching that explicitly aims to help students’ experience conceptual change learning, and they defined some guidelines consistent with the conceptual change model. They put four general guidelines for conceptual change. These are; a) students and teachers’ ideas about the target topic should be made an explicit part of classroom discourse, b) discourse should be made explicitly metacognitive, c) the status of ideas and concepts in terms of intelligibility, plausibility, and fruitfulness should be explicitly discussed and negotiated, and d) the justification for ideas and status decisions should be made an explicit component of the curriculum (Hewson, et al., 1998).

Literature Review

The recent NOS literature especially related to conceptual change theory showed that there are some factors, which facilitate or hinder understanding of NOS views. The most important factors can be ordered as epistemological beliefs, prior conceptions about NOS, and metacognitive awareness (Abd-el-Khalick, Bell & Lederman, 1998; Abd-El-Khalick & Akerson, 2004; Lederman, 1992; Southerland, Johnston & Sowell, 2006). This study was designed in the light of these factors.

Science educators have focused on some factors that would mediate understanding of NOS aspects, for example, epistemological beliefs, motivational level, and metacognitive aware-

ness (Abd-El-Khalick & Akerson, 2004); past science experiences, attitudes toward science, self-efficacy, learning dispositions and related general epistemological beliefs, and religious beliefs (Southerland et al., 2006).

Researchers conducted many important studies that contributed science education especially about nature of science. Some of them (e.g., Abd-El-Khalick & Akerson, 2004; Akerson, Abd-El-Khalick & Lederman, 2000; Schwartz, Lederman, & Crawford, 2004) are similar in terms of their goals, methodologies, and samples. Studies (e.g., Abd-El-Khalick & Akerson, 2004; Akerson, Abd-El-Khalick & Lederman, 2000) aimed at developing preservice teachers' NOS understandings and used the explicit-reflective approach as an instruction method. In addition, these studies use similar methods to collect data, similar questionnaires, interviews, and reflections papers. Although, some studies (e.g., Akerson, Abd-El-Khalick & Lederman, 2000; Schwartz, Lederman, & Crawford, 2004) were applied in method courses, some others were conducted in the science laboratory classes, and activities were designed for inquiry approach, minds on- hands on with together, also activities included science context.

Schommer (1990) emphasized five related, but independent dimensions representing personal epistemology. Schommer used epistemological questionnaire with five dimensions and shorthand terminology in parentheses are the following. 1) Knowledge is simple rather than complex (Simple Knowledge); 2) Knowledge is handed down by authority rather than derived from reason (Omniscient Authority); 3) Knowledge is certain rather than tentative (Certain Knowledge); 4) The ability to learn is innate rather than acquired (Innate Ability); 5) Learning is quick or not at all (Quick learning) (Schommer, 1990). At the end of the study, Schommer suggested five conclusions, these are "a) Personal epistemology can be characterized as a system of more or less independent beliefs, b) these beliefs have distinct effects on comprehension and learning, c) epistemological beliefs are influenced by home and educational background, d) these effects exist beyond the influence of variables found to influence comprehension and learning, and e) these effects are generalizable across two content domains" (Schommer, 1990, p.503).

Hewson et al. (1998) stressed that metacognition is particularly important in conceptual change learning because; it is related to knowledge of learners' own cognitive processes and products. There is closely relationship between metacognition and conceptual change. Gunstone (1994) emphasized that for proper conceptual change process a learner needs to be metacognitive. Hewson et al. (1998) stressed some strategies for encouraging metacognition. For example, asking questions students to consider their own past-recorded responses and encouraging students to discuss with their group members and whole-class.

In recent time, there are some studies, which focused to show relationships between metacognition and NOS understanding (Abd-El-Khalick & Akerson, 2004; Abd-El-Khalick & Akerson, 2009). Consistent with the use of explicit-reflection instruction, a conceptual change approach to teaching about the nature of science makes NOS an explicit part of the classroom discourse, provides learners with structured opportunities to explain their ideas, discuss the strengths and limitations of those ideas, and assess the consistency of their ideas with those of others. Additionally, discourse is metacognitive, that is, "learners need to make their ideas and thinking an object of cognition" (Abd-El-Khalick & Akerson, 2004, p. 791). One of the most important and recent study was conducted by Abd-El-Khalick and Akerson (2009). The researchers aimed using metacognitive strategies to develop understanding NOS views for prospective elementary teachers. This study was designed as empirical and the explicit-reflective method used in both groups, however, for the intervention group metacognition strategies were applied. The results of the study provide important contributions such as using metacognitive strategies promote prospective science teachers' understanding of NOS respect to comparison group, and using these strategies advance learners' awareness of metacognition.

Another study was conducted about epistemological belief by Schommer (1990). The study aimed to answer two questions; what are the students' beliefs about the nature of knowledge? In addition, how do these beliefs affect comprehension? The researcher conducted two studies she aimed to explore the relations between epistemological beliefs. At the end of the studies, the author reached five important conclusions, these were "a) Personal epistemology can be characterized as a system of more or less independent beliefs; b) these beliefs have distinct effects on comprehension and learning; c) epistemological beliefs are influenced by home and educational background; d) these effects exist beyond the influence of variables found to influence comprehension and learning; and e) these effects are generally across two content domains" (Schommer, 1990, p.503).

In literature, there is a gap about the relationship among epistemological beliefs, meta-cognitive awareness, and nature of science. It can be said that there are many common points between NOS and epistemological beliefs, because NOS refers to the epistemology of science (Lederman, 1992). Therefore, it is appropriate to think together between learners' epistemological beliefs about science and their NOS views. Furthermore, it can be said that if a method or instruction develops students' epistemological beliefs, this method or instruction can be used to improve students' views of NOS. It can be stated strong relations between metacognitive awareness and epistemological beliefs-NOS views, however, there is no research especially conducted to reveal these accepted relations. Therefore, this study aimed to contribute this area in science education literature.

In this study qualitative and quantitative research questions were investigated, the qualitative research question was; how do preservice science teachers' views change as a result of participating in these inquiry-based laboratory activities? Moreover, this study investigated the following quantitative research questions:

- 1) Does the explicit-reflective and inquiry-based NOS instruction improve PSTs' epistemological beliefs about science?
- 2) To what extent does the inquiry-based and explicit-reflective laboratory NOS instruction improve participants' metacognitive awareness?
- 3) Are there any correlations within and between students' pre- and post-instruction epistemological beliefs and metacognitive awareness?
- 4) Are there any correlations within and between students' pre- and post-instruction sub-categories of epistemological beliefs and metacognitive awareness?

Method

The primary intent of this investigation was to determine the impact of explicit-reflective and inquiry-based laboratory instruction on preservice science teachers' nature of science views, epistemological beliefs, and metacognitive awareness. This study is considered as a mixed methods concurrent embedded design experimental model, because the qualitative and the quantitative data were collected at the same time (Creswell, 2003). The data were merged together during the interpretation phase; they were analyzed separately in the result section. In the initial qualitative phase of the study, the researcher collected qualitative data to explore preservice science teachers' NOS views before the intervention. At the end of the intervention, qualitative data were collected to determine the impact of inquiry-based laboratory instruction and explicit-reflective teaching. The secondary purpose was to gather quantitative data to explore the relationships between nature of science views and epistemological beliefs, and metacognitive awareness. Therefore, the researcher collected quantitative data before and after the intervention.

Participants

For the Laboratory Application in Science II course 49 pre-service science teachers (PST) enrolled (three of them from past years) during the spring 2010 semester at a western university in Turkey. This course was re-designed and extended to provide meaningful and practical experiences by the researcher. At the beginning of the course, four PSTs did not accept to join on voluntarily for the study, therefore 45 PSTs formed the sample of this study (30 were female and 15 were male with a mean age of 21.6 year). All of the participants had the same science major background, and all of them were juniors. During the spring semester this course was taught in two different sections. At the beginning of the semester participants selected their own section and formed their study group (generally 4-5 students for each group).

The Study Context

In this study, the instruction was adopted from Ozgelen's (2010) study, all of the procedures and used activities were obtained from that study in the same course. The Laboratory Application in Science II course was a must for prospective elementary science teachers at faculty of education. This laboratory course provided opportunities for PSTs to participate 2-hour lab sessions. At the beginning of this part, there is a power-point presentation to provide the researcher's nature of science views reflect the science educators' views (e.g., Schwartz et al., 2004; Lederman et al., 2002). Moreover, PSTs took a quiz included two or three questions related to inquiry-based laboratory activities and the aspect of NOS at the beginning of the laboratory section. At the end of the laboratory activities, there was an hour in the organization of each course session for a week, focused presentation, and discussion about results of activities and relationship nature of science aspect. This part was addressed using the explicit-reflective nature of science instruction. Some researchers stressed on "reflection" as an important factor for conceptual change (Day, 1993; Irez & Cakir, 2006). In both of the explicit-reflective sections, preservice science teachers were engaged in reflective discussions of the target nature of science aspects followed by inquiry activities. The explicit-reflective NOS instruction focused on seven target NOS aspects during the semester. The instructors explained the nature of science aspect and managed discussion among groups every week.

During the semester, the instructors focused only upon one aspect of NOS each week. There are some debates about defining NOS; however, in this study the researcher used aspects of NOS identified by science educators to be relevant to K-16 education and about which there is a consensus (Abd-El-Khalick & Akerson, 2004; Lederman, Abd-El-Khalick, Bell & Schwartz, 2002; Schwartz, Lederman & Crawford, 2004). These include (1) The Empirical Nature of Scientific Knowledge; scientific knowledge is based on evidence and observations of the natural world. (2) Observations, Inference, and Theoretical Entities in Science; scientific knowledge includes observation and inference which are different. Observations are gathered through human senses and inferences are interpretations of those observations. (3) Scientific Theories and Laws; theories and laws are different kinds of scientific knowledge and one does not become the other. Laws describe observed or perceived relationships in nature. On the other hand, theories are inferred explanations for natural phenomena and mechanisms for relationships among natural phenomena. (4) The Theory-Laden Nature of Scientific Knowledge; scientific knowledge is theory-laden, scientists' theoretical and disciplinary commitments influence their works. (5) The Tentative Nature of Scientific Knowledge; scientific knowledge is never absolute or certain, scientific knowledge is subject to change with new observations and with the reinterpretations of existing new knowledge. (6) The Creative and Imaginative Nature of Scientific Knowledge; scientific

knowledge is created from human imaginations and logical reasoning, this creation is based on observations and inferences of the natural world. (7) The Social and Cultural Embeddedness of Scientific Knowledge; science affects and is affected by the various elements and intellectual spheres of the culture in which it is embedded. These elements include, but are not limited to, social fabric, power structures, politics, socioeconomic factors, philosophy, and religion. During the spring semester, PSTs did an activity related to only one aspect of NOS for each week.

In this study, the conceptual change model is used as a theoretical framework for researching the effectiveness of interventions intended to promote improved views of NOS. This model entails using the theory “to explicitly and functionally guide an intervention, design a study, collect and analyze data, and/or interpret findings” as well as using results to test and critically appraise the theory (Abd-El-Khalick & Akerson, 2006, p. 189).

In this study, conceptual change informed not only the design of the research, but also the design of instructional interventions. This part includes information about how teaching was matched with four guidelines before mentioned. First, every week before the laboratory, participants given laboratory sheets include basic readings about more informed views of the NOS aspects. In addition, before the laboratory activities participants took a quiz included two or three questions related to laboratory activities and the aspect of nature of science. Moreover, at the end of the laboratory activity, the researcher made a power point presentation about specific the aspect of NOS every week. These parts informed preservice science teachers with the science education community’s and researchers’ perspectives on NOS. This part of the study intended to elucidate and make preservice science teachers’ and the researcher’ NOS ideas an explicit part of classroom discourse. Thus, this part was suitable for Hewson et al.’s (1998) first guideline.

Second, during the intervention, all of the weeks, preservice science teachers were engaged laboratory activities related to views of NOS. At the end of the activity, each group discussed and completed their laboratory sheets. In addition to, at the end of the instructor’s presentation, all groups shared and discussed their results with other groups in the laboratory class. Therefore, participants attended small-group and whole-class discussions each week, with the intent of explicitly involving participants in meta-conceptual conversation about the target NOS ideas. This part related to our explicit reflective approach to NOS instruction, and consisted with the second guideline of Hewson et al.’s (1998).

Third, every week after the presentation the researcher managed whole-class discussion not related activity, especially stressed that the specific aspect of NOS. Participants were encouraged for discussion by the researcher. In addition to, each week at the end of the laboratory activities and discussions pre-service science teachers responded to write reflection paper, which includes three open-ended questions that were related to the laboratory’ topic and discussions. This part was coherent with the Hewson et al.’s (1998) third guidelines.

Fourth, at the end of the laboratory hours, participants asked some questions about their reflection papers and attended whole-class discussion to understand unclear points. In addition , preservice science teachers were expected to prepare an activity related the aspects of NOS suitable for elementary science curriculum. At the end of the semester each participant presented own activity for class and instructors. These parts consisted with the fourth guideline of Hewson et al.’s (1998) related to curriculum.

Engaging students in inquiry-based activities is an opportunity to develop their understanding of NOS (NRC, 2000). In order to complete inquiry-based laboratory activities, PSTs need to use their science process skills (SPS). The relationship between scientific inquiry and SPS was described by NRC (1996) as during scientific inquiry students should combine SPS and scientific knowledge to develop their understanding of science. Using inquiry as a method to develop preservice teachers’ NOS views is efficient (Akerson & Hanuscin, 2007). In this study,

SPS were classified in two different forms; these are Basic Science Process Skills and Integrated Science Process Skills. Basic SPS consist of observing, inferring, measuring, communicating, and classifying. Integrated SPS comprise of controlling variables, defining operationally, formulating hypotheses, interpreting data, and experimenting. In order to improve learners' ideas about NOS, science educators developed inquiry-based activities include science process skills (Bell, 2008).

The new design Laboratory Application in Science II included inquiry-based laboratory activities every week. In this course, PSTs had the chance to be actively involved in scientific activities and discussions. Every week PSTs had laboratory sheet, which included activity related to NOS aspect. PSTs completed these laboratory sheets using their SPS. For example, while completing these laboratory sheets PSTs were confronted with some directives such as: State your group purpose; State your group hypothesis; Set up your experimental design etc.

During the laboratory classes, PSTs were engaged in the laboratory activities related to views of NOS during the semester. Each PST in every group was expected to complete her/his laboratory sheets. While completing the sheets PSTs asked questions and discussed their tasks with each other. Furthermore, at the end of the instructor's presentation, all groups shared and discussed their results with other groups in the laboratory class. Therefore, PSTs joined small-group and whole-class discussions each week.

Qualitative Data Collection Procedure and Description of the Instrument

The Views of Nature of Science Questionnaire Version B (VNOS-B) is a seven-item open-ended questionnaire developed by Lederman, Abd-El-Khalick, Bell, and Schwartz (2002). The researchers revised some items of the VNOS-A (Lederman & O'Maley, 1990) to assess pre-service science teachers' views of the NOS. The VNOS-B questionnaire includes seven items related to science teachers' views of the tentative, empirical, creative, theory-laden, socially cultural, and also the function of and relationship between theories and laws, and distinction between observations and inferences (Abd-El-Khalick, Bell, & Lederman, 1998). There is a study in the literature managed by Lederman et al., (2002) to investigate the construct validity of the VNOS-B, according to this study the VNOS-B effectively differentiates between experts' and novices' views of NOS.

The questionnaire was used firstly at the beginning of the intervention to assess PSTs' NOS views, and was applied again at the end of the semester to find out changes in PSTs' NOS views. Pre and post administration of the VNOS-B were in the laboratory class, two instructors applied their sections.

Qualitative Data Analysis

All of the collected data were analyzed at the end of the course, because the researcher tried to avoid from some prejudgments would affect the study. The unit of analysis was a *statement*, defined by Palmquist and Finley as "a paragraph, group of sentences, sentence or phrase that contained a single unambiguous theme about the nature of science" (1997, p. 600). All statements were categorized as to whether they matched the contemporary views of science or traditional "myths" or "misconceptions" about science, or if they were a mix of contemporary and traditional views. During the analyzing data defining statements were validated through extensive discussions the researcher with the expert, who has experience with qualitative research related to NOS. First, the researcher developed and assigned codes and then the expert checked and discussed, and then the researcher rearranged the parts of analyses.

Quantitative Data Collection Procedures and Description of the Instruments

The Epistemological beliefs questionnaire was developed by Hofer (1997) was used to reveal pre-service science teachers' epistemological beliefs. It consists of 18 items on a five point Likert type scale [1 (strongly disagree) to 5 (strongly agree)] and four sub-scales; namely, (1) certainty/simplicity of knowledge (e.g., in science, most work has only one right answer); (2) justification for knowing (e.g., there is really no way to determine whether someone has the right answer in science); (3) source of knowledge (e.g., If my personal experience conflicts with ideas in the textbook, the book is probably right), and (4) attainability of truth (e.g., if scientists try hard enough, they can find the answers to almost anything). The Cronbach's alpha reliability coefficients of each sub-scales were reported as .80, .60, .64, and .74 respectively (Hofer, 1997). Pre and post administration of the instrument were in the laboratory class, the instructors applied their sections.

The Metacognitive awareness inventory (MAI) (Schraw & Dennison, 1994) instrument was used to determine pre-service science teachers' metacognitive awareness. This instrument consists of 52 items. Each item will be rated by participants on a bi-polar 0-10 continuous scale. While the right end of the scale indicated total agreement, the left end of the scale indicated total disagreement with each item. There are two major components in this scale: knowledge of cognition and regulation of cognition. Knowledge of cognition includes three different dimensions; i) declarative knowledge (e.g., I know what kind of information is most important to learn), ii) procedural knowledge (e.g., I have a specific purpose for each strategy I use), and iii) conditional knowledge (e.g., I use different learning strategies depending on the situation). Regulation of cognition includes five different dimensions; i) planning (e.g., I think about what I really need to learn before I begin a task), ii) information management strategies (e.g., I focus on meaning and significance of new information), iii) monitoring (e.g., I ask myself if I have considered all options when solving a problem), iv) debugging strategies (e.g., I change strategies when I fail to understand), v) evaluation (e.g., I ask myself if I learned as much as I could have once I finish a task). Pre and post administration of the instrument were in the laboratory class, the instructors applied their sections. The Cronbach's alpha coefficients of both factors were higher than .90 (Schraw & Dennison, 1994).

Since the design of the study was weak experiment and there was no control group in the study, Epistemological beliefs questionnaire and Metacognitive awareness inventory were administered to the preservice science teachers twice at the beginning, and at the end of the intervention.

Findings

Results of Qualitative Data

Table 1 was constructed in order to understand individual PSTs' developments in their understanding of NOS aspects. This table represents developments, declines and no changes from post VNOS-B according to pre VNOS-B results. It is important to note that the table shows only *changes*, not pre and post views about NOS aspects. The pre and post VNOS-B results were compared, as a result the Table 1 was developed.

Table 1. Each PST's developments NOS views from VNOS-B

(N) PS T	Empiri- cal NOS	Observation- Inference	Theories- Laws	Subjectivity	Tentativeness	Creativity	Social- Cultural	Total
1	+	+	+	0	+	+	0	+5
2	0	+	+	+	0	+	+	+5
3	+	0	+	+	0	+	+	+5
4	0	+	+	+	0	0	+	+4
5	0	+	+	+	0	+	+	+5
7	0	+	+	+	+	0	0	+4
9	+	+	+	+	+	+	0	+6
10	0	-	+	+	+	+	+	+5 -1
11	+	+	+	+	+	+	+	+7
12	0	0	+	+	+	+	+	+5
13	0	+	+	+	0	0	+	+4
14	+	+	+	+	+	+	+	+7
15	0	+	+	+	0	0	0	+3
18	+	+	0	+	+	+	0	+5
20	+	0	+	+	+	+	+	+6
22	+	+	+	0	+	+	0	+5
23	+	+	+	0	+	+	+	+6
25	0	+	0	0	+	+	0	+3
26	+	+	+	0	0	+	0	+4
28	+	+	+	+	+	+	0	+6
29	0	+	+	+	+	+	+	+6
30	0	+	+	+	+	0	0	+4
31	0	+	+	+	+	+	0	+5
32	+	+	+	+	+	+	0	+6
33	+	+	+	+	+	+	+	+7
34	0	+	+	+	+	+	+	+6
35	0	0	+	+	+	0	0	+3
36	0	+	+	+	+	+	0	+5
38	-	+	+	+	+	+	+	+6 -1
39	0	0	+	0	+	+	0	+3
40	0	+	+	+	0	0	0	+3
41	0	+	+	+	+	+	0	+5
44	+	+	+	+	+	0	0	+5
45	0	+	+	+	+	0	0	+4

+ indicates a change in views /developed understanding of NOS aspect after the intervention; 0 indicates no change in participant's views of NOS aspect after the intervention; - indicates a misconception about NOS aspect after the intervention

According to this table, if a PST stated informed NOS view in the post test but did not state in the pre test, "+" was signed related NOS aspect. It means that for specific NOS aspect the PST had contemporary views after the intervention. If a PST did not shown in the post-test any development according to pre test result, "0" was signed related NOS aspect. It means that for specific NOS aspect the PSTs' views did not change. Moreover, if a PST stated misconception in the post test but did not state in the pre test, "-" was signed. It means that for specific NOS aspect the PST had some misconceptions after the intervention

The Table 1 indicated that all of the PSTs showed developments about many of the NOS aspects. For empirical basis of NOS, 14 PSTs developed their understandings according to pre VNOS-B scores. For observation and inference, 28 PSTs stated contemporary views. For theory and law, 32 PSTs changed their understandings informed views. For subjectivity, 28 PSTs developed their understanding. For tentativeness, 26 PSTs declared contemporary views. For creativity and imagination, 25 PSTs changed their understanding informed views. For socio-cultural effect, 15 PSTs showed development their understandings of NOS aspect.

However, Table 1 also presents that two PSTs showed decline in their understanding of some aspect of NOS. One of them (PST #10) stated uninformed views about aspect of observation and inference. The PST stated that:

PST #10 from post VNOS-B: Atom looks like this... Scientists are sure [about atom structure] by the [imagines obtained from] electron microscopes.

She or he did not mention anything about scientific knowledge is observable and scientists can be sure in the pre VNOS-B.

The other PST showed uninformed views about aspect of empirical bases of NOS. While answering the post VNOS-B the PST stated that:

PST #38 from post VNOS-B: Opinions are very subjective, but scientific knowledge is more objective.

The PST did not point out anything related to objectivity of scientific knowledge in the pre application of VNOS-B. Individual PSTs' developments in terms of understanding NOS aspects were investigated using their answers for the pre and post VNOS-B questionnaire. The pre test was applied at the beginning of intervention and the post-test was applied at the end of the semester. PSTs' answers were assigned as inconsistent, transitional, and consistent according to science education reforms.

Analysis of Quantitative Data

Epistemological beliefs questionnaire and metacognitive awareness inventory were used in this study. The analysis of quantitative data was realized in two steps. In the first step, data-cleaning process was conducted for examining missing cases and outliers using descriptive statistics (Mean, percentage, frequency, and *SD*) for the data gathered through each of the instrument. After manipulating missing data and extreme cases, the data set was subjected to reliability analysis to calculate Cronbach's alpha reliability coefficients of each instrument. In the second step, separate inferential statistics (such as paired t-test and multiple correlations) were performed to test the hypotheses for each research question.

To determine which epistemological beliefs dimensions were improved significantly as a result of inquiry-based and explicit-reflective laboratory NOS intervention the targeted paired t-test was conducted.

In addition, multiple correlation analysis was conducted to determine whether there are statistically significant correlations participants' pre-intervention epistemological beliefs scores within themselves. Similarly, to determine any correlation within themselves for participants' post-intervention epistemological beliefs scores also correlated.

Moreover, for third research question multiple correlation analyses were conducted to determine whether there are statistically significant correlations participants' pre-intervention epis-

temological beliefs scores related to their metacognitive awareness and thinking dispositions measured at the beginning of the intervention.

For fourth research question, multiple correlation analyses were conducted to determine whether there are correlations participants' post-intervention epistemological beliefs scores related to their metacognitive awareness and thinking dispositions measured at the end of the intervention. Descriptive statistics for pre and post-epistemological beliefs survey are presented in Table 2.

Table 2. Descriptive scores of pre and post sub-dimensions of epistemological beliefs survey

Epistemological beliefs dimensions		Mean	SD	Max.	Min.
Certainty of knowledge	Pre	30.14	4.01	40	22
	Post	32.85	4.31	40	23
Justification for knowing	Pre	11.88	2.02	16	6
	Post	11.03	2.11	16	7
Source of knowledge	Pre	11.94	2.25	19	8
	Post	13.34	1.90	17	8
Attainability of truth	Pre	6.03	1.65	10	2
	Post	6.26	1.54	10	2

Note. High scores indicate agreement with more sophisticated epistemological beliefs.

Descriptive statistics for pre and post-metacognitive awareness inventory are presented in Table 3. In addition, Cronbach's alpha coefficients of sub-categories were determined as 0.89 and 0.94 respectively.

Table 3. Means, standard deviations, maximum and minimum scores of pre and post sub-dimensions of metacognitive awareness inventory

Sub-dimensions of Metacognitive awareness		Mean	SD	Max.	Min.
Knowledge of cognition	Pre	128.00	15.44	160	75
	Post	131.75	12.54	156	98
Regulation of cognition	Pre	266.78	30.23	320	174
	Post	273.24	25.03	318	163

Research Question 1. *Does the explicit-reflective and inquiry-based NOS instruction improve PSTs' epistemological beliefs about science?*

To determine which epistemological beliefs dimensions were improved significantly as a result of inquiry-based and explicit-reflective laboratory NOS intervention the targeted paired t-test was conducted. A paired-samples t-test was conducted to evaluate the impact of the inquiry-based and explicit-reflective laboratory NOS intervention on prospective science teachers' scores on the epistemological beliefs survey. The mean value from pre Epistemology survey is 60.00, with a standard deviation of 6.29. The mean value from the post Epistemology survey at the end of the semester is 63.51, with a standard deviation 5.97. According to result of the paired sample t-test, there was a statistically significant increase in epistemology scores from pre Epistemology survey

(M=60.00, SD=6.29) to post Epistemology survey (M=63.51, SD=5.97), $t(51)=3.44$, $p<.005$. The eta squared statistic (.18) indicated a large effect size (Cohen, 1988), it is high enough to warrant practical significance for the difference determined.

The further step was to explore that, is there a significant difference between pre and post epistemological beliefs scores on each dimension. For this purpose a paired samples t-test was performed. Table 4 shows that preservice science teachers' post-epistemological beliefs scores for two dimensions were significantly higher than their pre-epistemological beliefs scores. In order to determine the differences in two sets of scores were unlikely to occur by chance the effect size values were calculated. One of the most commonly used effect size statistics is Eta squared. In this part for all of the statistics analysis Eta squared values were calculated. To interpret eta squared values this guidelines can be used; .01=small effect; .06=moderate effect; .14=large effect (Cohen, 1988). Effect size values of certainty of knowledge and source of knowledge dimensions were large. It can be concluded that there were large effects, with substantial differences in the certainty of knowledge and the source of knowledge scores obtained before and after the inquiry-based and explicit-reflective laboratory NOS instruction. However, according to results of paired sample t-test, there is no statistically difference between pre and post values of justification for knowing and attainability of truth dimensions.

Table 4. Paired-sample t-test results

Epistemological beliefs dimensions	Mean pre	Mean post	t	df	Effect size
Certainty of knowledge	30.14	32.85	3.95*	51	0.23
Justification for knowing	11.88	11.03	-2.19	51	0.08
Source of knowledge	11.94	13.34	3.87*	51	0.22
Attainability of truth	6.03	6.26	0.85	51	0.01

* $p<.001$

According to Table 4, after the inquiry-based and explicit-reflective laboratory NOS instruction preservice science teachers were more likely to support the following views: (1) certainty and simplicity of knowledge; scientific knowledge is subject to change and it is opposed to being unchanging and concrete and (2) source of knowledge; scientific knowledge does not depend on any outside authority. Results of this study advocate that the inquiry-based and explicit-reflective laboratory NOS instruction was effective in improving participants' some epistemological beliefs about science. After the intervention, preservice science teachers held more sophisticated epistemological beliefs about science.

Research Question 2. To what extent does the inquiry-based and explicit-reflective laboratory NOS instruction improve participants' metacognitive awareness?

A paired-samples t-test was conducted to evaluate the impact of the inquiry-based and explicit-reflective laboratory NOS intervention on prospective science teachers' scores on the metacognitive awareness survey. The mean value from pre metacognitive awareness was 394.78, with a standard deviation of 44.14. Moreover, the mean value from the post metacognitive awareness at the end of the semester is 404.99, with a standard deviation 36.08. According to result of the paired sample t-test, there was no statistically significant difference between pre and post application of metacognitive awareness inventory. Although there are some increases mean scores for

sub-categories of metacognitive awareness that knowledge of cognition and regulation of cognition, there was no statistically significant difference between pre and post application. This finding can be explained by small sample size and some participants did not complete pre and/or post metacognitive awareness survey applications.

Research Question 3. *Are there any correlations within and between students' pre- and post-instruction epistemological beliefs and metacognitive awareness?*

In addition, correlation analyses were conducted to determine whether there are correlations participants' pre-intervention epistemological beliefs and metacognitive awareness scores within themselves. Similarly, to determine any correlation within themselves for participants' post-intervention epistemological beliefs scores and metacognitive awareness also correlated.

According to Table 5, all of the correlations are positive; it means that high scores on one associated with high scores on the other, or low scores on one associated with low scores on the other. It was expected that all scores were positive and high scores for this study. To determine the strength of the relationships this guidelines can be used; $r=.10$ to $.29$ or $r=-.10$ to $-.29$ small; $r=.30$ to $.49$ or $r=-.30$ to $-.49$ medium; $r=.50$ to $.10$ or $r=-.50$ to $-.10$ large (Cohen, 1988).

Table 5. Correlations among participants' pre-post epistemological beliefs and metacognitive awareness

Measures	1	2	3	4
1. Epistemological beliefs pre-test	1			
2. Metacognitive awareness pre-test	0.06	1		
3. Epistemological beliefs post-test	0.28*	0.26	1	
4. Metacognitive awareness post-test	0.18	0.08	0.30*	1

* $p < .05$

According to results of the correlation analyses, it was found that there is very small and not statistically significant correlation between pre-epistemological beliefs scores and pre-metacognitive awareness scores ($r=.06$). However, Table 5 shows that post-intervention epistemological beliefs was correlated with post-metacognitive awareness scores ($r = .30$, $p < .05$). This suggested medium positive relationship between epistemological beliefs and metacognitive awareness. In addition, it was found that there was a correlation between pre and post interventions of epistemological beliefs ($r = .28$, $p < .05$), it was closed to medium correlation.

As a conclusion, the relationship between participants' epistemological beliefs and metacognitive awareness was investigated using Pearson product moment correlation coefficient. Preliminary analyses were performed to ensure no violation of the assumption of normality, linearity and homoscedasticity. There was a medium positive correlation between the two variables after the intervention [$r=.30$, $n=52$, $p<.05$], with high scores of metacognitive awareness associated with high scores of epistemological beliefs.

Research Question 4. *Are there any correlations within and between students' pre- and post-instruction sub-categories of epistemological beliefs and metacognitive awareness?*

In order to investigate for sub-categories of epistemological beliefs scores and metacognitive awareness scores Pearson product moment correlation coefficient for pre and post applications. Table 6 shows correlations among participants' pre-epistemological beliefs and pre-

metacognitive dimensions. Preliminary analyses were performed to ensure no violation of the assumption of normality, linearity and homoscedasticity.

Three correlations were determined among sub-dimensions at the beginning of the intervention. First; certainty of knowledge dimension correlated with source of knowledge dimension ($r = .30, p < .05$). This suggested medium positive relationship between two variables before the intervention. Second; attainability of truth dimension correlated with source of knowledge dimension ($r = .44, p < .01$). This suggested medium positive relationship between two variables before the intervention. And, third; regulation of cognition correlated with knowledge of cognition ($r = .85, p < .01$). This suggested a strong relationship between two variables before the intervention.

Table 6. Correlations among participants' pre-epistemological beliefs and pre-metacognitive dimensions

Measures	1	2	3	4	5	6
1. Certainty of knowledge	1					
2. Justification for knowing	-0.00	1				
3. Source of knowledge	0.30*	0.01	1			
4. Attainability of truth	0.19	0.03	0.44**	1		
5. Knowledge of cognition	0.17	-0.03	-0.10	-0.07	1	
6. Regulation of cognition	0.20	-0.04	-0.10	-0.02	0.85**	1

* $p < .05$, ** $p < .01$

It can be concluded from the Table 6; the other pre correlations among sub-dimensions were very small and there was no any statistical significance among them. After the laboratory instruction, the relationship between participants' post epistemological beliefs and metacognitive awareness was investigated using Pearson product moment correlation coefficient. Preliminary analyses were performed to ensure no violation of the assumption of normality, linearity and homoscedasticity.

Table 7. Correlations among participants' post-epistemological beliefs and post-metacognitive dimensions

Measures	1	2	3	4	5	6
1. Certainty of knowledge	1					
2. Justification for knowing	0.11	1				
3. Source of knowledge	0.13	-0.10	1			
4. Attainability of truth	0.19	-0.26	0.37**	1		
5. Knowledge of cognition	0.26	-0.16	0.02	0.38**	1	
6. Regulation of cognition	0.33*	-0.05	0.05	0.32*	0.82**	1

* $p < .05$, ** $p < .01$

According to Table 7, generally all correlation values increased after the intervention. Especially, it was found five significant correlations among sub-categories at the end of the semester. First; certainty of knowledge dimension correlated with regulation of cognition ($r = .33$, $p < .05$). Although there was no statistically significant relationship at the beginning of the intervention, the post correlation result suggested medium positive relationship between two variables after the intervention. Second; similarly pre correlation result, attainability of truth dimension correlated with source of knowledge dimension ($r = .37$, $p < .01$). This suggested medium positive relationship between two variables after the intervention. Third; similarly pre correlation result, regulation of cognition correlated with knowledge of cognition ($r = .82$, $p < .01$). This suggested a strong relationship between two variables after the intervention. Fourth; attainability of truth dimension correlated with regulation of cognition ($r = .32$, $p < .01$). Although there was negatively relationship at the beginning of the intervention, the post correlation result suggested medium positive relationship between two variables after the intervention. Lastly; attainability of truth dimension correlated with knowledge of cognition ($r = .38$, $p < .01$). Although there was negatively relationship at the beginning of the intervention, the post correlation result suggested medium positive relationship between two variables after the intervention.

Discussion and Implications

At the end of the study, all of the PSTs showed developments about many of the NOS aspects. It can be concluded that inquiry-based laboratory instruction informed by the conceptual change theory provided PSTs' improve their NOS understanding. For empirical basis of NOS, 14 PSTs developed their understanding according to pre VNOS-B scores. Past studies indicated that preservice teachers in Turkey held some inadequate views about empirical based on NOS. (Erdogan, Cakiroglu, & Tekkaya, 2006; Liang, Chen, Chen, Kaya, Adams, Macklin, & Ebenezer, 2009). It can be seen that, the inquiry-based and explicit-reflective NOS instruction had relatively effect on PSTs to enhance their understanding about empirical NOS aspect.

At the end of the semester, 28 PSTs stated contemporary views about observation and inference, such as observations and inferences are different, both of them are important for generating scientific knowledge. This NOS aspect was related to as scientists should be objective, McComas (1998) expressed that some teachers naively believed that scientists should make the same inferences and observations from the same phenomena, because they should be objective. After the intervention, 32 PSTs developed their understandings about theories and laws. Recent research about NOS focused on to determine some misconceptions related to hierarchical structure about theories and laws (e.g., Hanuscin, Phillipson-Mower, & Akerson, 2006; McComas & Olson, 1998; Yalvac, Tekkaya, Cakiroglu, & Kahyaoglu, 2007). The results showed that, the PSTs changed these misconceptions.

At the end of the laboratory instruction, 28 PSTs developed their understanding about subjectivity and they stressed on some factors for subjectivity of scientific knowledge such as, scientists' creativities and imaginations, and their educational backgrounds. Murcia and Schibeci, (1999) and Haidar, (1999) studied with preservice teachers' views about NOS and they articulated that preservice teachers expressed that scientists should be objective and their research should not be influenced by existing theories. The current study showed that 26 PSTs developed their understandings about tentativeness of scientific knowledge. They proposed that scientific knowledge is not absolute truth, it is subject to change. This result is similar to other studies in literature (Akerson et al., 2000; Liang et al., 2009).

After the inquiry-based laboratory instruction, 25 PSTs changed their understanding about creativity and imagination for scientific knowledge. There is a widespread misconception

in NOS literature, scientists do not use their creativities and imagination in generating scientific knowledge (Erdogan et al., 2006; Liang et al., 2009). At the end of the semester, 15 PSTs realized that socio-cultural factors affect development of scientific knowledge. Science literature showed that in order to improve learners' views about this NOS aspect is more difficult other NOS aspects (Abd-El-Khalick et al., 1998; Akerson et al., 2000; Tairab, 2001). According to results, less than half of the sample showed development; however, it should be noted PSTs did only one activity in a limited time. Therefore, it can be concluded that inquiry-based laboratory instruction supported positive effect on PSTs to develop their NOS understanding.

In order to enlarge prospective teachers' epistemological beliefs, researchers applied conceptual change interventions (Abd-El-Khalick & Akerson 2004; Akerson et al. 2000; Schwartz et al., 2004). Researchers claimed that some dimensions of epistemological beliefs can be considered to some of NOS aspects (Deniz, 2011a). More research is needed to explore the relationship between students' epistemological beliefs and their classroom practices (Sandoval, 2005). The current study tried to answer these ideas with its findings. After the intervention, PSTs held more sophisticated epistemological beliefs about certainty and simplicity of knowledge, this quantitative result is consistent with qualitative results, which, tentativeness of scientific knowledge from VNOS-B questionnaire. In addition, PSTs enhanced their beliefs about source of knowledge; it is consistent with qualitative findings, which, subjectivity of scientific knowledge from VNOS-B. These results are similar with the past studies proposed conceptual change to enlarge students' epistemological beliefs (Abd-El-Khalick 2001; Akerson, Morrison, & McDuffie, 2006; Deniz, 2011b). On the other hand, according to pre and post application of Epistemological Beliefs questionnaire, there was no statistical difference for the dimension of justification for knowing. This quantitative result is consistent with the qualitative results, which, empirical based on scientific knowledge from VNOS-B questionnaire, because only 14 PSTs showed developments. This unexpected result can be explained under conceptual change theory, when a learner confront with a new situation, sometimes his or her past knowledge-experiences reject the change and defense their old-generally mis-conceptions (Hewson et al., Thorley (1998). It can be concluded that, the inquiry-based laboratory activity for empirical based NOS would be less effective accordance with other activities.

Results showed that, there was no statistically significant difference between pre and post application of metacognitive awareness inventory. One of the most recent study (Abd-El-Khalick & Akerson, 2009) focused on metacognitive strategies to develop prospective teachers' NOS views and their metacognitive awareness. The researchers concluded that using metacognitive strategies (Concept mapping, Investigating the development of the ideas of peers, Response to case studies) improved the effectiveness of explicit-reflective NOS instruction in impacting preservice teachers' NOS views and their metacognitive awareness. However, in the current study, metacognitive strategies were not applied during the intervention. Moreover, the lack of sample size (for quantitative analysis) and being PSTs' mother language is different from instruments' language can be accepted for possible explanation. With this result, it was revealed that explicit-reflective and inquiry-based NOS instruction does not enough to develop PSTs' metacognitive awareness, if researchers want to improve metacognitive awareness they should applied not only explicit-reflective methods but also metacognitive strategies. This result again stressed on metacognitive awareness cannot be enlarged by using implicit interventions (Abd-El-Khalick & Akerson, 2009).

At the end of the study, the finding about high scores of metacognitive awareness associated with high scores of epistemological beliefs is similar with recent studies (Abd-El-Khalick & Akerson, 2004; Deniz, 2011b). Past studies stressed on correlation between epistemological belief dimensions and metacognitive awareness dimensions (Deniz, 2011b). Some correlations were

determined among sub-dimensions at the beginning of the intervention. One of them; certainty of knowledge dimension correlated with source of knowledge dimension. This correlation supported the relationship between tentativeness and subjectivity of scientific knowledge (Lederman, 2007). The other; regulation of cognition correlated with knowledge of cognition. At the end of the intervention, it was found some important correlations among sub-categories different from pre correlations. Although, there was no statistically significant relationship at the beginning of the intervention, the post correlation result showed that the certainty of knowledge dimension correlated with the regulation of cognition. Other correlations between the attainability of truth with the source of knowledge dimension, the regulation of cognition with knowledge of cognition, the attainability of truth with the regulation of cognition, and the attainability of truth with the knowledge of cognition. These correlations supported the view that metacognitively aware students develop more sophisticated epistemological beliefs (Abd-El-Khalick & Akerson, 2004; Deniz, 2011b).

This study aimed to explore the relationships among epistemological beliefs, metacognitive awareness, and nature of science. These relations were revealed to some extent, these relations can help science teachers and science educators during the planning their instructions. Which factors are concerned and emphasized during the teaching NOS should be known by educators. Developing students NOS conceptions was an important goal of science education; however educators should know this is related to epistemological beliefs. Therefore, before their instruction they should reveal their students' beliefs about science. Moreover, students' metacognitive awareness should be determined before instructions. Science teachers and science educators should follow these suggestions for the effective NOS teaching. Otherwise, their students could not develop NOS aspects adequately.

In this study, there are some limitations to generalize revealed results. First is about the lack of sample size, although, the sample size enough for the qualitative part, for the quantitative analysis does not represent all preservice science teachers. The other limitation about language, this study was carried out in Turkey. The university' education language is English, but preservice science teachers are not native speakers. All of the instruments applied in original forms and preservice science teachers' answers collected as English. This study tried to reveal relationships among epistemological beliefs, metacognitive awareness, and nature of science using explicit-reflective and inquiry-based instruction in both qualitative and quantitative methods. Research is needed to eliminate these limitations and should include other related concepts such as, self efficacy and thinking dispositions to reveal the possible relationships among epistemological beliefs, metacognitive awareness, and NOS aspects.

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Epistemolojik inançlar, üstbilişsel farkındalık ve bilimin doğası arasındaki ilişkilerin incelenmesi

Bu çalışma, epistemolojik inançlar, üstbilişsel farkındalık ve bilimin doğası arasındaki ilişkileri incelemeyi amaçlamaktadır. Çalışmanın örneklemini Türkiye'deki bir üniversitede iki gruptan oluşan Laboratuvar Uygulamaları II dersine kayıtlı 45 fen bilgisi öğretmen adayı oluşturmaktadır. Katılımcıların tamamı aynı fen altyapısına sahip üçüncü sınıf öğrencilerinden oluşmaktadır. Her iki gruptaki öğretmen adaylarına kavramsal değişim teorisi temel alınarak doğrudan-yansıtıcı ve araştırma-temelli bilimin doğası öğretimi yapılmıştır. Bu çalışmanın modeli karma yöntemlerden biri olan eşzamanlı gömülü tasarım modelidir. Bir dönemlik eğitim sonucu bütün fen bilgisi öğretmen adaylarının bilimin doğasına yönelik anlayışlarının geliştiği belirlenmiştir. Bunun sonucunda kavramsal değişim teorisi ile araştırma temelli laboratuvar eğitiminin öğretmen adaylarının bilimin doğasına yönelik anlayışlarını geliştirdiği sonucuna varılmıştır. Ayrıca, çalışmanın sonucunda öğretmen adaylarının bazı epistemolojik inançları, üstbilişsel farkındalıkları ve bilimin doğasına yönelik görüşleri arasında istatistiksel olarak anlamlı ilişkilerin olduğu belirlenmiştir. Ortaya çıkan bu ilişkiler mevcut fen eğitimi literatürü ışığında tartışılmıştır.

Anahtar Kelimeler: Epistemolojik inançlar, üstbilişsel farkındalık, bilimin doğası