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Inquiry-based Professional Development Practices for Science Teachers

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ABSTRACT

In science education reform movements, there is an emphasis on teaching science through inquiry, and teacher education is an important part in this process. In this context, this study aims to investigate the effect of inquiry-based professional development training on science teachers' beliefs and self-efficacy about inquiry-based teaching and science process skills. A group of 30 science teachers participated in the study. The data collection tools used were "Beliefs about Inquiry-based Teaching Scale," the "Inquiry-based Science Teaching Self-efficacy Scale," and the "Science Process Skills Test." During two days of short-term professional development training, teachers attended five workshops that introduced the inquiry method. Analyses of the collected data showed that professional development training was effective in improving teachers beliefs ($t = -6{,}57$; $p = .00$), self-efficacy ($t = -5{,}80$; $p = .00$), and process skills ($t = -{-5{,}76}$; $p = .00$). The results of the study suggest that additional research about the improvement of students' science learning and about the effect of professional development on different variables such as teachers' learning design skills should be done.

Keywords: Inquiry-based teaching, professional development, self-efficacy, belief, science teachers.

INTRODUCTION

Recent studies have reported that students' interest in science and mathematics has decreased as has their interest in making a career in these fields (European Commission, 2007). Although many countries made effort to handle this issue, the current situation is unsatisfactory. Therefore, several countries changed their education systems, including Turkey that adopted a constructivist learning theory in its national science education program in order to create science-literate citizens in the future. A constructivist learning theory concerns an individual's mental information processing. This approach emphasizes that knowledge forms through one's own active mental process not transferring from one to another and suggests the efficacy of inquiry-based teaching (Duban, 2008; Schroeder & Zarinnia, 2001).

Inquiry involves asking questions or seeking knowledge, searching and getting knowledge about something. The inclusion of the term "inquiry" in education was proposed by John Dewey, a science teacher who asserted that science is taught only by the inclusion of students' personal knowledge and thus, encouraged teachers to use the inquiry method as a

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teaching strategy. In inquiry-based learning (IBL), students try to investigate and understand the things around them by working like a scientist. This type of learning provides opportunities for students to develop the skills (observing, measuring, collecting data, drawing conclusions etc.) needed during their lifetime, learn to deal with problems that cannot be solved, deal with changes and difficulties in their understanding, and revise researches for solutions (Kılınç, 2007). IBL further provides an understanding of core scientific facts, the acquisition of skills needed for understanding these facts, an understanding of the nature of science, and the development of positive attitudes toward science (Aktamış, Hiğde & Özden, 2016; Chiappetta & Adams, 2004). Researchers have provided much evidence about the advantages of IBL (Kahn and O'Rourke, 2004; Kılınç, 2007; On, 2010; Patrick, Mantzicopoulos & Samarapungavan, 2009; Yaşar & Duban, 2009). In one of these studies, an inquiry-based earth system curriculum was implemented in fifth grade classrooms of five different schools. The results revealed a significant improvement in students' success: 92% of them learned science from the curriculum (Lambert & Whelan, 2008). IBL was reported to be effective in increasing students' academic achievement and developing positive attitudes toward science and inquiry skills (Taşkoyan, 2008); furthermore, it was showed that IBL contributes to individuals' mental development and working skills as a team and helps the development of reading, writing, and language skills (National Science Foundation, [NSF], 2000).

IBL helps science teachers in teaching science to their students who have the ability to think critically, generate creative solutions to problems, and become scientifically literate by following scientists' methods. In IBL classrooms, teachers' roles vary as diagnostic, motivator, guide, innovator, experimenter, investigator, modeler, advisor, collaborator, and learner (Crawford, 2000). One study about teachers' roles in IBL classrooms mentioned that teachers must encourage students to discuss their views and explore and put forward their ideas by asking questions that lead to critical thinking, and must provide students with enough time to answer (Chin, 2007). Some research, however, has revealed inadequate implementation of inquiry-based instruction. According to these findings, teachers stated that following:

- They were reluctant to use IBL because of their inadequate knowledge (Lederman, 1992).
- They lacked experience of using IBL (Arslan, Ogan Bekiroğlu, Süzük & Gürel, 2014; Kleine, Brown, Harte, Hilson, Malone & Moller, 2002).
- They had beliefs about inquiry as it is appropriate for only bright students.
- There was a discrepancy between science content and their beliefs (Keys & Kang, 2000; Wallace & Kang, 2004; Windschitl, 2002).

Teachers' beliefs about self-efficacy also cannot be ignored alongside negative beliefs and the lack of knowledge about inquiry. Albert Bandura's concept of self-efficacy beliefs has been used to express an individual's judgments. In this context, the examination of teachers' self-efficacy beliefs is important. Studies have indicated that teachers' self-efficacy beliefs affect their performance and motivation (Caprara, Barbaranelli, Steca & Malone, 2006), and only teachers with high self-efficacy can perform IBL (Dawson, Cavanaugh & Ritzhaupt, 2006).

Moreover, it is important for teachers to have a thorough understanding of and develop awareness about the science process skills needed to implement IBL. Students make observations, ask questions, design and conduct experiments, establish a hypothesis, test the hypothesis by making predictions and interpreting the results, and share findings with others. Students' science process skills can be developed by an inquiry approach that allows them to use these skills. For teachers, having knowledge about science process skills in addition to subject-matter knowledge can better engage their students in active learning practices. Existing literature has also reported that students' gains toward science process skills vary statistically according to the teachers' level of using science process skills (Aydoğdu, 2006).

As indicated earlier, the effect of IBL depends on teachers' knowledge of this method (Abd-El-Khalick & Lederman, 2000). It is usual for teachers to face difficulties while implementing new pedagogical approaches. Studies have indicated that curriculum reform movements are shaped and changed by teachers' understanding and beliefs (Keys & Bryan, 2001); reform movements in education require changes in teachers' beliefs and values (Anderson, 2002), and teachers return to traditional curricula in the absence of professional training (Bybee, 2002 cited by Lawrence, 2003). Researchers have thus regarded it as important to provide professional development and other support to teachers in order to help them implement IBL (Bodzin & Beerer, 2003; McIsaac & Falconer, 2002). In this context, successful professional development training can lead to the following:

- It can help in changing teachers' beliefs and practices (Cohen & Hill, 2000; Garet, Porter, Desimone, Birman & Yoon, 2001).
- It is an important aid for teachers to determine the aims that affect students' behaviors in classrooms and schools (Young, 2001).
- It provides ways to increase students' academic achievement (Falk, 2001 cited by Villegas-Reimers, 2003).
- It helps teachers in creating an investigator class culture and IBL experiences (Supovitz & Turner, 2000).
- It causes positive, strong, and important development in terms of teachers' attitudes and practices (Supovitz, Mayer & Kahle, 2000).
- It provides means for teachers to keep their knowledge and skills up to date (European Union, 2010).
- It provides opportunities for teachers to transform their theoretical knowledge to observable behaviors in their classrooms (Birman, Desimone, Porter & Garet, 2000).

A great deal of research exists about inquiry-based professional development. Results of these researches indicate that professional development training is effective both on teachers' content knowledge (Capps & Crawford, 2013; Lewisa et. al, 2011) and their pedagogical knowledge about the inquiry method (Brand & Moore, 2011; Lotter, Harwood & Bonner, 2007). Despite this large number of studies about inquiry-based professional development, unfortunately, studies examining teachers' beliefs and self-efficacy are limited and the evaluation processes of these studies are unclear. Science process skills are fundamental to inquiry. Therefore, this study, as distinguished from previous studies, included science process skills and formative assessment strategies training in professional development training.

This study aimed to investigate the effect of inquiry-based professional development activities on science teachers' science process skills, beliefs about the inquiry method, and self-efficacy beliefs. The following problems were investigated in the study:

- Is there any significant difference between science teachers' pretest and posttest scores on the tool "Science Process Skills Test"?
- Is there any significant difference between science teachers' pretest and posttest scores on the tool "inquiry-based science teaching self-efficacy scale"?
- Is there any significant difference between science teachers' pretest and posttest scores on the tool "beliefs about inquiry-based teaching scale"?

METHODS

a) Research Design

In this study, one group pretest-posttest design which is one of the weak experimental design was used. In this model, measurements of one group were made before and after the treatment. According to this model, if posttests have higher scores than pretests, it is due to the effectiveness of the treatment (Fraenkel and Wallen, 2003). Although this model is weak, it is preferred because this study focuses on a training program. However, to increase the validity of this study, qualitative and quantitative measurements were considered in the data collection process. The experimental process of this research is as follows:

Table 1. *Experimental process of the research*

Group	Pretest	Implementation	Posttest
Science teachers	-Science Process Skills Test -The Inquiry-based Science Teaching Self-efficacy Scale -Beliefs about Inquiry-based Science Teaching Scale	Inquiry-based professional development activities	-Science Process Skills Test -The Inquiry-based Science Teaching Self-efficacy Scale -Beliefs about Inquiry-based Science Teaching Scale -Semi-structured Interviews

b) Participants

Teachers' volunteerism and accessibility was the basis for the determination of participants. Hence, convenience sampling was employed (Fraenkel & Wallen, 2003). Thirty science teachers (17 females and 13 males) from various middle schools in İzmir participated in the study.

Three of the female teachers had 0–5 years of teaching experience, two had 6–10 years, three had 11–15 years, and nine had 16 or more years of professional experience. Three of the male teachers had 0–5 years of experience, two had 6–10 years, and eight had 16 or more years of professional experience.

c) Data Collection Tools

This study used the tools the "Science Process Skills Test," the "Inquiry-based Science Teaching Self-efficacy Scale," "Beliefs about Inquiry-based Teaching Scale," and semi-structured interviews to collect data.

Science Process Skills Test: This test was used to determine changes in teachers' science process skills. The test was developed by Enger and Yager (1998) and was adapted to Turkish by Koray, Köksal, Özdemir, and Presley (2007). It includes 31 multiple-choice questions and its KR-21 reliability coefficient is .81. This study only used 10 questions related to skills (making observations, hypothesizing, predicting, planning and investigating, making scientific communication, and interpretation) in professional development training.

The Inquiry-based Science Teaching Self-efficacy Scale: This scale was developed by Smolleck (2008) and was adapted to Turkish by İnaltekin and Akçay (2011). It comprises 69 five-point Likert-type items, and the Cronbach alpha value of the scale is reported as .83.

The Beliefs about Inquiry-based Teaching Scale: This scale is used to determine whether a change in teachers' beliefs about inquiry has occurred. It was developed by

Dockers (2010) by examining the existing scales in the literature and was adapted to Turkish by the researcher (Kocagül, 2013). The scale comprises two parts and includes 44 items. In the adaptation process, the scale was applied to 372 preservice science teachers, and validity and reliability studies were performed on the obtained data. As a result of factor analysis, it was noted that while the first part of the scale comprises only one factor called "characteristics of inquiry," the second part of the scale comprises two factors called "barriers related to method" and "barriers related to teachers' lack of knowledge." The Cronbach alpha reliability value was found to be .87 for the first part and .83 for the second part. The Cronbach alpha value for the whole scale was.78.

Semi-structured interviews: Interviews were conducted with nine randomly selected teachers after the training in order to determine their views about training and inquiry-based teaching. To provide validity, the study utilized the views of two teaching staff members and three research assistants.

d) Data Analysis

To analyze the quantitative data, a paired sample t-test was conducted by using the software SPSS-15. The level of significance in this comparison was determined to be .05. In the analysis of qualitative data obtained from semi-structured interviews, the teachers' statements were recorded with their permission and then transcribed.

e) Application

The study presupposed that the inquiry method is not as difficult to implement as it is thought but that it can be practiced in classrooms by making small changes in the current lesson plans. For this purpose, five workshops were prepared by utilizing web-search-related professional development and related literature. The first of the workshops illustrated three different approaches that can be used to practice inquiry in classrooms. The second workshop focused on science process skills developed through short-time activities. In the third workshop, teachers experienced an inquiry-based lesson as students. In the fourth workshop, teachers examined the differences between the types of activities in order to determine which one of them is adapted to the inquiry method, and discussed the pedagogical effects of this differentiation. They studied formative assessment strategies in the last workshop. Experts in the field weighed in on the suitability of the workshop activities. These professional development activities were carried out for two days. Although it was not expected that variables such as beliefs and self-efficacy would change in such a short time, two days were preferred for the implementation of workshops. In this training, as it was only aimed that something useful could be done for teachers' awareness about inquiry-based teaching, any change in teachers' beliefs and efficacies can be interpreted as a criterion for measuring teachers' awareness. There were three workshops on the first day and two on the second day. Before the professional development training started, quantitative data collection tools as pretests were applied to teachers. Before each workshop, short presentations were made for teachers about the purpose of the activity, their tasks, and the points they should focus on during the processes. Participants prepared for the next workshop with a 20–25 minute break between each workshop held on the same day. Teachers performed inquiry-based professional development activities in the form of station work based on group work. In station work, the number of groups was determined according to the activity. For example, in the first workshop, teachers were divided into three groups of 10. In the second workshop related to science process skills, teachers were divided into seven groups, each comprising 3-4 teachers. In context of station work, teachers had time to complete the task on their table, and they passed to the next table as the time for the first task ended. After completing the activity, discussion sessions were organized, wherein the teachers shared their data among themselves and discussed how they could implement this activity into their classrooms and how it contributed to their development as teachers. After completing all of the workshops, quantitative data collection tools as posttests were applied to the teachers again. In addition, semi-structured interviews were conducted with nine teachers selected randomly in order to determine the gains of IBL both for them and their students. These interviews were used for supporting the quantitative data.

FINDINGS

Table 2 shows the statistical scores of teachers' answers to quantitative data collection tools before and after the training.

Table 2. *Average Scores of Teachers' Answers Given to Quantitative Data Analyses and Results of t-Test*

	N	$\overline{X}$	sd	t	p
Science Process Skills Test					
Pretest	30	13,53	1,83		
Posttest	30	15,47	1,68	−5,76	.00*
The Inquiry-based Science Teaching Self-efficacy Scale					
Pretest	30	255,07	12,78		
Posttest	30	273,30	18,04	−5,80	.00*
Beliefs about Inquiry-based Teaching Scale					
Importance Pretest	30	70,87	4,31		
Importance Posttest	30	75,47	3,32	−6,57	.00*
Teaching Pretest	30	64,13	5,67		
Teaching Posttest	30	68,70	7,74	−3,39	.00*
Learning Pretest	30	40,30	10,27		
Learning Posttest	30	38,23	9,67	1,49	.14
Barriers Pretest	30	50,77	6,70		
Barriers Posttest	30	60,33	7,06	−5,76	.00*

*$p < .05$ difference is significance.

Teachers who attended training showed significant development in terms of science process skills, self-efficacy toward inquiry-based science teaching, importance given to the inquiry method, inquiry teaching preferences, and perceived barriers about inquiry.

According to Table 2, only the posttest scores of the learning inquiry method decreased. Data obtained from the semi-structured interviews also supported positive gains related to variables. After the science process skills workshop, teachers stated that before the workshop, they had inadequate knowledge about science process skills, and they learned new skills in the workshop. For example, one teacher said the following about science process skills gains:

> "I learned the concept of making scientific communication. Until this time, I thought that scientific communication is possible only by verbal way. But now, I learned the importance of scientific communication in inquiry activities and this can be done via graphics, tables and etc."

Similarly, teachers were aware of their competencies to implement the inquiry method into a classroom and stated that there were positive improvements and changes in their self-efficacy beliefs after the training. The following are sample expressions related to self-efficacy:

> "Questions that I asked to plan activities were more restricted before. Because I tried to give information in theory directly. But now, I can let them prove this information themselves."
>
> "I learned better about how I applied the inquiry method to activities in my lessons."
>
> "Inquiry method creates changes in terms of teachers. Teachers can provide learning environment to be more interesting and intriguing and so he/she can encourage students to query, investigate, and debate."
>
> "I have been renewed with this training. This gives energy to me and also I realized my limits and this realization created a break."

Teachers also stated that their beliefs about the inquiry method as well as their self-efficacy beliefs changed and improved. In this context, the majority of teachers made comparisons between their lessons and an inquiry-based lesson, realized the contributions of the inquiry method to students, and expressed the changes in their ideas. Some sample expressions are as follows:

> "I think that inquiry method can encourage students not to be afraid of risks and decide with senses."
>
> "I think that traditional activities create a more restricted learning environment for students. But students are more free to investigate and make experiments in inquiry activities. For this reason, I think that inquiry activities can lead students to become more responsible in their researches."
>
> "Inquiry method allows students to query via their own hypothesis instead of accepting information directly and it increases the retention of information."
>
> "Instructions of activities in our lessons are clear and so students' working is more restricted and they are not free. I thought that teaching a lesson like this can be more enjoyable and students can be more active."
>
> "Instructions of activities in my lesson were given clear and they hadn't been adapted to inquiry. After this training, I realized that I allowed my students to query in a limited way. They didn't query by their own hypothesis. Now I am aware of inquiry method as a teacher."
>
> "I saw that it wasn't as difficult as I thought. I realized that it is required to design activities for each topic. I also realized that I have biases and judgments for inquiry method because of traditional methods that have been used for years. I saw that I get used to simplicity and luxury of traditional methods to teach science. I realized that adapting activities to inquiry requires time so team work is important to achieve this."

However, it was also seen that some teachers maintained their negative beliefs to inquiry. They said that the following:

> "I am very sad not to practice this method in my class. Because crowded classrooms and recklessness of students about science process skills prevent me to use inquiry method in my class".

Per the results of this study, it can be said that inquiry-based professional development activities positively affect teachers' skills needed for practicing inquiry and their self-efficacy and beliefs. This may suggest that similar professional development training can bring significant changes to teachers' ideas about using inquiry in their classrooms.

DISCUSSION and CONCLUSION

This study was conducted to test the hypothesis that inquiry-based professional development activities affect teachers' science process skills and their self-efficacy and beliefs about inquiry.

The first problem was expressed as, "*Is there any significant difference between science teachers' pretest and posttest scores on the science process skills test?*" The analysis showed a statistically significant increase in teachers' scores. Theoretical instructions about science process skills during the process and teachers' active involvement in the activities may have an effect on this result. This finding is in line with previous reports from researchers that the inquiry method is effective to develop preservice teachers' science process skills (Ateş, 2004) and that professional development training improves teachers' nature of science understandings (Yeşiloğlu, Küçüker, Taşdelen & Köseoğlu., 2012).

The second problem was expressed as, "*Is there any significant difference between science teachers' pretest and posttest scores on the inquiry-based science teaching self-efficacy scale?*" The analysis related to this query showed that there was a significant development in teachers' self-efficacy beliefs. During the training, it was emphasized that practicing inquiry method is not as difficult as it is thought, and it can be practiced by making small changes in activities and use of language. This may have affected teachers' self-efficacy beliefs. This result supports the findings of other studies indicating that introductory workshops about inquiry are effective to develop teachers' self-efficacy beliefs (Eshach, 2003) and that professional development trainings increase teachers' self-efficacy from a low to a high level (Roberts, Henson, Tharp & Moreno, 2001).

The analysis related to the third problem, expressed as "*Is there any significant difference between science teachers' pretest and posttest scores on the beliefs about inquiry-based teaching scale?*" showed that there was a significant development in teachers' scores on the importance attributed to inquiry, their thoughts related to the frequency of using inquiry, and the perceived potential barriers about inquiry. Activities in professional development training might have been effective and resulted in this finding. This training aimed to introduce the inquiry method during the activities. In this context, three different approaches to practice inquiry, adaptation of activities to inquiry by making small changes, and an example of an inquiry-based lesson are included in the training. Teachers' active participation in the activities is believed to have a positive influence on the development of their beliefs. Consistent with the results of other studies, the findings of this study indicate that inquiry-based professional development has a positive effect on teachers' views about inquiry (Capps & Crawford, 2013) and teachers' understanding (Lotter et. al., 2007) and beliefs (Cohen &Mill, 2000; Hubbard & Abell, 2005). The fact that some teachers maintain negative beliefs about inquiry in interviews may be a result of their lack of inquiry experiences in the past. Some studies the literature have reported that teachers' negative beliefs about the inquiry method may stem from their inexperience about this method when they were college students and novice teachers (Akerson & Hanuscin, 2007; Kazempour, 2009).

This two-day training conducted with a group of 30 science teachers. An increase in training time may create differences. It can therefore be said that the preferred method of the current study creates limits on the interpretation of its obtained findings.

Future studies can investigate the extent to which teachers reflect their gains obtained from professional development training to their learning environments and the advantages of this reflection in terms of students and classroom culture.

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