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Using Inquiry-Based Experiments to Improve Pre-Service Science Teachers' Science Process Skills

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Abstract

The purpose of this study was to investigate the effect of inquiry-based experiments on pre-service science teachers' science process skills. The study group consisted of 60 pre-service teachers in total, enrolled in the undergraduate program of Science Teacher Education, Faculty of Education at a state university. The study which used randomized quasi-experimental design with pre-test – post-test and control group, designed as a mixed method study. Experimental practices were performed within a 10-week period. Science Process Skills Observation Form, developed by the researchers, was used as data collection tool in the study. IBM SPSS Statistics software was used for the analysis of quantitative data and content analysis was employed for analyzing the qualitative data. As a result of the analyses, inquiry-based experiments were more successful than confirmatory ones in terms of improving the science process skills of pre-service teachers. It is estimated that the results of this study will significantly contribute to the planning processes of teacher education programs as well as to the future studies on inquiry-based learning.

Keywords: Inquiry-based science teaching, Science process skills, Pre-service science teachers, Science education.

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INTRODUCTION

In the 21st century, the focus of our education systems consists of gaining the skills based on activating knowledge instead of teaching knowledge. These skills are significant in that people can be active in improving and making use of knowledge multiply rather than acquiring knowledge in a single way. Thanks to these skills, it is possible that people can change into individuals who not only acquire the present knowledge through several methods but also question, interpret, develop and share it. One of these skills, which scientists have and current curriculums also employ, is science process skills. Science process skills are defined as the skills which enable students to learn permanently and actively by taking responsibilities during learning process (Çepni, Ayas, Johnson & Turgut, 1997). These skills include science processes such as observation, measuring, classification, recording data, relating number and space, prediction, inference, collecting and analyzing data, designing-doing experiment and deduction (Güler, 2018). Science process skills lead people to work like a scientist and enable the information they get to be reliable. In fact, these skills are a scientist's working process (Lind, 1998). In other words, using science process skills means doing science. The purpose of science curriculums is to raise individuals who live by doing science and approach scientifically to the events in their environment. Therefore, the subjects that science education includes explain nature and function of nature. In this regard, scientific laws and explanations related to all events happening within the environment where human beings live, are involved in science education. Hence, one of the most important way through which individuals can comprehend how nature works and adopt a scientific approach about nature is science education. It is necessary to study just like a scientist to be able to learn the concepts science courses include.

When both characteristics of the people aimed at being raised and the purposes of science education are analyzed, it can be clearly observed that there is a circulation during the process of qualified individuals' training. On one hand, people who have scientific skills are required so that science education can achieve its goal totally, on the other hand it is of great importance to train individuals whose scientific skills are more developed after science education achieves its goal. That's why, a slight outcome which will take part in this circulation from any point will be able to initiate a circulation that leads new developments by enlarging like a snowball. At this point, the most important component of science education is laboratory practices. Laboratory practices is a process in which practices and simulations of daily events mentioned in science lessons are carried out and theoretical learning is consolidated by this way. This process is called the process of doing science which curriculums aim. Laboratory practices is applied in two ways. One of these is the traditional approach which is widely known as recipe or prescription and the other one is inquiry-based approach (Colburn, 2008). In recent years, the approach which has been employed most at science teaching and especially at laboratories is inquiry-based approach.

Inquiry-based learning has been defined as the process which students collect data by making observations, plan the research process by asking research questions, analyze the data they collect by doing experiments, compare their present knowledge with their findings, present and discuss their own explanations (National Research Council, 2000). Inquiry-based learning leads people to use their creativity and skills in accordance with their interest. Thus, people act in accordance with their interest without expecting feedback from the external supports. They design the necessary scientific steps to solve problems delicately just like a scientist.

The findings they obtain contribute to their problem-solving process or developing new and more effective stages. What people adopting inquiry-based learning process will learn is determined by the cases they face and their interest instead of a teacher who always gives feedbacks. The individuals are encouraged to come up with ideas, develop and present them (Krajcik, Blumenfeld, Marx, & Soloway, 2000; Eryaman, 2008). Therefore, it is possible that laboratory practices which is a significant part of science education can stand out and science teaching can become more productive and qualified. The fact that inquiry-based learning focuses on daily-life examples and skills makes it more important. If students apply what they learn in daily life, their learning can be more meaningful and permanent (Oguz-Unver & Yurumezoglu, 2014). This learning process which encourages

individuals to acquire knowledge actively ensures education to achieve the goal of gaining vital skills fully (Roth & Roychoudhury, 1993). According to the research studies, there are quite many studies which point out that inquiry-based learning is more successful than traditional approach (Basağa, Geban & Tekkaya, 1994; Mao & Chang, 1998; Ortakuz 2006; Şensoy & Aydoğdu, 2008; Özdilek & Bulunuz, 2009; Miller, 2014; Maxwell, Lambeth, & Cox, 2015). It has been observed that students' academic achievement has improved considerably in most of these studies (Trundle, Atwood, Christopher, & Sackes, 2010; Bozkurt, 2012; İnal, 2013; Kaya ve Yılmaz, 2016). Especially in recent years, a great number of studies show that inquiry-based learning has positive effects on science process skills, critical thinking skills and questioning skills which are primary outcomes that science teaching aims to gain (Basağa, Geban ve Tekkaya, 1994; Brickman, Gormally, Armstrong & Hallar, 2009; Demirkıran, 2016; Dilbaz, 2013; Duban, 2008; Ergül ve diğer., 2011; Kaya ve Yılmaz, 2016; Longo, 2012; Şensoy ve Yıldırım, 2017; Yazgan, 2013).

A science teacher needs to learn science process skills so that s/he can gain a scientific viewpoint related to the events in his environment. Besides, s/he needs to experience these scientific stages directly to gain and improve science process skills. When the studies about inquiry-based learning are viewed, it is clearly noticed that experiences resulting from the practices effect students positively. It is assumed that science teachers who are regarded as important components during the process of gaining scientific skills are supposed to experience the process of acquiring these skills and their effects are to be viewed (Smolleck, Zembal-Saul & Yoder, 2006). In this regard, the aim of this study was to investigate the effect of inquiry-based experiments on pre-service teachers' science process skills.

METHOD

Research Design

Since the participants are considered as a class within a certain course, and the study employed a convenience sampling method. Therefore, this study is quasi-experimental. In addition, since the experimental and control groups are involved, pretest-posttest quasi-experimental design with controlled group (Creswell, 2016: 172) was preferred. During the implementation process, while inquiry-based experiments were employed for the experimental group, confirmatory experiments, which are also called traditional, were used for the control group. The general forms of the experiments were similar; however, they were designed as inquiry-based and traditional in terms of practice styles. The data to be obtained from the study were planned to provide more reliable and detailed information about the results by presenting different viewpoints. Thus, mixed method was preferred for collecting data. Mixed method is defined as the method in which quantitative and qualitative data are used together so that the results to be obtained from the research can be more explanatory and coherent. While mixed method has different practice styles according to the cases of quantitative and qualitative data usage, convergent parallel mixed design was used among the given mixed designs during this research. Quantitative and qualitative data are collected and analyzed separately in this design. After the analysis, quantitative and qualitative findings are compared or associated with each other. After the comparison and association, the findings are interpreted (Creswell, 2016).

Participants

The study group of the research involves 60 pre-service teachers who study Science Teaching at Faculty of Education at a state university. The participants were enrolled in General Physics Laboratory course. Participants were freshmen students and were taking the course for the first time. The students are assigned to the laboratory groups randomly without considering any achievement ranking etc. during the process of course registration. 32 participants were assigned to group A and 28 of them were assigned to group B by the institution at the beginning of the term. These groups were

determined as experimental and control groups of the research and group A was selected as experimental group and group B was selected as control group without any pre-assessment.

Data Collection

Science process skills (observation, classification, communicating, measuring, relating number and space, making prediction, making inference, determining and controlling factors, hypothesizing, interpreting data, operational defining, doing experiment) which include a scientist's study steps can be used separately or together at different stages of the experiments. Besides, the individuals not also can use these skills at a quite low level but also, they are likely to present a quite rich variety of skills. That's why, it is of great importance to view the whole experiment process while assessing these skills. The individuals who have science process skills are expected to be able to manage the problem-solving process by using these skills actively if required rather than knowing them by memorizing or a different way. Such a complicated situation is doable by investigating the individuals' problem-solving processes and their behaviors. This versatility science process skills have is likely to make the reliability of the results of multiple–choice questions or questionnaires controversial. Therefore, alternative data collection tools such as observation forms, interviews and rubrics are benefited from. (Yıldırım, Çalık, & Özmen, 2016). Haladyna (1997: 67) stated that abilities requiring creative thinking such as science process skills shouldn't be assessed by multiple–choice tests. Considering these situations, semi-structured observation form was utilized to determine science process skills in this study. The first author took part in the process as participant observer as it is necessary to lead the pre-service teachers during the practices and the experiments are supposed to progress in a controlled way.

The semi-structured observation form developed by the researcher contains respective scoring of all science process skills for each student. These scorings were supplied by observations about the cases of students using science process skills. The scorings were preferred based on study group instead of individual. Because, while there is cooperation in the study groups during experiments, it may not be possible for all the group members to carry out a stage of the experiment simultaneously. In that case, the skill used at that stage can be observed through only one or a few students. However, this does not necessarily mean that the other students do not have these skills. This kind of scoring might not be able to present reliable data related to students' skills. Thus, "group score" were given within the study groups during the scoring process and observation notes about the group were taken. The grades involve 3 categories and they are defined as "1=at low level, 2=at mid-level, 3=at successful level". During the grading process, "Science process Skills Assessment Criteria", prepared by the researchers was utilized. These criteria were prepared in order to pre-determine how science process skills were to be graded at the observation form. Before the criteria table was used in the study, it was edited in accordance with 2 science educators' feedbacks.

In addition, an "explanation" part about each group was included in the observation form. While the researcher graded students during the observations, he could note down important and different points he noticed. It was aimed that both a grading scale and a descriptive assessment scale were used simultaneously in a united way and this could provide more reliable results.

Observation form of science process skills was used as pre-test and post-test during the first and last week of the semester. Moreover, all the courses in which pre-tests and post-tests were applied were video typed. The video records taken during the courses were watched by the researchers in order to improve validity of the observations and notes taken and necessary editing and additions were made on the observation forms.

Design and Implementation of the Teaching Process

Before the application process of research, data collection tools as well as other components to be used at the applications were prepared. The most important ones of these components are the

experiments to be used for instruction of the course. The experiments were designed in accordance with the content of General Physics Laboratory course. The applications were carried out by means of guided inquiry-based experiments within the experimental group. On the other hand, they were conducted through traditional confirmatory-based experiments within the control group. Therefore, while worksheets of the experiments were designed as guided inquiry-based form for the experimental group, they were designed as confirmatory form for the control group. In addition to the experiments related to the content strands determined, warm-up activities were designed so that the pre-service teachers could adapt to their study groups and recognize the application forms they will use in the experiments. Through these activities, it was aimed that the pre-service teachers were to experience what kind of learning process they would follow. As a result of this, it was assumed that the pre-service teachers would not be influenced by external factors irrelevant to the experiment subjects during the application of the experiments. In accordance with the experts' opinions, after the experiments were considered as adequate in terms of containing the subjects, the stag in which worksheets were prepared began. As the experiments conducted within the scope of the research were applied in 2 separate ways as "guided-inquiry based" (experimental group) and confirmatory-based (control group), experiment worksheets were designed in accordance with these methods. While the worksheets were being designed, some precautions were taken to prevent any external influence on the pre-service teachers except teaching process's own influence. Within the context of these precautions, visual varieties that can make considerable differences between the groups were not included in the worksheets and these worksheets were cared to be designed in a simple way. Furthermore, chapters of the worksheets were designed identically and only the clause forms made the process different. Thus, an influence except the teaching method was not allowed. After that, necessary materials for all experiments were prepared and a pilot scheme setting was designed. A group containing 15 pre-service teachers who study Science Teaching and participated in pilot studies of data collection tools were involved in the pilot study. These 15 participants are students who study at the 2nd, the 3rd and the 4th grades and passed the given course successfully. After the application of the pilot study, the researcher viewed the worksheets filled by the pre-service teachers so that worksheets could be reviewed. The worksheets were reviewed, and all experiments were set in accordance with the data obtained from pilot study. General Physics Laboratory II in which main applications were conducted involves a-14-week process which is an academic term. In total 10 experiments developed by the researchers were carried out within these courses.

FINDINGS

Quantitative Findings

Six study groups involved in the experimental group and five study groups involved in the control group. Groups were scored as pre-test and post-test based on observation form. These scores were quantitative data related to the groups. It is pointed out that if each sub-group involves 15 people or more, parametric tests can be used and non-parametric tests are supposed to be utilized at other tiny samples (Büyüköztürk, 2012). That's why, Mann-Whitney U test, which is a non-parametric test, was used for quantitative data.

First, pre-test scores of the groups were compared. Table 1 reveals the results related to Mann-Whitney U test which compares pre-test scores of the experimental and control groups.

Table 1. Mann-Whitney U Test Results Related to Science process Skills Pre-test Scores

Group	N	Mean	Sum	Median	Mann-Whitney U	Z	p
Experimental	6	5.92	35.50	21			
Control	5	6.10	30.50	19	14.50	-.094	.925
Total	11						

When Table 1 is viewed, there is no statistically significant difference between pre-test scores of experimental (Md=21, n=6) and control (Md=19, n=5) groups. In other words, the groups can be regarded as equal before the applications. Then, the post-test scores of the groups were compared. Table 2 reveals the results related to Mann-Whitney U test conducted to compare the post-test scores.

Table 2. Mann-Whitney U Test Results Related to Science process Skills Post-test Scores

Group	N	Mean	Sum	Median	Mann-Whitney U	Z	p
Experimental	6	7.67	46.00	28			
Control	5	4.00	20.00	19	5.00	-1.838	.066
Total	11						

When Table 2 is viewed, there is not a statistically significant difference (p=.066, p>.05) between post-test scores of experimental (Md=28, n=6) and control (Md=19, n=5) groups. Given this finding, it can be asserted that there is not a meaningful difference between science process skills of the experimental and control groups after the applications. However, when the groups' medians are viewed, while the experimental group's median is Md=21 at the pre-test, it is Md=28 at the post-test. As for the control group, median is Md=19 at both pre-test and post-test.

It is clearly seen that while p value which stands for significance of the difference between the groups is p=.925 at the pre-test, it is p=.066 at the post-test. Although it is not statistically significant, the fact that median value of the experimental group increased at the post-test and p significance value approached to .05 value can be interpreted as a development for science process skills of the experimental group. Quantitative findings prove that although there is a positive development on the experimental group, there is not a statistically significant difference between the groups.

Qualitative Findings

Qualitative data consists of the observation notes recorded by the first author to determine the changes in science process skills. The notes related to each skill that were taken by the researcher are included in this section.

a- Findings Related to Observation Skills

When the researcher notes related to the observation skills were investigated, it was revealed that both groups were not adequate at observing the experimental procedures at the first applications. As a habit resulting from conducting confirmatory experiments, the pre-service teachers were found to view only the samples supplied before the experiment and the findings to be obtained from the experiment afterwards. Although there were a few changes which were likely to influence the result, the pre-service teachers were found to ignore these stages.

At the last applications, the experimental group observed not only first step of the experiment but also the whole process of it. As for the control group, it was revealed that the necessary steps regarding following the experiment process were not taken and the observations were just the ones performed at the beginning and ending parts of the experiment.

Samples of observation notes about the experimental and control groups are provided here:

*"…Group members are good at observing the instructor and the materials he supplied. However, different cases faced during the application of experiment are not being viewed enough within these groups. They focus on only the change to come out at the last stage…" (**Experimental group-Pre-test**)*

"…The groups are following the process of the experiment as much as the beginning stage. In addition to following the stages of different groups, they are making comparisons through their own experiments…Observations related to the result are being noted in more detail by means of brainstorming within the group…"

(Experimental group-Post-test)

"…The samples supplied by the teacher are being viewed in detail within the 7th, 8th, 10th and 11th groups. Observations about changes in the case are being made. However, when they move on the stage of designing experiment, they are not following several changes happening till the last stage…" ***(Control group-Pre-test)***

"…While the given steps are being applied precisely during the stage of designing experiment, any interpretation is not being made about the changes happened during these stages. At the conclusion stage, comparison of the experiment with the anticipated situations or sample situations is not being made and the observations consist of just the ones made at the beginning…" ***(Control group-Post-test)***

b- Findings Related to Classification Skills

When the researcher notes related to classification skill were investigated, it was revealed that while the experimental group was only able to view sample cases supplied at the beginning of the experiment at pre-test, they used this skill for the materials by making more classification at the post applications. What is more, some groups were noticed to make necessary comparisons by reviewing this classification at the end of the experiment. When the study groups in the control group were viewed, they were revealed to make classification at just one stage of the experiment at the post application like the pre applications.

Besides, it was determined that participants in the control group viewed the supplied material for the experiment instead of viewing the case study, and the behaviors related to classification appeared during this stage. Considering these findings, it can be stated that while classification skill became more prominent within the experimental group at the post applications, the restrictions at the pre applications carried on within the control group.

Samples of observation notes about the experimental and control groups are provided here:

"…Before getting started to the experiment, the case study and the experiment to be done are being compared in all groups. What is presented and what kind of studies are to be conducted are being viewed. However, after this stage, the 1st, the 2nd, the 4th, the 5th and the 6th groups are not making any classification related to the materials…" ***(Experimental group-Pre-test)***

"…The 1st, the 3rd and the 6th groups classify the materials they will use during the experiment according to their roles in the experiment in addition to comparisons of the case study and the experiment they will do. The roles determined at this classification are considered while designing the experiment…" ***(Experimental group-Post-test)***

"…There is not any case in which materials are viewed before and after the experiment within the groups. The materials are being imitated just like the way it is given at the case study. Any application related to classification is not included in the other stages, either…" ***(Control group-Pre-test)***

"…The 7th and the 9th groups are viewing the materials of the experiment directly without comparing the data supplied at the case study with the experiment…They are viewing at which stages they will use the experiment materials by classifying them before the experiment. They are not making any other classification except this one..." ***(Control group-Post-test)***

c Findings Related to Communication Skills

When the researcher notes related to communication skills were investigated, it was determined in both groups that participants were able to carry out the communicating stages partly before the experiment. These communications generally consisted of suggestion of ideas about the application stages of the experiment before getting start to the experiment. When the process of using worksheets effectively was viewed, it was observed that writing the data down and supporting these data with visual elements were more limited. It was ascertained that the communication behaviors at beginner level which were conducted at pre-applications remained stable in both groups at the post-applications. However, when the observation notes related to the post-applications of the experimental group were viewed, it was determined that the experimental group recorded the data in more detail and employed the visual elements more often.

Samples of observation notes about the experimental and control groups are provided here:

"…The 1st, the 3rd and the 6th groups are active in communicating at both the beginning and application stages of the experiment. These groups are sharing justified ideas as to how they can design the experiment by explaining their observations to each other before the experiment…" ***(Experimental group- Pre-test)***

"…The 4th group is getting to the experiment by exchanging opinions before the experiment. Besides, they are recording the findings obtained from the experiment to the necessary points in detail…During the presentation of data, illustrations are being added to the data obtained from these parts…" ***(Experimental group-Post-test)***

"…In all groups, there is an exchange of ideas as to how to do the experiment. The experiments are being done in accordance with the ideas determining an application method …" ***(Control group-Pre-test)***

"…The groups are discussing what to do at each stage by viewing the application stages before getting start to the experiments…The 8th and the 11th groups are noting down the processes they go through during the experiment to the worksheets in addition to these stages…" ***(Control group-Post-test)***

d Findings Related to Measuring Skills

When the researcher notes related to measuring skills were investigated, it was revealed that the pre-service teachers did not have any difficulty in determining the unit to be measured at the experiment. However, it was determined that the ongoing stages of measuring process had limitations. It was noticed that while only one group could pass to the next stage at the pre-test in experimental group, all groups except one could pass to the next stage at the post-test and were able to determine the measuring instrument precisely. Moreover, while the participants in control group could determine the correct measuring tool at pre-test, only two groups were able to pass to achieve this at the post-test. The other groups were not able to determine the correct measuring tool and they were incapable of carrying out the measuring process precisely. Given these findings, it is possible to state that while the experimental group made progress in measuring skill at post-test, the control group was more inadequate at post-test.

Samples of observation notes about the experimental and control groups are provided here:

"…All the groups are determining what they are supposed to count correctly during the application of experiment …However, only the 3rd group is good at determining the correct assessment tool and using this assessment tool correctly …" ***(Experimental group- Pre-test)***

"…All the groups are determining the case they are supposed to assess …All groups except the 4th one are determining an assessment tool so as to measure this valency and they are able to use it correctly…" ***(Experimental group- Post-test)***

"…The 10th group is able to determine the kind of valency of assessment process which will be applied during the experiment and select an assessment unit and assessment tool in accordance with it…The other groups are incapable of determining the assessment unit which they are supposed to consider…" ***(Control group-Pre-test)***

"…The groups are not able to determine correct assessment tools and assessment units while measuring the valency. Only the 8th and the 11th groups are able to determine the correct assessment tool. Yet, these groups are incapable of determining which assessment unit is to be considered within the assessment tool…" ***(Control group- Post-test)***

e Findings Related to Relating Numbers and Space Skills

When the researcher notes related to relating number-space skills were investigated, it was observed that most of the participants did not have difficulty in determining direction of forces included in the experiment. However, they were able to set the direction of forces accurately to only some extent. It was revealed that most of the participants in the experimental group were only able to predict the direction correctly and this case occurred in both at pre-test and post-test in the same way. Control group showed same performance in both pre and post-tests. Given this point, it is possible to assert that relating number-space skills after applications of both the experimental and control group are similar to the ones before applications.

Samples of observation notes about the experimental and control groups are provided here:

"…While the groups are setting the forces and their directions they need to determine within the experiment, they have the most difficulty in the basis of direction…" ***(Experimental group-Pre-test)***

"…All groups except the 4th one are good at determining the directions …While the 1st group is making determinations related to forces correctly, the other groups are only able to determine the direction related to force…" ***(Experimental group-Post-test)***

"…is able to set the ways and directions of all the forces applied correctly. However, the other groups are incapable of determining the way although they are able to determine the directions correctly…" ***(Control group-Pre-test)***

"…Within the 8th group, the way and direction of the force are confused with the ways and directions of the external forces emerging during the experiment …" ***(Control group-Post-test)***

f Findings Related to Prediction Skills

When the researcher notes were investigated, it was revealed that the pre-service teachers in experimental group were more inadequate on making prediction at pre-test applications. It was observed that while some of the participants in the group made predictions before the experiment, others did not make any predictions before or after the experiment. When the post-test applications were viewed, it was clear that all the groups made pre-experimental predictions and some of the groups made predictions during the application of the experiment. When the control group was viewed, it was revealed that all groups made pre-experimental predictions. As for the post-test applications, some of the groups were not able to make any predictions. Whereas, it was observed that these pre-service teachers carried out the stages within the worksheets step by step and they were not involved in any pre-study related to the next stages. In the light of these findings, it can be stated that there are more positive changes within the experimental group in comparison with the control group.

Samples of observation notes about the experimental and control groups are provided here:

*"…The 1st, the 3rd and the 6th groups are making predictions related to the experiment to be done and they are sharing them with their friends. They are determining how to do the experiment in the light of these predictions…"****(Experimental group- Pre-test)***

*"…While all groups are observed to make pre-experimental predictions, the 1st and the 3rd groups are noticed to make predictions about the next stages during the experiment…"****(Experimental group-Post-test)***

*"… All the groups are making predictions about their own experiments based on the case study before starting the experiment…They are making predictions about the next stages by viewing the previous stages while doing the experiment…"****(Control group-Pre-test)***

*"…The 9th and 11th groups are trying to develop their practices by making use of pre-experimental predictions and the ones during the experiment…The other groups are mostly checking whether they are applying the stages supplied within the worksheets correctly or not…."****(Control group-Post-test)***

g The Findings Related to Making Inference Skills

The researcher notes related to making inference skill point that both the control and experimental groups changed positively after the applications. Participants in both groups tried to make inference more often and view the application process of their own experiment more carefully. The number of participants who did not make any inference in both groups decreased and the inferences made reflected on the results of their own experiments rather than being limited to the case studies at the beginning.

Given these findings, it can be stated that making inference skills of both experimental and control groups improved after the applications.

Samples of observation notes about groups are provided here:

*"…The inferences made are being reviewed after their own experiments. They are interpreting the result they got from their experiment by discussing similarities and differences between these two cases. Except one group, making inference is based on only the case study…"****(Experimental group-Pre-test)***

"…It is observed that the 1st, the 3rd and the 6th groups make inferences during all stages of the experiment process and review this process in the light of these inferences… The

*participants in the group present their inferences related to the influence of the cases conducted during each stage on the result. Thus, they ensure these inferences to be discussed within the group…"**(Experimental group-Post-test)***

*"…The 11th group is making some inferences by evaluating the case study within the group. However, it is observed that the other groups are making inferences based on neither the case study nor the experiment they did…"**(Control group-Pre-test)***

*"…Only two groups (7 and 10) are not making any inferences. These two groups are presenting their findings at the end of the experiment by applying the stages of their own experiments directly after they view the case study…"**(Control group-Post-test)***

h Findings Related to Determining and Controlling Variables Skills

When the findings related to determining and controlling variables skill were investigated, it was observed that the pre-service teachers had difficulty in even defining dependent variables within the explanations about the case study or the experiment to be done during pre-test applications. However, when post-test applications were viewed, it was revealed that both groups changed positively in terms of determining the variables. It was determined that there were groups who were able to define the processes to be applied to the variables within both groups. However, it is possible to notice the participants who were not able to apply this stage precisely within both groups. Given all these findings, it was determined that participants in both the experimental and control groups made progress in determining and controlling the variables after the application process.

Samples of observation notes about the experimental and control groups are provided here:

*"…The 2nd, the 4th and the 5th groups have difficulty in determining which value or case to follow. Since they are not able to make a distinction related to the dependent and independent variables, they are not able to start the experiment clearly…"**(Experimental group-Pre-test)***

*"…The 3rd and 6th groups are able to determine how to change each variable and which variable supposed to be controlled by determining the variables correctly…"**(Experimental group-Post-test)***

*"… Only one group (the 11th group) is coming up with explanations as to which one is dependent variable and what can be done. The other groups are not discussing as to which feature is which variable or which processes to carry out …"**(Control group-Pre-test)***

*"…Two groups (the 9th and 11th) are able to determine which variable has what kind of role during the processes conducted. They are viewing the application process of the experiment on the basis of these variables . They ensure each stage to be conducted by making speeches about what kind of change these stages aim …"**(Control group-Post-test)***

i Findings Related to Hypothesizing Skills

When the researcher notes related to hypothesizing skills were investigated, it was determined that the pre-service teachers had difficulty in hypothesizing during pre-test applications. This case was similar for all participants. However, it was noticed at post-test applications that the participants began to question the application processes by hypothesizing before the experiment. While the hypotheses developed by the experimental group were forming the application steps of the experiment, the hypotheses developed by the control group led them to apply the steps given. It was determined that none of the study groups developed hypotheses by means of the inferences after the experiment. Considering the findings, it can be asserted that the application process led the students' hypothesizing skills were improved in both experimental and control groups.

Samples of observation notes about the experimental and control groups are provided here:

"…Studies about the hypothesis were observed only in the 3rd group among all. They reviewed their hypotheses after the experiment, yet they did not develop a new hypothesis. The other groups did not develop hypothesis during any stage…" ***(Experimental group-Pre-test)***

"…The 2nd and the 4th groups did not develop hypothesis at any stage…The other groups are coming up with a hypothesis and deciding which stages to conduct and how to interpret the changes in the materials in the light of this hypothesis…" ***(Experimental group-Post-test)***

"….They are taking down necessary notes by applying the processes during the stages given within their experiments. However, any hypothesis is not being developed at the beginning and end of the experiments…" ***(Control group-Pre-test)***

"…The 9th and the 11th groups are viewing the stages to be applied in the experiment before starting the experiment. A hypothesis about the result of the experiment is being developed in the light of the applications required to be done during each stage …" ***(Control group-Post-test)***

j The Findings Related to Recording and Interpreting Data Skills

The researcher notes related to recording and interpreting data skills pointed out that participants in both experimental and control groups interpreted the data they collected during the pre-test applications. However, it was observed that these interpretations were not associated with the hypotheses or the application stages and were limited to a slight interpretation. When the post-test applications were viewed, it was revealed that some of the participants in the experimental group associated the data with the application stages of the experiment and the rest kept interpreting about data although they did not develop this association. Therefore, it is possible to claim that the experimental group showed a positive change at post-test.

When the control group was viewed, it was observed that the pre-service teachers making interpretations about the data to a great extent at the pre-test were less involved in presenting interpretations about the data at the post-test. According to the findings, just one group evaluated the data together with the application stages of the experiment and most of them did not make any interpretations about the data. Given the findings, there is a progress on the experimental group in terms of recording and interpreting the data at the end of the application process.

Samples of observation notes about the experimental and control groups are provided here:

"…Although the 4th group collected some data they are supposed to interpret during the experiment, they are not making any interpretations about these data. They are interpreting their findings by observing the other groups' interpretations and experiment processes. The other groups are interpreting the data they obtained…" ***(Experimental group-Pre-test)***

"…The 1st and the 6th groups are using all of the stages they applied during their experiments while interpreting the data. They are trying to explain and form why the data came up in this way through the application steps…" ***(Experimental group-Post-test)***

"…The 7th and the 10th groups are recording data without making any interpretation about the data. These data are being compared with the case study in terms of only the results… Each data is being interpreted as a group before they are written on the worksheet during the process of collecting. Thus, it is possible to interpret the data collected before passing to the next stage…" ***(Control group-Pre-test)***

"…The 11th group is especially viewing what kind of results the data presents. The other groups except this one are only writing down the data after they are collected. The participants are collecting data by cooperating during this process. However, they are not making any interpretations…" ***(Control group-Post-test)***

k The Findings Related to Operational Defining Skills

According to the researcher notes related to operational defining skills, the general problems of participants were related to determining the values they assess and direct or indirect assessment ways to assess this value. It was determined that the pre-service teachers were inadequate on designing this process and they tried to solve this through exchange of ideas within the group.

The pre-service teachers' pre-test and post-test applications presented similar data in both experimental and control groups. Given these findings, it can be stated that the application process did not lead to any change in operational defining skills of both groups.

Samples of observation notes about the experimental and control groups are provided here:

"…All of the groups are presenting ideas about the measurements to be performed during the stage of application of the experiment…Some of the groups are making mistakes during the measurement stages because of the false determinations about the beginning and ending times of measurements…" ***(Experimental group-Pre-test)***

"…Only one of the groups is able to present the necessary stages so that the measurements to be performed at the experiment can be performed correctly. Although the other groups present opinions about the measurement stage, they are not able to determine a final way in order to make correct determiantions…" ***(Experimental group-Post-test)***

"…The pre-service teachers in two of the groups are observing the other groups without suggesting any way related to the measurement processes…The other groups are exchanging ideas in order to put forward the necessary ways for the measurement processes. They are trying the ways which they regard as the most beneficial ones for the measurement…" ***(Control group-Pre-test)***

"…They are trying to determine what to measure and how to measure and how they can associate the values they measure with each other at the measurements they will perform. Two of the groups are partly good at this point…" ***(Control group-Post-test)***

l Findings Related to Conducting Experiment Skills

The notes related to conducting experiment skills revealed that the process which the pre-service teachers conducted most easily was to prepare experiment setup physically. However, when the other stages which are necessary for the experiment to be done successfully and clearly were viewed, distinctions were noticed in the groups. It was revealed that the participants in both experimental and control groups applied doing experiment stages "partly" to a large extent. The pre-service teachers carried out the stages of determining the variables and hypotheses of these experiments in addition to designing them physically. When the data obtained from the post-test applications were examined, it was observed that one among the groups was able to carry out the stage of doing experiment skill. When the experimental and control groups were viewed separately, both groups were found to go through a positive change at post–test applications. Yet, this positive change in the experimental and control groups occurred in a similar way in both groups. In the light of these findings, it can be said that conducting experiment skills of the experimental and control groups improved at the post-test and this improvement is similar in both groups.

Samples of observation notes about the experimental and control groups are provided here:

"… is only able to plan the form of the experiment expected physically and the data to be obtained from the application process are being neglected slightly. The other groups are conducting the processes of determining the hypothesis of the experiment, making several plans about variables and testing the hypothesis during the experiment. Each of these stages are occurring in different groups…" ***(Experimental group- Pre-test)***

"…All of the groups are good at designing the experiment physically. Only one group is not able to pass to the stages of designing the experiment based on a certain hypothesis and viewing it…One of the groups is putting forward justified opinion as to whether the experiment is to be repeated or not at the end of the experiment by applying its all stages…" ***(Experimental group-Post-test)***

"…The groups are able to set the physical design by making a plan as to how the experiment will be done. All the groups except the 10th one are applying one of the stages of associating the experiment with the hypothesis, determining how to follow the variables during the process and testing the hypothesis in addition to designing the experiment…" ***(Control group-Pre-test)***

"…The 11th group is progressing in a certain sense from the beginning to the end of the experiment. They are considering the case they determined as hypothesis while designing the experiment. Moreover, they are comparing the findings obtained from the experiment with the hypothesis directly…" ***(Control group-Post-test)***

m The Findings Related to Modelling Skill

When the researcher notes related to modelling skill are investigated, it was observed that the pre-service teachers were considerably adequate on building experiment setups at both pre-test and post-test. However, it was determined that they did not tend to design any model during the process of interpreting the case study. The groups in which the processes of modelling based on the case studies and viewing are observed are quite few. However, when the post-test findings were viewed, while the number of groups modelling and building controlled experiment setup increased in the experimental group, a significant change like this was not noticed in the control group. When the findings were viewed generally, while modelling skills of the experimental group changed positively, any difference between pre-test and post-test was not noticed in the control group.

Samples of observation notes about the experimental and control groups are provided here:

"…Most of the groups are passing to the stage of designing their own experiments after viewing the case study. The groups determining the problem status are heading to the planning about their experiments by viewing the materials…" ***(Experimental group-Pre-test)***

"…Three of the groups are setting a pattern while viewing the case study. They are discussing within the group by viewing the changes occurred in the case study. While they are talking as to what to do in their experiments, they are designing an experiment in which they considered this pattern, too…" ***(Experimental group-Post-test)***

"…Two of the groups are not designing an experiment setup after viewing the case study. They are working with simple drawings which will help them plan the experiment they will do and comprehend the sense of the case happened…" ***(Control group-Pre-test)***

"…Only a single group (the 11th group) is able to apply all of the stages during which they present the setups and experiments in the light of the case study. The other groups are interested in designing their own experiment directly by just watching the case study…" ***(Control group-Post-test)***

CONCLUSIONS AND DISCUSSION

When the findings obtained from quantitative data are investigated separately, they support Germann (1989) who found that guided inquiry-based approach did not make a significant difference on science process skills of high school students in comparison with traditional approach. Similarly, Yıldırım (2012) compared guided inquiry-based approach with traditional approach. He employed multiple-choice questions to collect the data. He found no significant difference between test and control groups in terms of science process skills.

When quantitative and qualitative findings were investigated together, it was observed that inquiry-based experiments helped most of the science process skills of the pre-service teachers to improve. In addition, it was determined that there were positive changes in the skills in which any difference could not be noticed in comparison with the control group, yet, confirmatory experiments could have the same positive influence on the given skills. Therefore, while there was not a statistically significant difference between the groups in the quantitative findings, the increase in the scores of the test group was supported by the results qualitative data presented. Yakar & Baykara (2014) stated that inquiry-based activity applications helped preservice science teachers improve important skills such as determining and changing variables and determining the problem status. In another study, Bozkurt (2012) pointed that there was a significant difference in science process skills of pre-service teachers on behalf of the test group after the inquiry-based applications conducted with primary school teachers. The findings obtained from this study are similar to the studies in the literature (Altunsoy, 2008; Chang & Mao, 1999; Çelik, 2012; Duban, 2008; Köksal, 2008; Kaya, 2009; Yakar & Baykara, 2014). Moreover, several studies in which inquiry-based learning process were compared with traditional confirmatory approach support the studies which found that inquiry-based learning were better at improving science process skills at both secondary school level (Bozkurt, 2012; Duran & Dökme, 2018; Ergül et al., 2011; İnal, 2013; Koksal & Berberoglu, 2012; Longo, 2012; Ulu, 2011) and at bachelor's level (Basağa, Geban & Tekkaya, 1994; Karakuyu, Bilgin & Sürücü, 2013; Tatar, 2006; Usta Gezer, 2014). In this respect, the results obtained from the research proved that inquiry-based approach developed pre-service teachers' science process skills by overlapping with literature.

As an applied course, Physics Laboratory Course aims pre-service teachers to use and improve their skills at the same time while consolidating their learning about theoretical course. Therefore, the effects of laboratory applications can reflect to the skills first. Pre-service teachers make use of certain science process skills and thus, improve these skills in a laboratory course involving conducting experiments. However, when the amount the science process skills improved is considered, the approach employed in laboratory matters. Individuals are encouraged to use certain skills and form their own research process during each stage at laboratory applications in which inquiry-based approaches are conducted. Thus, students are able to use science process skills more often and in a more complex way at each stage. This case can make it possible for the influences of inquiry-based laboratory applications to differ from the influences the other approaches can have. The results obtained from the research revealed that inquiry-based approach is especially better at this point than traditional approach and it improved science process skills of pre-service teachers better.

REFERENCES

Alkan Dilbaz, G. (2013). *Araştırma temelli öğrenmenin tutum, akademik başarı, problem çözme ve araştırma becerilerine etkisi.* Yüksek lisans tezi, Mersin Üniversitesi Eğitim Bilimleri Enstitüsü, Mersin.

Altunsoy, S. (2008). *Ortaöğretim biyoloji öğretiminde araştırmaya dayalı öğrenme yaklaşımının öğrencilerin bilimsel süreç becerilerine, akademik başarılarına ve tutumlarına etkisi.* Yüksek lisans tezi, Selçuk Üniversitesi Fen Bilimleri Enstitüsü, Konya.

Basağa, H., Geban, Ö., & Tekkaya, C. (1994). The effect of the inquiry teaching method on biochemistry and science process skill achievements. *Biochemical Education, 22*(1), 29-32.

Bozkurt, O. (2012). Fen eğitiminde araştırmaya dayalı öğrenme yaklaşımının öğrencilerin akademik başarılarına ve bilimsel süreç becerilerine etkisi. *Mustafa Kemal Üniversitesi Sosyal Bilimleri Enstitüsü Dergisi, 9*(18), 187-200.

Brickman, P., Gormally, C., Armstrong, N., & Hallar, B. (2009). Effects of inquiry-based learning on students' science literacy skills and confidence. *International Journal for The Scholarship Of Teaching and Learning, 3*(2), 1-22.

Büyüköztürk, Ş. (2012). *Sosyal bilimler için veri analizi el kitabı: İstatistik, araştırma deseni, SPSS uygulamaları ve yorum* (17 b.). Ankara: Pegem.

Chang, C., & Mao, S. (1999). Comparison of Taiwan science students' outcomes with inquiry-group versus traditional instruction. *Journal of Educational Research, 92*(6), 340-346.

Colburn, A. (2008). Making inquiry successful. *The Science Teacher, 75*(9).

Creswell, J. W. (2016). *Araştırma deseni: Nitel, nicel ve karma yöntem yaklaşımları.* (S. B. Demir, Çev.) Ankara: Eğiten.

Çelik, K. (2012). *Canlılarda üreme, büyüme ve gelişme ünitesinin araştırmaya dayalı öğrenme yöntemi ile işlenmesinin öğrencilerin akademik başarılarına, bilimsel süreç becerilerine ve fen ve teknoloji dersine yönelik tutumlarına etkisi.* Yüksek lisans tezi, Dokuz Eylül Üniversitesi Eğitim Bilimleri Enstitüsü, İzmir.

Çepni, S., Ayas, A., Johnson, D., & Turgut, F. M. (1997). *Fizik Öğretimi.* Ankara: YÖK/Dünya Bankası Milli Eğitimi Geliştirme Projesi, Hizmet Öncesi Öğretmen Eğitimi.

Demirkıran, Z. A. (2016). *Fen Bilimleri dersinde araştırma-sorgulamaya dayalı uygulamaların etkileri*. Yüksek lisans tezi, İstanbul Aydın Üniversitesi Sosyal Bilimler Enstitüsü, İstanbul.

Duban, N. (2008). *İlköğretim fen ve teknoloji dersinin sorgulamaya dayalı öğrenme yaklaşımına göre işlenmesi: bir eylem araştırması.* Doktora tezi, Anadolu Üniversitesi Eğitim Bilimleri Enstitüsü, Eskişehir.

Duran, M., & Dökme, İ. (2018). Araştırmaya dayalı öğrenme yaklaşımının kavramsal anlama düzeyi ve bazı öğrenme çıktıları üzerine etkisi. *Trakya Eğitim Dergisi, 8*(3), 559-577.

Ergül, R., Şimşekli, Y., Çalış, S., Özdilek, Z., Göçmençelebi, Ş., & Şanlı, M. (2011). The effects of inquiry-based science teaching on elementary school students' science process skills and science attitudes. *Bulgarian Journal of Science and Education Policy, 5*(1), 48-68.

Eryaman, M.Y. (2008). *Teaching as practical philosophy*. Saarbrücken, Germany: VDM Verlag Dr. Müller.

Germann, P.J. (1989). Directed-inquiry approach to learning science process skills: Treatment effects and aptitude-treatment interactions. *Journal of Research in Science Teaching, 26(3),* 237–250.

Güler, B. (2018). *Sorgulamaya dayalı fizik deneylerinin fen bilimleri öğretmen adaylarının sorgulamaya dayalı fen öğretimi özyeterliklerine, kavramsal anlamalarına ve bilimsel süreç becerilerine etkisi.* Doktora tezi, Dokuz Eylül Üniversitesi Eğitim Bilimleri Enstitüsü, İzmir.

Haladyna, T. M. (1997). *Writing test items to evaluate higher order thinking.* Massachusetts: Allyn & Bacon.

İnal, P. (2013). *Araştırmaya dayalı öğrenmenin madde konusunda ilköğretim öğrencilerinin akademik başarıları, kavramsal anlamaları, tutumları, bilimsel süreç ve iletişim becerileri üzerine etkisi*. Doktora tezi, Marmara Üniversitesi Eğitim Bilimleri Enstitüsü, İstanbul.

Kaya, B. (2009). *Araştırma temelli öğretim ve bilimsel tartışma yönteminin ilköğretim öğrencilerinin asitler ve bazlar konusunu öğrenmesi üzerine etkilerinin karşılaştırılması.* Yüksek lisans tezi, Marmara Üniversitesi Eğitim Bilimleri Enstitüsü, İstanbul.

Kaya, G. & Yılmaz, S. (2016). Açık sorgulamaya dayalı öğrenmenin öğrencilerin başarısına ve bilimsel süreç becerilerinin gelişimine etkisi. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi*, 31(2), 300-318.

Koksal, E. A., & Berberoglu, G. (2012). The effect of guided-inquiry instruction on 6th grade Turkish students' achievement, science process skills and attitudes toward science. *International Journal of Science Education*, 1-13.

Köksal, E. A. (2008). *Öğretmen rehberliğindeki sorgulayıcı araştırma yöntemi ile bilimsel süreç becerilerinin kazandırılması.* Doktora tezi, Orta Doğu Teknik Üniversitesi Fen Bilimleri Enstitüsü, Ankara.

Krajcik, J., Blumenfeld, P., Marx, R., & Soloway, E. (2000). Instructional, curricular and technological supports for inquiry in science classrooms. In *Inquiry into inquiry: science learning and teaching* (s. 283-315). Washington DC: American Association for the Advancement of Science.

Lind, K. (1998). Science process skills: Preparing for the future. Monroe 2-Orleans Board of Cooperative Education Services.

Longo, C. M. (2012). *Effects of an inquiry-based science program on critical thinking, science process skills, creativity and science fair achievement of middle school students*. Connecticut: Western Connecticut State University.

Mao, S. L., & Chang, C. Y. (1998). Impacts of an inquiry teaching method on earth science students' learning outcomes and attitudes at the secondary school level. *Proceeding National Science Council ROC (D) Inquiry Teaching and Students Learning, 8*(3), 93-101.

Maxwell, D. O., Lambeth, D. T., & Cox, J. T. (2015). Effetcs of using inquiry-based learning on science achievement for fifth-grade students. *Asia-Pacific Forum on Science Learning and Teaching, 16*(1).

Miller, D. K. (2014). *The effect of inquiry-based, hands-on labs on achievement in middle school science.* Lynchburg: Liberty University.

National Research Council. (2000). *Inquiry and the national science education standards.* Washington DC: National Academy Press.

Oguz-Unver, A., & Yurumezoglu, K. (2014). Primary science students' approaches to inquiry-based learning. *International Online Journal of Primary Education, 3*(2), 76-84.

Ortakuz, Y. (2006). *Araştırmaya Dayalı Öğrenmenin Öğrencilerin Fen-Teknoloji-Toplum-Çevre İlişkisini Kurmaya Etkisi.* Yüksek lisans tezi, Marmara Üniversitesi Eğitim Bilimleri Enstitüsü, İstanbul.

Özdilek, Z., & Bulunuz, N. (2009). The effect of a guided inquiry method on pre-service teachers' science teaching self-efficacy beliefs. *Türk Fen Eğitimi Dergisi, 6*(2), 24-42.

Roth, W.-M., & Roychoudhury, A. (1993). The development of science process skills in authentic contexts. *Journal of Research in Science Teaching*, 30(2), 127-152.

Smolleck, L. D., Zembal-Saul, C., & Yoder, E. P. (2006). The development and validation of an instrument to measure preservice teachers' self-efficacy in regard to the teaching of science as inquiry. *Journal of Science Teacher Education,* 17, 137-163.

Şensoy, Ö., & Aydoğdu, M. (2008). Araştırma soruşturma tabanlı öğrenme yaklaşımının fen bilgisi öğretmen adaylarının fen öğretimine yönelik öz-yeterlik inanç düzeyine etkisi. *Gazi Eğitim Fakültesi Dergisi, 28*(2), 69-93.

Şensoy, Ö., & Yıldırım, H. İ. (2017). Araştırma soruşturma tabanlı öğrenme yakla-şımının yaratıcı düşünme ve bilimsel süreç becerilerine etkisi. *Cumhuriyet International Journal of Education-CIJE, 6*(1), 34-46.

Trundle, K. C., Atwood, R. K., Christopher, J. E., & Sackes, M. (2010). The effect of guided inquiry-based instruction on middle school students' understanding of lunar concepts. *Research in Science Education, 40*, 451-478.

Ulu, C. (2011). *Fen öğretiminde araştırma sorgulamaya dayalı bilim yazma aracı kullanımının kavramsal anlama, bilimsel süreç ve üstbiliş becerilerine etkisi*. Doktora tezi, Marmara Üniversitesi Eğitim Bilimleri Enstitüsü, İstanbul.

Usta Gezer, S. (2014). *Yansıtıcı sorgulamaya dayalı genel biyoloji laboratuvarı etkinliklerinin fen bilgisi öğretmen adaylarının laboratuvar kullanımı özyeterlik algıları, eleştirel düşünme eğilimleri ve bilimsel süreç becerileri üzerine etkisi.* Doktora tezi, Marmara Üniversitesi Eğitim Bilimleri Enstitüsü, İstanbul.

Yakar, Z., & Baykara, H. (2014). Inquiry-based laboratory practices in a science teacher training program. *Eurasia Journal of Mathematics, Science and Technology Education*, 10(2), 173-183.

Yazgan, B. S. (2013). *Araştırmaya dayalı sınıf dışı laboratuar etkinliklerinin öğrencilerin araştırma-sorgulama becerilerine ve çevreye karşı tutumlarına etkisi.* Doktora tezi, Marmara Üniversitesi Eğitim Bilimleri Enstitüsü, İstanbul.

Yıldırım, A. (2012). *Effect of guided inquiry experiments on the acquisition of science process skills, achievement and differentiation of conceptual structure.* Master thesis, Middle East Technical University, Ankara.

Yıldırım, M., Çalık, M., & Özmen, H. (2016). A meta-synthesis of Turkish studies in science process skills. *International Journal of Environmental & Science Education,* 11(14), 6518-6539.