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INQUIRY-BASED SCIENCE LABORATORIES: AN ANALYSIS OF PRESERVICE TEACHERS' BELIEFS ABOUT LEARNING SCIENCE THROUGH INQUIRY AND THEIR PERFORMANCES

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Introduction

Before the 19th century, many educators viewed science as a body of knowledge to be presented to the students through direct instruction (Domjan, 2003). Studies conducted concerning the learning of science through inquiry date back around 100 years. Though the significance of questioning, inquiry, and discovery had been emphasized since Socrates, the reform movements supporting inquiry-based instruction only began in the 19th century (Keller, 2001). As a result, the focus of science education moved from the memorization of scientific facts and concepts towards inquiry-based learning in which students seek answers to their questions (Gibson & Chase, 2002).

Inquiry-based teaching includes practices that promote the learning of scientific concepts and processes as well as "how scientists study the natural world". When learners are engaged in inquiry-based learning environments they should (1) be engaged in scientifically oriented questions; (2) give priority to evidence, allowing them to develop and evaluate explanations that address scientifically oriented questions; (3) formulate explanations from evidence to address scientifically oriented questions; (4) evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding; and (5) communicate and justify their proposed explanations (NRC, 2000). These five elements are essential characteristics of an inquiry-based learning environment and also describe the inquiry practices that students should strive to appropriate (Apedoe, 2007). Inquiry-based teaching promotes deeper and more meaningful learning (NRC, 2000). The ability to interact with the instructor, other learners, and materials has been shown to promote deeper meaning and understanding of new knowledge as well as develop higher-level thinking skills (Anderson, 2002). Inquiry-based teaching also af-

Abstract. *This study investigated the effects of inquiry-based instruction on preservice teachers' beliefs concerning learning science through inquiry and their performance to apply a scientific inquiry process. A case study design was used in the study and the data were collected through interviews, observations and written documents. Two preservice teachers with different experiences in their previous science education were selected. The preservice teachers learnt both science and scientific inquiry process through open inquiry activities. The results of the research show that past experiences of preservice teachers are effective on beliefs about learning science through inquiry. The open inquiry science activities which allow preservice teachers' making discussion, collaboration, and interaction were effective in developing their beliefs concerning learning science through inquiry and increasing their ability to apply a scientific inquiry process. The overall findings indicate that inquiry-based activities should frequently be a preferred instruction method in preservice teacher education.*

Keywords: *Inquiry-based instruction, open inquiry activities, preservice teacher education, science education.*

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fects students' affective skills (Gibson & Chase, 2002; Laipply, 2004; Yager & Akçay, 2010). Students felt they were more involved in the learning process, they had generally favorable attitudes regarding their learning experiences in inquiry-based classrooms (Abd-El-Khalic et al., 2004), and they took responsibility for their learning (Plevyak, 2007).

Teachers who enact instruction in an inquiry-rich environment foster student engagement by starting with what students have already observed and/or experienced and allow student questions to guide the learning process, which are at the heart of culturally responsive teaching (Leonard et al., 2011). Engaging students in inquiry requires a teacher to have appropriate pedagogical tools, confidence, an understanding of science in its social context, experiences with scientific inquiry, and agreement with the goals of reform-based science education standards (Trautmann, MaKinster & Avery, 2004). However, researchers have emphasized that many teachers have lack of experiences concerning scientific inquiry, and they have difficulties in practice (Brown & Melear, 2006; Lotter, Harwood, & Bonner, 2007; Blanchard, Southerland & Granger, 2008). Teacher lacking inquiry experience feel unprepared to lead students in formulating questions, designing experiments, and representing data – activities that are pedagogically risky but also central to current conceptions of science education reform (Kennedy, 1997; Singer, Marx, & Krajcik, 2000; Windschitl, 2003; cited in Trautmann, MaKinster & Avery, 2004). Furthermore; curriculum limitations, management issues, lack of instructional time, examination-related anxieties, accountability pressures, and efficiency beliefs directly influence teachers to implement inquiry-based instruction (Abd-El-Khalic et al., 2004; Plevyak, 2007; Leonard et al., 2011). Like in-service teachers, pre-service elementary teachers' understanding of scientific inquiry is insufficient, they are not prepared and are not confident about their understanding of inquiry or lack of self-efficacy to teach science with inquiry (Varma, Volkmann & Hanuscin, 2009; Duncan, Pilitsis & Piegaro, 2010).

Teacher beliefs about students and student learning, the nature of science, epistemology, and the role of the teacher are all significant elements of teacher beliefs systems that may impact views of inquiry (Wallace & Kang, 2004). Teachers who use an inquiry approach must have rich and deeply developed understandings of science content, student learning, the nature of science, and ways to engage students in investigative practices (Keys & Bryan, 2001). Unfortunately, most of preservice science teachers enter their preparation program have never been engaged in learning science as inquiry in which they have developed the question being investigated or the means to resolve it (Windschitl, 2000; Haefner, 2004). Meyer et al. (1999) stated that science preservice teachers at the beginning of their program held beliefs of learning indicating that the learners' role was considered to be receptive to knowledge presented by several sources. They tend fairly traditional views about student learning (Bendixen et al. 2002; Northfield et al. 1996 cited in Seung, Park, Narayan, 2011). There is considerable evidence that the entering beliefs of preservice teachers affect what and how they learn, and how they approach teaching in the classroom (Richardson, 2003). Teacher education programs play a role in the development of preservice teachers' beliefs about teaching and learning (Hancock & Gallard, 2004). Stronger role identities associated with inquiry teaching and learning may facilitate student teachers' use of inquiry and related supporting practices within these contextual realities (Eick & Reed, 2002). In this study investigated the effects of inquiry-based instruction preservice teachers' beliefs concerning learning science through inquiry and their performance to apply a scientific inquiry process.

Inquiry-Based Instruction in Preservice Teacher Education

One of the aims of science teacher education is to prepare preservice teachers for teaching science through inquiry as supported by the constructivist theory (NRC, 1996). The authors of the Salish I Research Project (1997) indicate that many preservice teachers do not apply inquiry-based instruction in their courses after their undergraduate education (cited in Brown & Melear, 2006). Roth (1998) suggests that the lack of inquiry-based science in schools could stem from the fact that students from both high schools and undergraduate schools had not experienced science through the inquiry method. Preservice science teachers took science courses that did not prepare them for authentic scientific inquiry and this negatively affected their understanding of scientific concepts. Thus, he argues that preservice science teachers may not have had the required experience or acquired the necessary competencies to be able



to teach inquiry-based science. Similarly, Duschl (1983) states that the type of science experiences an individual has influence his or her beliefs of science teaching and learning. They may believe in the value of hands-on experiences for children, but not know how to translate these into classroom content for the children. Having the opportunity to learn new (and rigorous) content by building on prior knowledge and engaging in social interactions may help preservice teachers to resolve this dilemma. As stated by Crawford (2007), preservice teachers should make explicit the connections between an inquiry process, their understanding of how people learn science, and their teaching practice.

If teachers view science as inquiry and their students as constructive learners, they will want to teach science in a way in which students can actively construct their ideas and explanations and to enhance their inquiry abilities (Bass, Contant & Carin, 2009). For this, they need to believe that the best instructional approach that helps student learning is an inquiry-based instruction, and to believe in their own abilities (NRC, 1996). This belief and confidence can be formed through the observations they make and the practices they perform over a long period that begins the day a preservice teacher starts his/her undergraduate education and it also involves vocational training (Harwood, Hansen & Lotter, 2006). If science teachers are required to teach in a way that is rich in terms of inquiry, then they should be given the opportunity to have such experiences when they are students and be taught by teacher educators who have adopted this teaching method (Kubota, 1997). One space generally considered to offer opportunities for preservice teachers to learn about inquiry is in laboratory or practical work (Trumbull, Bonney & Grudens-Schuck, 2005).

The Inquiry-Based Activities in Science Education

The laboratory has been given a central and distinctive role in science education, and science educators have suggested that there are rich benefits for learning from using laboratory activities (Hofstein & Lunetta, 1982). Laboratory activities help students learn science by enabling them to acquire conceptual and theoretical knowledge and to understand the nature of science through an introduction to inquiry methods. Thus they are given the opportunity to conduct scientific studies using the process of scientific inquiry (Ottander & Grelsson, 2006).

According to the NRC (1996, 2000), laboratory activities entail a wide range of activities from open inquiry, in which students take the lead in identifying the problem, generating questions, designing investigations, making and recording observations, interpreting data, creating explanations, and developing models and arguments—to more structured inquiry, in which teachers determine the questions and specific procedures of the investigation (Crawford, 2007). Teachers have to master both theoretical and practical knowledge and know how to exploit multiple methods of inquiry and engage students in scientific inquiry that requires students to ask questions, design studies, collect and interpret data and draw conclusions, and do so in a developmentally appropriate manner (NRC, 1996). Preservice teachers should be provided with the opportunities to gain experience related to “relative” science laboratory practices (Brown & Melear, 2007). This way they can improve their ideas concerning how to teach science, guide their own skills in science teaching, and apply the core principles of inquiry-based teaching (Schwarz & Gwekwerere, 2007).

The Purpose of the Study and Research Questions

The Turkish science education system has been engaged in a reform movement to develop student inquiry skills since 1997 (Turkish Ministry of National Education, 2005). Teachers are thought to be central to the educational change process (Bybee, 1993). Because of this, preservice teachers should gain experience, improve their abilities and develop their beliefs concerning inquiry-based instruction. The purpose of this study is to investigate effects of inquiry-based instruction on preservice teachers' beliefs concerning the learning of science through inquiry and their performance to apply a scientific inquiry process. The following research questions were asked and addressed in this study:

(1) What are preservice teachers' beliefs about learning science through inquiry before and after the inquiry-based instruction?



(2) How do open inquiry activities affect the preservice teachers' performance concerning the practices of the scientific inquiry process?

Methodology of Research

A case study design was used in this research to be able to deeply define and analyze the preservice teachers' development. Case study research is a qualitative approach in which the investigator explores a bounded system (a case) or multiple bounded systems (cases) over time through detailed, in-depth data collection involving multiple sources of information (e.g., observations, interviews, audiovisual material, and documents and reports) and reports a case description and case-based themes (Creswell et al., 2007).

Participants

Two preservice teachers were selected for this study, from a pool of 41 preservice teachers who were taking the "Science and Technology Laboratory" course. While choosing the participants for the study, the researcher used an extreme/deviant case sampling technique, which comes under the category of purposeful sampling. The extreme/deviant case sampling involves seeking out the most outstanding cases, or the most extreme successes and/or failures, so as to learn as much as possible about the outliers (Kemper, Stringfield & Teddlie, 2003, p.280). The effect of past experiences of preservice teachers on their beliefs about learning through inquiry was examined. Moreover, how instruction based on inquiry affected their beliefs and inquiry skills was determined. In this study two preservice teachers were worked in order to analyze their beliefs and skills in depth. Qualitative research is characterized by in-depth inquiry, immersion in a setting, emphasis on context, concern with participants' perspective, and description of single setting, not generalization too many settings. To obtain the desired depth of the information, qualitative researchers deal with small samples. Thus, researcher interacts with samples over a long period of time and in great depth (Gay & Airasian, 2000). The cases described in this paper are two preservice teachers (pseudonyms: Melih and Cihan) whose past experiences in science education most differed. Both preservice teachers were second year students from the department for primary school teacher education who were willing to participate in the study.

Before starting the study, information was collected concerning the preservice teachers' previous experiences of science via an information form. In this form, there are open-ended questions as to how the preservice teachers learnt science in elementary and secondary school, how frequently they conducted experiments on science courses and what the roles of students and teachers were in those activities. After the answers were examined, the participants were placed in two categories, i.e. the active and the passive participant. The active participant is one who has learnt science in a student-centered way and has taken an active role in classes. The passive participant is one who has learnt science in a teacher-centered way, where the teacher transfers knowledge to the students, there are no hands-on/mind-on learning activities and the student has the role of an observer and/or listener in courses where learning through experience is given no place. The past experiences of these preservice teachers in relation to science are as below.

Passive participant Melih: He said that his teachers usually concentrated on direct instruction or making the students take notes in his previous science courses. He added that there were science laboratories at his schools, but they used the science laboratory only a few times. He said that the demonstration experiments were performed by the teachers and the students observed their teachers.

Active participant Cihan: He maintained that his science teachers in the past conducted courses based on activities. He went on excursions (nature excursions, museum excursions), he prepared projects and he conducted experiments in the science courses. He explained that he generally conducted experiments in collaboration with his classmates in the science laboratories.



Research Design

The research was conducted during the fall-spring semesters in the 2007–2008 academic year. The preservice teachers had taken Theoretical Biology, Physics, and Chemistry courses in the previous year. The “Science and Technology Laboratory” courses are one of the main courses in the second years where preservice teachers meet for two hours a week and have the opportunity to learn science concepts and theories via experiments. The goal of the instruction was to assist the preservice teachers’ understanding of science concepts through scientific inquiry and to teach them how to teach science to their students in an inquiry-based manner. Prior to the beginning the study, pre-interview was conducted with each of them on their beliefs concerning learning. After, the instruction process started. It can be explained in three stages.

Stage One: The preservice teachers were informed about the aims and significance of the science laboratory, the preparation of and use of worksheets, scientific inquiry methods, science process skills, laboratory equipment, safety rules in the laboratory, and first aid in the first six weeks of the laboratory practices.

Stage Two: The second stage included the implementation of 12 science experiments. The author determined the inquiry-type science experiments which were completely ‘open’ to investigation (e.g. changes in matter, circuits, and microscopic forms of life). In the following 12 weeks, the preservice teachers engaged in open inquiry activities in order to learn the science content and the scientific inquiry process and for them to develop their views on inquiry-based learning. In this stage, the preservice teachers used worksheets. The preservice teachers defined their problems related to the topic. Each of them stated a hypothesis, identified the variables and planned experiments. They implemented experiments using the appropriate tools and the gathered data. Next, they interpreted their findings by discussing them with their groups. They discussed their results with their teaching assistant and clarified their scientific explanations using the evidence from their investigations. The teaching assistants controlled their inquiry process by means of asking questions. After the laboratory, the preservice teachers wrote laboratory reports on their laboratory practices. In this stage, they gained experience of the scientific inquiry process, the application of open inquiry activities and the use of worksheets.

Stage Three: The preservice teachers were asked to design worksheets themselves at the end of 12 weeks. The author determined the science topics in primary science curriculums (e.g. sound, heat, and plants). At this stage, the preservice teachers prepared worksheets related to the subject matter with their groups before entering the laboratory. In the laboratory, they analyzed the worksheets with their teaching assistant and conducted experiments using the worksheets for eight weeks. After the laboratory, they corrected the mistakes or added the missing parts and they submitted the worksheets to the researcher one week later. They went on to write their laboratory reports in this stage too. In this stage, they gained experience of designing worksheets relevant to science topics, of implementing open inquiry activities and of developing their beliefs of inquiry-based teaching. At the end of the laboratory instruction post-interviews were conducted with two preservice teachers. The instructional design and data sources are shown in Figure 1.

Data Collection

Interviews

Three semi-structured interviews were conducted with each participant over the course of the research. The purpose of the pre (September, 2007) and post-interview (June, 2008) was to determine the preservice teachers’ beliefs on learning science as inquiry. The mid-interview was done after the first stage (March, 2008) to learn the participants’ beliefs of instructional practices and their new learning experiences within this process. In order to examine the preservice teachers’ beliefs thoroughly, studies in the literature (Eick & Reed, 2002; Makang, 2003; Plevyak, 2007) were looked through and the interview form was accordingly prepared.

To provide internal consistency of the interview form, a specialist in science education examined



the interview form. Later, researcher conducted a pilot interview with two preservice teachers, and clarified whether the questions were understandable or not. Then, pilot interviews were transcribed and the specialist controlled whether the questions entailed the topic at hand and provided the necessary information. According to the suggestions, researcher arranged the interview form (Appendix 1).

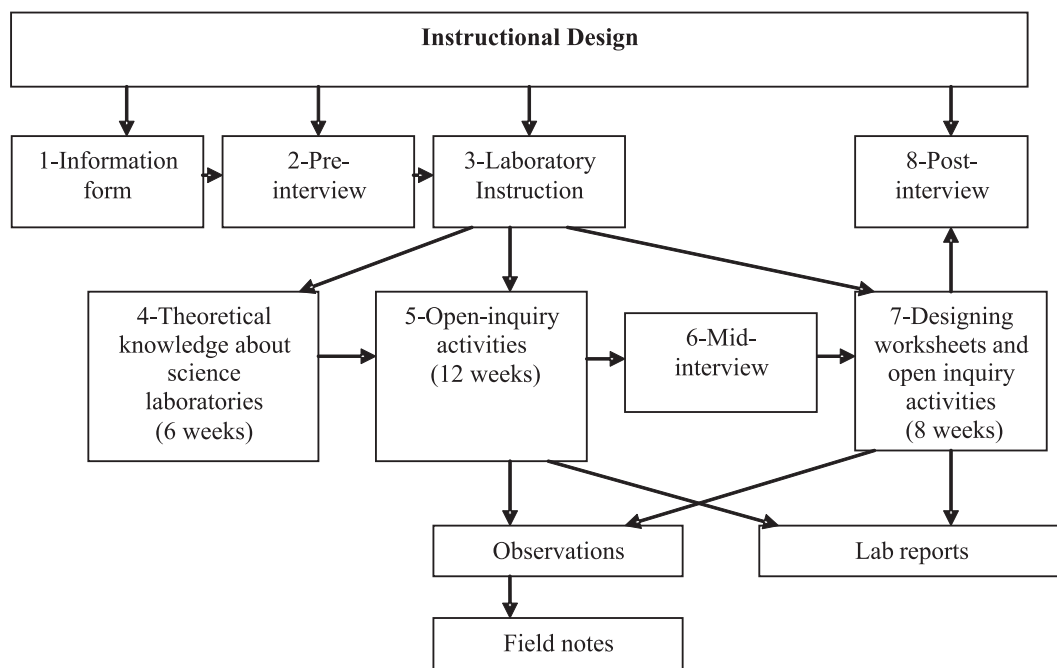


Figure 1: Instructional design and data sources.

Written Documents

The data concerning preservice teachers' performances before and after the course was gathered through their laboratory reports. Before they came to the class, they prepared their laboratory reports concerning the inquiries they had made on the topic. At the end of the each class they wrote their laboratory reports concerning what they had learnt during the activities. Taking into account the criteria in the "Primary trait scoring rubrics for laboratory reports" (Doran et al., 2002), the preservice teachers prepared their laboratory reports. The rubric is comprised of four categories which are planning, performance, analysis and application. Another category entitled "preparing" was added to the rubric to evaluate the preservice teachers' preparations before the laboratory work. The individual laboratory reports of preservice teachers were regularly examined in order to follow their improvements within this process. By giving them feedback researcher tried to correct faulty and deficient information these reports.

Observations

In order to evaluate the preservice teachers' performance during the activities, observations were conducted by the researcher and two teaching assistants. The observers recorded field notes by observing a preservice teacher from the group every week. The observations were conducted by taking the criteria in the observation form developed by the researcher into account. The observation form was arranged by analyzing observation forms and checklists in the literature (Fisher et al. 1998; Llewellyn, 2002; Buxton & Provenzo, 2007) and revised taking the opinions of a specialist in science education. There are many observation form and checklist to evaluate performance of students in the science laboratory. Some of them unstructured; some of them which have categories structured type. Many of them determine



students' scientific process skills. Categories which have criteria consist of steps of scientific inquiry process. In this study, researcher wanted to observe preservice teachers both scientific process skills and their active participation in the laboratory. For this reason, observation form was arranged on two categories: (1) participating activities (5 items) and (2) applying a scientific inquiry process (15 items). First category includes criteria which determine their role in the activities. Second category includes criteria which determine their scientific process skills. Preservice teachers' performances in the science laboratory were scored by using this observation form (Appendix 2).

Data Analysis

In the research, semi-structured interview data were analyzed by descriptive analyses. Analysis was made four steps; (1) becoming familiar with data and identifying main themes in it (reading); (2) examining the data in depth to provide detailed descriptions of the participants (describing); (3) categorizing and coding pieces of data and grouping them into themes (classifying); and (4) interpreting and synthesizing the organized data into general conclusions (interpreting) (Gay & Airasian, 2000). Analysis of the interview data was explained with reference to a study by Wallace and Kang (2004). Firstly, all of the interview transcripts were read by the researcher. Then, the data was unitized into segments representing a single idea, using one to three sentences. The unitized data were descriptively coded, using coding categories suggested by the interview questions. These descriptive categories included beliefs about (a) learning of science and (b) inquiry-based learning. After descriptive coding, the specialist in the science education examined the data for the two preservice teachers and created interpretive codes within each descriptive category. Next, the researcher and specialist met and compared their interpretive coding lists, adding, deleting, and combining codes until a consensus coding scheme was achieved. Then, the researcher and specialist were independently recoded data of two preservice teachers, according to the consensus coding scheme. It was seen that agreement between two evaluators was almost perfect (Miles & Huberman, 1994). From these data, a summary was made of the most important coding categories for each participant's beliefs. Once each participant's beliefs about each category were characterized, researcher went back to the data to select excerpts that exemplified each main category as a further check on validity.

In addition to interview data, written documents (laboratory reports and field notes) were analyzed. Document analysis is a systematic for reviewing or evaluating documents (Bowen, 2009). It is most often used to enhance and enrich research utilizing other qualitative methods (Love, 2003). It requires that data be examined and interpreted in order to elicit meaning, gain understanding, and develop empirical knowledge (Corbin & Strauss, 2008; cited in Bowen, 2009). Documents were analyzed by content analysis. Content analysis has been defined as a systematic, replicable technique for compressing many words of text into fewer content categories based on explicit rules of coding (Stemler, 2001). In the evaluation of the laboratory reports, the "Primary trait scoring rubrics for laboratory reports" prepared by Tamir et al. (1982) and adapted by Doran et al. (2002) was used. Laboratory reports were evaluated according to the categories in the rubric. The research that pre-service teachers made about the subject before the lesson, and the conceptual framework that they prepared, were examined in the "Preparing" category. The planning process they prepared in order to answer the research problem was examined in the "Planning" category. The accuracy of their observations and measurements was examined in the "Performance" category. The ways in which they organized and interpreted the research data were examined in the "Analysis" category. Their knowledge and skills of associating their previous and new knowledge, and applying it in everyday life, was evaluated in the "Application" category. Each category was graded from 1 to 5, giving an overall grade for each laboratory report. A total of 20 laboratory reports by pre-service teachers were graded this way. Finally, the mean laboratory report grade of each pre-service teacher was calculated, which gave their performance grade. According to ranges of scores, the performances of preservice teachers were evaluated as; very weak (≤ 20), weak (21–40), moderate (41–60), good (61–80) and very good (81–100). While evaluating laboratory reports, researcher and teaching assistant who was responsible for the preservice teachers scored reports individually. Researcher calculated the agreement percentage (Cohen, 1960) between evaluators. The average of the scores from the agreement between the two evaluators was ≥ 0.81 according to the range defined by Landis and Koch (1977) and I graded



the weekly laboratory report. When the agreement percentage was <0.81 , researcher discussed it with the teaching assistant and graded the report after achieving the agreement percentage.

Additionally, the preservice teachers' performances in the laboratory were analyzed according to the observations and field notes. When preservice teachers applied the open inquiry activities in the laboratory, they were observed by researcher and teaching assistants. We recorded field notes about their performance, following the categories the form of observation. Then, we scored each preservice teacher's performance individually using the observation form. According to ranges of scores, the performances of preservice teachers were evaluated as; very weak (1-20), weak (21-40), moderate (41-60), good (61-80) and very good (81-100). Then, I checked the agreement percentage between evaluators. The average of the scores from the agreement between the two evaluators was ≥ 0.80 ; researcher graded their performance in the laboratory.

Trustworthiness of the Data

An attempt was made to maintain the trustworthiness of this study by (a) obtaining data from multiple sources, (b) benefiting from the literature and consulting with a specialist while preparing the data tools and analyzing them, and (c) obtaining data for the whole research process. The findings were triangulated through methods, sources, and analyst triangulation (Patton, 1999). Using methods that involve triangulation is one of the ways to increase the validity, strength, and interpretative potential of a study, to decrease investigator biases, and to provide multiple perspectives (Denzin, 1970).

Results of the Research

The data recorded within the process is presented into two headings; (1) beliefs about (a) learning of science, (b) inquiry-based learning, and (2) performance in inquiry-based laboratory. Each preservice teacher's data were explained separately.

Melih

Beliefs

Learning of science: Teacher-centered methods -direct instruction, questioning, and note taking-were used in Melih's previous science courses. He explained that he had difficulty understanding of science and he had not liked science in the past. He described science lessons taught by the teacher as "boring", "incomprehensible" and "complicated". He stated that traditional methods were ineffective for learning science. According to him, science could be better learnt when taught through the use of visual materials such as models, video, and materials. He believed that subjects presented using visual materials were learned permanently.

In the first weeks of the study, it was determined that Melih only had a superficial knowledge of the subjects and he lacked confidence in answering the questions related to the subjects. Over the four weeks he had difficulty in adapting to the process of learning science with open inquiry activities. It was observed that he did not actively participate in the lessons however he was trying to give meaning to the learning process. The questions he asked in the lesson, answers he gave to questions and his comments in the process of inquiry showed that he started to learn by inquiry and meaningfully. At the mid-interview, Melih expressed the idea that he had learnt many concepts of science until now. He stated that he understood the science subjects very well with open inquiry activities and he tried to explain the cases he encountered in the everyday life with the concepts he had learned.

It was seen that there were many changes in Melih's beliefs about learning science end of the study. At the post-interview, he stated that science can be best learnt by inquiry. He explained that the observation, measurement and comments he had made helped him to learn the subjects. He believed that knowledge he learned by inquiry was permanent. He expressed how science could best be learnt thus:



- M: Science is learnt through scientific inquiry. Students should learn inquiry processes and skills, just as we did in this laboratory. (The student) is one who does not easily forget the knowledge he/she has acquired this way. The child may not understand when the teacher simply "instructs" them or the child immediately forgets what is taught even if he/she understands the topics. I will guide students towards learning by inquiry (Post-interview).

Inquiry-based learning: At the pre-interview, it was determined that Melih's belief about learning through inquiry was weak. Faulty and deficient applications in science lessons in the past had negatively affected his belief about learning through inquiry. When asked what learning science through inquiry could be, he explained it thus:

- M: Students search different sources such as books, journals, magazines, and the Internet related to science topics, and they acquire information from these sources (Pre-interview).

According to Melih's beliefs revealed at the pre-interview, undertaking inquiry was limited to obtaining information from sources then reading and understanding this information. Melih stated that these kinds of practices were frequently used in science courses in the past. He said that he had investigated science topics given out as assignments from different sources and presented the results to his teachers either orally or in written form. Melih thought that learning science through inquiry was ineffective. He believed that the knowledge he gained this way was mainly based on memorization and said that inquiry was tiring and time consuming. Moreover, he added that these kinds of practices could be boring when they do not attract the student. I found that Melih had a limited knowledge about scientific inquiry process and did not have positive belief concerning inquiry-based learning.

At the beginning of the learning process, it was determined that Melih's inquiry skills were insufficient. He had difficulty in asking quotations and formulating problems due to his lack of knowledge and he did not have adequate inquiry experience. He was weak in designing experiments and conducting controlled experiments. Furthermore, his ability to comment was insufficient. At the mid-interview, he said that it was the first time he had learnt stating hypothesis, identifying variables, designing experiments, and using some laboratory equipment. Melih maintained that he had some worries at the beginning while doing the experiments, but in time his worries diminished.

- M: I felt fearful in the first and second weeks. I even did not know how to use the equipment. I felt that I learnt some things but still could not be sure. The subject of the third experiment (electric circuits) was a little more familiar to me. I began to feel more comfortable. I began to work in the laboratory more comfortably and felt more self-confident as we proceeded (Mid-interview).

He stated that he had developed his skills for observation and data analysis in this process. He maintained that he could associate the topics he learnt with examples from daily life and was aware of the fact that there were still many questions that needed inquiry. He stated that the applications were quite enjoyable and as he learnt the topics his interest towards the lesson increased.

As a result of the applications Melih adapted to learning process with inquiry over time. At the end of the process important changes on Melih's belief about learning through inquiry were observed. It can be seen that Melih used the expression "learning through inquiry" in his statements in the post-interview. He expressed the thought that he understood how to learn science through inquiry and he had never performed these kinds of applications before. He stated that he used observation, measurement, conducting experiments and commenting skills when undertaking inquiry. He maintained that he gained much useful knowledge and had benefited from the different sources. He also added that he learnt science topics through inquiry activities. By expressing the idea that knowledge learnt through inquiry would be permanent, he changed his belief from the one he held at the pre-interview stage when he believed knowledge could be delivered through memorization. He expressed the idea that his knowledge and skills in relation to scientific inquiry were enhanced in the laboratory and that from



now on he wanted to learn science by associating it with daily life and through inquiry. He frequently emphasized that he enjoyed learning science through inquiry.

Performance in Inquiry-based Laboratory

Melih had difficulty adapting to the open inquiry activities within the first four weeks. He was hesitant while explaining opinions and conducting the experiments. My field notes related to his performance as follows.

Researcher: Melih acted mostly according to the instructions of his group. When his friends offered a different opinion, he could easily change his opinion and had difficulty in defending his own views. When the cause of this issue was questioned, it was clear that he was not confident about his knowledge of science and skills. He indicated that he had difficulty in formulating problems and making logical explanations about the cause-effect relationship within the problem (First observation).

According to the observation form results, it was seen that his performance at the beginning was weak. He had a low performance in particular in stating the hypothesis, identifying variables and designing experiments.

However, after the four weeks, he participated in the classes more actively and became more willing to develop himself and to learn the science topics. He explained his opinions, produced new ideas and paid more attention to different opinions. He was also successful in using laboratory equipment and applying scientific inquiry methods. He improved his skills fast and developed his performance in time. The five week observation data on Melih's laboratory performance is shown in Table 1.

Table 1. Melih's scores according to his performance in the laboratory.

	1st Observation	2nd Observation	3rd Observation	4th Observation	5th Observation
Participating activities	10	16	19	20	22
Applying scientific inquiry process	32	44	56	63	72
Total	42 (weak)	60 (moderate)	75 (good)	83 (good)	94 (very good)

When I analyzed Melih's laboratory reports, I saw that he had prepared his laboratory reports carefully. Throughout the term, he came to classes having researched many sources and having studied the content in these sources. However, his performance in the planning, performance, analysis and application parts was weak in the first three weeks according to his laboratory reports. Melih's plan was poor, ineffective plan needing considerable modifications. He made inconsistently and inaccurately observation and measurement. He was able to organize data only when provided explicit directions, and can only answer specific, narrow questions about conclusions. He was unable to apply, extend findings to other situations. In the following weeks, he got either good or very good scores for all of the parts. He was able to well-presented plan. He made consistently and independently observation and measurement. He started to interpret data collected and present reasonable conclusions. He connected findings to prior work and cites viable uses or applications. The average of his laboratory reports over all the weeks is good.



Cihan

Beliefs

Learning of science: Cihan had learnt science in classes in which active participation was encouraged and student-centered methods were applied. He expressed the thought that he had learnt science through practices by carrying out observations, designing experiments and looking through sources. He stated that his knowledge of science topics was at a good level, he loved science and enjoyed learning it. He thought that science should be learnt through practices such as observation, experiment, projects and inquiries. He stated that inquiry-based instruction should be applied in science classes.

Cihan did not have difficulty during the activities in the laboratory because he learnt science also through inquiry previously. His inquiry skills and confidence in his knowledge of science were effective in his success in the laboratory. Throughout the study, he acquired knowledge and skills in open inquiry activities and these acquisitions contributed to the development of his beliefs. At the mid-interview, Cihan stated that the laboratory work was effective for his learning unfamiliar concepts and it reinforced what he knew, and he also added that he enjoyed learning through inquiry. He expressed the thought that finding answers to questions he was curious about was very exciting.

Cihan's beliefs at the post-interview are similar to those at the pre and mid-interviews. Additionally, in the post-interview, he touched upon the importance of working with groups, the interaction between students and the positive impact of discussion on learning.

- C: Students best learn from one another. They discuss and share their knowledge when they work together (Post-interview).

He suggested that he understood better that students could not acquire permanent knowledge without inquiry. He expressed his view on the qualities students should have to be able to conduct an inquiry thus:

- C: Students should be interested in and curious about the events in their environments. They should ask questions and think about how they can answer them. The more inquiry they do, the more they develop their skills (Post-interview).

Inquiry-based learning: In the past Cihan had learned science in student-centered classrooms. His experiences contributed to his development of positive beliefs about learning and gaining experience. Cihan defined learning science through inquiry as follows:

- C: Science is everywhere in our lives and there is so much information to be discovered in the world. Acquiring this information -by making observations, conducting the experiments, and examining sources- through inquiry just as scientists in science laboratories is learning science through inquiry (Pre-interview).

Such expressions as "discovery", "science laboratories", "scientist" features in his response. He believed that student should be active in learning through inquiry process. He stated that he liked conducting experiments and thought that learning science this way was effective at the pre-interview. He believed that information learnt in this way was comprehensible. He maintained that he wanted to improve his skills and increase his knowledge more by learning different practices that could be undertaken for science topics.

Cihan did not have any difficulty during the open inquiry activities in the laboratory. He was good at formulating the problem, designing controlled experiments, organizing data and communicating with his friends using scientific language. His inquiry skills and confidence in his knowledge of science were effective for his success on the course. It was observed that he actively participated in all the activities during the study. He acquired more knowledge and skills in inquiry-based activities and



these acquisitions contributed to the development of his beliefs. Cihan stated that he had done a lot of inquiry activities in previous science lessons however his participation to the activities much more increased in this lesson.

- C: I am learning a lot of information with inquiry. Conducting experiments in laboratory excites me. It is fun to carry out research on questions the answers of which we are curious about, and to plan the inquiry process. I was undertaking research mostly on the questions that my teachers had asked in my previous lessons. In this lesson, we were determining the research questions (Mid-interview).

At the post-interview, he suggested that he understood better that students could not acquire permanent knowledge without inquiry. He stated that he had learnt science topics in this laboratory through inquiry, and that he always enjoyed learning this way. He explained that they had researched information from the sources before the lesson and found the answers for their questions by carrying out observation and measurements and they answered the inquiry questions during the class, and again at the end of the lesson through several methods such as searching the sources, observation and interview. He stated that his skills at asking questions, doing an inquiry, problem solving, making comments and communicating had been enhanced in this process. He expressed his view on the qualities students should have to be able to conduct an inquiry thus:

- C: Students should be interested in and curious about the events in their environments. They should ask questions and think about how they can answer them. The more inquiry they do, the more they develop their skills (Post-interview).

Performance in Inquiry-based Laboratory

According to the observation results, it can be stated that Cihan's performance in the laboratory is "very good" throughout the semester (Table 2). While he was working in the laboratory, he made reasonable explanations that related to the problems, used scientific language effectively while expressing his suggestions, and he evidenced his findings and displayed confident behaviors. He was keen to state problems and to propose solutions, persuading his colleagues and making use of the materials. Cihan's colleagues within the group paid attention to his ideas and relied on his knowledge. Field notes related to his performance as follows.

- Researcher: He is working by considering all the stages of scientific inquiry. He is consistently making observation and measurement with correct tools. He is good at designing experiment, manipulating tools. He is correctly formulating generalizations and defending his ideas with logical proofs (Fourth observation).

When I examined Cihan's laboratory reports, I saw that he had prepared for the class through conducting inquiry by means of different sources. He had some deficiencies in planning, analysis and application parts in the first two weeks. His plan was O.K. but some help was needed. He did not a very critical approach to problem. He was able to summarize and organize observation and data, but is unable to formulate generalizations. He related conclusions only to very similar work and proposed applications are closely related to his work. However, he entirely corrected those deficiencies in his later reports. He was able to perspective plan for investigation. Plan was clear, concise, and complete. He consistently and accurately summarized observations and data. He cited appropriate relationships and generalizations with assumptions. He related conclusions from activity to underlying models and proposed further related work. The reports Cihan prepared throughout the semester were scored as "very good".



Table 2. Cihan's scores according to his performance in the laboratory.

	1st Observation	2nd Observation	3rd Observation	4th Observation	5th Observation
Participating activities	18	21	23	23	24
Applying scientific inquiry process	53	62	72	70	73
Total	71 (good)	83 (good)	95 (very good)	93 (very good)	97 (very good)

Discussion

The purpose of the present study is to investigate the effects of inquiry-based science laboratories on preservice teachers' beliefs concerning learning science through inquiry and their abilities to apply the scientific inquiry process. None of the preservice teachers in this study had previously taken a course on instruction methods. It can be said that their experiences of previous science courses were effective on their beliefs concerning science learning. It is known that the previous educational experiences of in-service and preservice teachers and the beliefs they hold affects their beliefs about instruction and practices within the classroom (Appleton & Asoko, 1996; Davies & Rogers, 2000; Duru, 2006). Several studies have reported that most pre-service teachers have a belief in traditional instruction in the first years of their undergraduate program (Markic & Eilks, 2008; Tanase & Wang, 2010; Elmas, Demirdöğen & Geban, 2011). Unfortunately, there were few preservice teachers who had positive experiences in their previous science classes and felt positively about teaching through inquiry-based instruction (Plevyak, 2007).

At the pre-interview Melih thought that the inquiry-based instruction only could be used prior to the class in order to get prepared for the lesson. He touched upon the challenges of this process rather than its positive aspects before the study. This result implies that his teachers might be guilty of malpractice in the past. Several researchers suggest that in-service and preservice teachers' having false knowledge, beliefs and negative attitudes towards inquiry-based instruction because of malpractices in their previous education, too (Llewellyn, 2002; Lee et al. 2004; Duran, McArthur & Hook, 2004). Anderson (2002) claims that teachers may not fully understand how to teach their students inquiry-based learning when they have not experienced and understood the processes of science. Due to teachers' deficiencies and mistakes in their knowledge and practices, students come to misbelieve in inquiry-based instruction. Based on the present data, it is seen that Melih's unfavorable past experiences negatively affect his beliefs concerning inquiry-based instruction. In contrary, Cihan had positive beliefs about inquiry-based science instruction. His favorable experiences positively affect his beliefs.

Despite their different levels of abilities and beliefs at the beginning of the study, Melih and Cihan came to have common beliefs by the end of it. By then, the participants maintained that science should be learnt through scientific inquiry, within group works, an association with daily life, and they both emphasized the effectiveness of student-centered practices. In the present study, preservice teachers learned science subjects and scientific inquiry methods through open inquiry activities. They explained the concepts by associating them with examples from everyday life. They worked in small groups while making these activities. They shared their previous knowledge and the knowledge they acquired during this process with their group peers and teaching assistant. They explained their opinions, listened alternative opinions, discussed with fellows, defended their ideas. In other words, they learned scientific inquiry methods together through inquiry, collaboration, discussions and the interactions they made in this process. The communication they established during this process, with both their peers and the teaching assistant, contributed to them developing a more positive belief towards inquiry-based learning. According to Anderson (2002), collaboration is a powerful stimulus for the reflection which is fundamental to changing beliefs, values, and understandings. Hofstein & Lunetta (2004) stated that



through collaboration, students can also come to understand the nature of scientific inquiry. When students interact with problems that they perceive to be meaningful and connected to their experiences, and when teachers are guided by what we know about learning, the students can begin to develop more scientific concepts in dialogue with peer investigators. If positive students' perceptions of the science laboratory learning environment, i.e., cooperative learning, collaboration, and developing a community of inquiry are among the important outcomes of school laboratory experiences. Similarly, many researchers emphasized that collaboration, discussions and interactions are very important for pre-service teachers to acquire knowledge, beliefs and perceptions for inquiry-based approaches (Duran, McArthur & Hook, 2004; Liang & Gabel, 2005; Brown & Melear, 2007; Crawford, 2007; Plevyak, 2007). Choi (2007) analyzed elementary school teachers' beliefs concerning inquiry-based science instruction and the effects of those beliefs on practices within the classroom. Fourteen teachers were enrolled in science methods course that emphasizes inquiry-based instruction and worked in small groups. At the end of the course, it was found that they had developed their practical knowledge and skills concerning inquiry-based instruction, had positive beliefs and applied these practices in their classes successfully. As is also seen in the literature, an increase in-service and preservice teachers' knowledge and abilities concerning the application of inquiry-based science instruction assists the development of positive belief and their preference for inquiry-based science instruction within their classes.

In open inquiry activities, it is of vital importance that inquiry skills be used in an effective way. According to the data obtained from the observation form and the laboratory reports, preservice teachers improved their scientific inquiry skills. Melih at first had difficulty adapting to the scientific inquiry process and participating in the experiments actively. Similar situations have been found in the other research studies. Duran, McArthur and Hook (2004) investigated how preservice middle childhood students perceived the learning environment in a reform-based physics course. A basic physics course which was given in a lecture style form was changed into an inquiry-based course. At the beginning of the study, some students were frustrated with the new learning style and they expected the teacher to tell them what they should do or to give them the right answers for the questions. However, in time they observed that they had got used to these practices; they studied in a more relaxed way and they were more effective in their own learning. Additionally, Brown and Melear (2007) arranged a course for preservice secondary science teachers in which they could conduct authentic, extended, open-ended inquiry. They designed a model in which the preservice teachers were placed with scientists in expert/novice roles and each teacher would actively strive for constructing knowledge. According to the results, the participants developed scientific skills and content knowledge. Researchers have suggested that long-term professional development programs designed to develop understanding, knowledge, and skill of preservice and in-service teachers (Trautmann, MaKinster & Avery, 2004; Liang & Gabel, 2005; Taraban et al., 2007; Sadeh & Zion, 2009). Moreover, in this study it was found that the preservice teachers much enjoyed learning science through inquiry. Liang and Gabel (2005), Taraban et al. (2007), Liang and Richardson (2009) state that learning through inquiry are effective in the students' developing their scientific skills and it enhances their attitudes towards science and inquiry. In order for preservice teachers to develop their abilities and beliefs in favor of teaching and learning science through inquiry, they should be given opportunities to conduct open inquiry activities in the science laboratory.

Conclusions

In conclusion, it was determined that the inquiry-based learning beliefs of the two preservice teachers with different previous science learning experiences were totally different when they came to the teacher education program. Melih, who learned science in the past in traditional classrooms, had weak knowledge, skill and negative beliefs about learning science through inquiry. However, Cihan who learned science through inquiry in the past had developed his knowledge and skills and acquired a positive attitude about the lesson and self-confidence. Accordingly, we can say that in science lessons given in primary and elementary schools the teacher role has an important effect on shaping preservice teachers' beliefs about learning. When the content of science is conveyed and the process is not taken



into consideration, and when students' active participation is not allowed, students' knowledge and skills cannot improve concerning with an inquiry process.

This study revealed that preservice teachers learned science with inquiry and developed their beliefs and improved inquiry skills with a studying in a science laboratory. Discussions, collaboration and interactions among pre-service teachers while engaged in open-inquiry activities contributed to their development of positive beliefs and inquiry skills. Even though Melih, who had a low level of readiness for learning through inquiry, had difficulty in adapting himself to the process, long-term applications helped him to gain necessary experiences. Being engaged in the scientific inquiry process while learning science is effective in increasing both participants' positive beliefs about learning through inquiry and improving their inquiry skills.

Learning through inquiry is emphasized in elementary science curriculums which were renewed in Turkey in 2005-2006. In order to implement these new curricula preservice teachers teacher training programs should facilitate the development of knowledge and understanding of learning through inquiry. The responsibility for enhancing preservice teachers' understanding of scientific inquiry, their abilities regarding the nature of scientific inquiry, and abilities to design and carry out reform based instruction, all fall squarely upon the shoulders of the science teacher educator (Crawford, 2007). Therefore, some suggestions may be put forward concerning teacher educators and researchers.

Implications

In the present study, it was determined that pre-service teachers' beliefs about inquiry-based instruction were affected by their previous experiences. Therefore, such preconceptions about learning and teaching should be identified when they start their undergraduate program. The experiences that pre-service teachers acquired as undergraduate program can affect their beliefs about inquiry-based instruction. It is necessary to efficiently apply inquiry, reflective practice and assessment strategies in curriculums in order to strengthen teachers' beliefs about learning and teaching (Sandholtz, 2011). Inquiry-based instruction should frequently be a preferred in preservice teacher education and preservice teachers have to be supported and encouraged by teacher educators to use supplementary materials, design student-centered activities and experiments and to design creative and supportive learning environments in their future classes (Elmas, Demiröğen & Geban, 2011).

Laboratory has a central role in science education. National Science Education Standards (NRC, 1996) recommended an approach for preparing future teachers to this pedagogical method. Accordingly, the science teacher can learn science content by participating in research at a scientific laboratory. Laboratory activities contributed to preservice teachers developing beliefs concerning what science teaching should be. Educators of the science teachers provide with preservice teachers inquiry-based scientific experiences in laboratory courses. In science laboratory courses, instead of demonstrations or textbook based experiments, guided or open inquiry should be prioritized.

This research was limited to two preservice teachers whose developments were thoroughly analyzed. The preservice teachers were chosen because of their different experiences as students in their earlier lives. In future studies, preservice teachers' beliefs selected for sampling could be analyzed through different dimensions by identifying different variables (attitude towards science, content knowledge) which could affect the shaping of their beliefs. In this research, preservice teachers' practice was assessed before and after the class by means of laboratory reports, activities they conducted during the laboratory were observed and their beliefs were sought through interviews. Through the use of different data gathering tools, future studies could also analyze the development in preservice teachers.

It has been established in this study that preservice teachers' abilities for using scientific inquiry process and beliefs concerning learning science by inquiry improved as a result of the open inquiry activities. However, the study could not be followed through to see whether the participant preservice teachers used these practices in their classes when they become teachers. The effectiveness of the instruction that was provided here could be researched in future longitudinal studies examining whether the beliefs of preservice teachers persist when they become teachers, and how they use the knowledge acquired and skills developed in their classes.



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Appendix 1: The interview form.

	Questions
Pre and post interview questions	How did you learn science up until now?
	What is the best way to learn science?
	How one learns through inquiry in science courses?
	Did you learn science through inquiry in the past?
	Do you think that learning science through inquiry is effective? Why?
Mid interview questions	Do you like learning science through inquiry?
	Are open inquiry experiments effective to learn science topics?
	Which knowledge and skills do you use when doing research in laboratory?
	What kind of skills improves when you are doing open inquiry experiments?
	What do you feel about your activities in the laboratory?



Appendix 2: Observation form.

Categories	Skills	Very weak (1)	Weak (2)	Moderate (3)	Good (4)	Very Good (5)
Participating activities	Explaining opinions					
	Listening other opinions					
	Discussing with fellows					
	Defending ideas with logical proofs					
	Providing original ideas					
Applying scientific inquiry process	Formulating a question or problem to be investigated					
	Formulating hypothesis					
	Identifying variables (independent, dependent, control)					
	Designing experiment					
	Carrying out observation and measurement					
	Manipulating tools					
	Recording results					
	Working according to own design					
	Transforming result into standard form					
	Determining relationships					
	Discussing accuracy of experimental data					
	Drawing conclusions					
	Formulating generalization					
	Making inferences					
	Formulating new questions or problems					

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