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The Effectiveness of Predict-Explain-Observe-Discuss-Explain (PEODE) Based Laboratory Work Activities on Pre-Service Science Teachers' Science Process Skills

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Abstract. This research aims at investigating the effectiveness of the Predict-Explain-Observe-Discuss-Explain (PEODE) based laboratory work activities on pre-service science teachers' science process skills. A quasi-experimental research model with pre- and post- test via control group was employed in the research. The semi-experimental study was based on 46 pre-service science teachers enrolled in the primary Science Education Program a state university. In the research, randomly selected two groups were used, one experimental group (EG; n = 22) and one control group (CG; n = 24). While the control group participated in traditional laboratory activities work, the experimental group took part in the PEODE-based laboratory work activities. Laboratory activities were carried out in both groups for a total of 9 weeks, two hours a week. Science process skills test (SPST) measuring five different scientific process skills were presented to them as pre- and post-test in order to assess pre-service science teachers' science process skills. The test scores were analyzed quantitatively with a statistical analysis program. At the end of the research, while there was no significant differences total score of the SPST, significant statistical differences were found between the experimental and control groups in "Making Operational Comments" and "Designing the Research" sub-skills.

Keywords: Primary Education, Science Education, Predict-Explain-Observe-Discuss-Explain (PEODE), Science Laboratory, Scientific Process Skills

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INTRODUCTION ~ Science laboratories are an indispensable learning environment for students to understand science concepts by connecting between "the knowledge they have learned in schools" and "their own experiences". In addition, they are also essential to acquire scientific process skills that enable students to solve complex problems (Hofstein & Lunetta, 1982; Hofstein & Lunetta, 2004; Seven & Engin, 2018; Wolf & Fraser, 2008). Despite the issue about the importance of science laboratories, science laboratories could not be used effectively in schools due to limited facilities of the schools, their physical deficiencies, and disadvantages of traditional laboratory experiments (Ayas, Çepni, & Akdeniz 1994-a, b; Coştu et al., 2005; Koretsky, Kelly & Gummer, 2011; Seven & Engin, 2018). Based on the results in the related studies on science laboratory, an effective alternative approach to the traditional one, namely "cook-book type", has been introduced and discussed in the literature (e.g. Boyd-Kimball, & Miller, 2018; Brownell et al., 2012; Nicolaidou et al., 2019). Several of the alternative approaches comprise research-based (Brownell et al., 2012), inquiry-based (Şeşen

& Tarhan, 2013), project-based (Tsaparlis & Gorezi, 2005), constructivist-based (Shiland, 1999), argumentation-based (Karaer, Karademir & Tezel, 2019), POE (Prediction-Observation-Explanation) based (Bilen, Köse, & Uşak, 2011; Bilen & Aydoğdu, 2012) laboratory approach and so on. POE-based laboratory, as one of these approaches, has been used frequently in the literature for the last decade (Barut, 2020; Bilen & Aydoğdu, 2012; Haglund et al., 2015; Sarı, 2017). The POE has recently been modified as enriched with discussions, and it has been used in many studies (e.g. Coştu, Ayas, & Niaz, 2012; Coştu & Karataş, 2015; Samsudin et al., 2017). The POE enriched with discussions was first introduced to the literature as PDEODE (Prediction-Discussion-Explanation-Observation-Discussion-Explanation), supported by discussions before and after the "Observation (O)" phase of the POE. It has been used to promote conceptual change (Asyhari & Hariyanti, 2020; Coştu et al., 2010; 2012; Demircioğlu, 2017), but not utilized enough to enhance laboratory works.

As the aforementioned explanations, the PDEODE that is enriched by POE with discussions could be utilized to make laboratory works more effective due to gathering positive points of the POE and the argumentation (Coştu et al., 2012). This method was enriched by making discussions before and after the observation phase in the POE. Although the method is considered effective in teaching in the literature, it may be problematic for students to have discussions before the observation (O) phase because the students may catch some clues or the teachers may give clues about the experimental results. Therefore, it is more proper to eliminate the discussion phase before the observation from PDEODE. As a new contribution to science education, the authors utilized the PEODE method instead of PDEODE in order to enhance laboratory works.

According to the rationale of the study, this research aims at investigating the effectiveness of the PEODE-based laboratory works on pre-service science teachers' science process skills. For this purpose, the main problem of the research is; "What is the effect of the PEODE-based laboratory works on pre-service science teachers' scientific process skills?". In addition to this main problem, the research seeks to answer the following sub-problems.

1. Is there a significant difference between pre- and post- scientific process skills test (SPST) scores in both the experimental and control groups?
2. Is there a significant difference between the "Defining Variables" sub-category of the pre- and post- SPST in both the experimental and control groups?
3. Is there a significant difference between the "Making and Defining Hypothesis" sub-category of the pre- and post- SPST in both the experimental and control groups?
4. Is there a significant difference between the "Making Operational Explanations" sub-category of the pre- and post- SPST in both the experimental and control groups?

5. Is there a significant difference between the "Designing the Research" sub-category of the pre- and post- SPST in both the experimental and control groups?
6. Is there a significant difference between the "Graph and Data Interpretation" sub-category of the pre- and post- SPST in both the experimental and control groups?

THEORETICAL FRAMEWORK

The POE enriched with discussions was first introduced to the literature as PDEODE. This method has been commonly used in the science education literature. In the research, the PEODE method was used instead of the PDEODE in order to enhance laboratory works. As a theoretical framework, the PEODE method was initially introduced, and then the scientific process skills and related studies were given a critical way.

The PEODE method comprised five steps. In the first step (P: Prediction), an experiment is presented by asking the students to make a prediction individually as to what will happen as a result of the experiment. In the second step (E: Explain), the students justify their predictions via reasoning. In the third step (O: Observe), the students work in their groups to experiment, and individually write their observations of what would happen. In this step, the students also observe changes in the experiment, and the instructor guides them to focus on observations. In the fourth step (D: Discuss), the students are asked to discuss in their groups and then to reconcile their predictions with the actual observations. Afterwards, they are asked to analyze, evaluate, and review their friends' views. In the last step (E: Explain), the students compare all inconsistencies between observations and predictions. The PEODE-based laboratory works were used to enhance pre-service science teachers' science process skills.

Scientific process skills facilitate learning by activating students in science and providing retention in learning for students with research methods and ways (Çepni et al., 1997). Hence, these skills are intended to be developed in both our country (MoNE, 2013; MoNE, 2018) and international (The International Study Center [ISC], 2000; 2009) science education programs. It is also possible to see a reflection of the importance of scientific process skills in research papers in science education. Therefore, these skills have been used at various levels. Moreover, strategies, methods, and techniques have been used to allow students to gain them effectively. Focusing on the literature review, a wide variety of researchers has investigated scientific process skills to acquire these skills at various levels. For example, primary school level (Aktamış & Ergin, 2007; Anagün & Yaşar, 2009; Aydınlı, 2007; Aydoğdu, 2006; Erdoğan, 2010; Güler, 2010; Hazır ve Türkmen, 2008; Keskinkılıç, 2010; Kula, 2009; Saat, 2004; Şahbaz, 2010; Şenyüz, 2008; Tatar, 2006), secondary school level (Azar, Presley & Balkaya, 2006; Dori & Sasson, 2008; Dönmez & Azizoğlu, 2010; Geban, 1990; Roth & Roychoudhury, 1993; Temiz, 2007; Temiz & Tan, 2009; Yang & Heh, 2007), as a higher level, pre-service teachers (Bozdoğan et. al., 2006; Campbell, 1979; Downing & Filer, 1999; Farsakoğlu et al., 2008; Kanlı, 2007; Karslı et al., 2010; Koray et al., 2007; Laçin Şimsek, 2010; Scharmann, 1989; Sinan & Uşak, 2011), teachers (Campbell, 1979; Karslı et al., 2009; Nicosia et al., 1984) and so on. Based on these studies, this shows that scientific process skills are not acquired at the desired level (Akar, 2007; Aydoğdu, 2006; Hazır, 2006; ISC, 2000; 2009; Temiz, 2001; Temiz & Tan, 2009). In addition to including these skills in science, they can also be acquired by participating teachers in interactive teaching that are compatible with the science curriculum enabling students to gain these skills. In addition, these skills essentially must be developed in the teachers or pre-service teachers. In order to fulfill these requirements, they must have gained these skills truly before performing the teaching tasks. However, the related studies of teachers and teacher candidates about scientific process skills (Farsakoğlu et al., 2008; Karslı et al., 2009; Karslı et al., 2010; Laçin Şimsek, 2010; Sinan & Uşak, 2011) showed that the acquisition of their skills was insufficient because they could not develop them at the desired level. In this context, this research, as a new contribution to science education literature, seeks to use the PEODE-based laboratory works to improve the pre-service science teachers' skills.

METHOD

Research Design

This research employed a quasi-experimental research model with pre- and post- test via the control group. In the context of the research model firstly, an experimental and a control group were randomly selected. Secondly, SPST was applied to both groups as the pre-test. Thirdly, while the intervention was made to the experimental group, the traditional approach was made to the control group. Lastly, SPST was applied to both groups as post-test (Büyüköztürk, 2011; Karasar, 2012; Robson & McCartan, 2016). The research procedure is presented in Table 1.

Table 1. The Research Procedure

	Pre-test	Intervention	Post-Test
Control Group (n=24)	SPST*	Traditional Lab	SPST
Experimental Group (n=22)	SPST	PEODE-based Lab	SPST

* SPST: Scientific Process Skills Test

Research Sample

A total of 46 pre-service science teachers enrolled in the 3rd grade of the "Science Education Program" at a state university in Istanbul were selected in this research. The sample was taking courses of "Science Laboratory Practices-2" and "Special Teaching Methods-2". The research was conducted on two groups previously classified by the lecturer who teaches the courses in order to perform teaching activities within the scope of the context. While one of the two groups was randomly designated as the experimental group (n = 22), the other was designated as the control group (n = 24).

Research Instruments and Procedures

To perform laboratory activities, the sample was divided into four groups in both the experimental and control groups. There were six pre-service science teachers in all groups (except two groups in the experimental group, where there were five pre-service teachers). The pre-service science teachers participated in laboratory works in groups during the practice hours of the two lessons given above. In the laboratory works, the researchers chose fundamental science concepts that the pre-service science teachers will frequently use in their future teaching life and that a plethora of misconceptions exist and related to daily life events (see Table 2). Laboratory activities in both two groups were carried out within a total of nine weeks (two hours per week) in accordance with the content presented in the Table 2. Each laboratory activities in the experimental groups were presented to the pre-service science teachers in worksheets. A worksheet is written materials consisting of three parts (Coştu, Karataş, & Ayas, 2003; Demircioğlu & Atasoy, 2006). In the first part of the worksheet, there were an encouraging questions related to real life events. In the second part, the PEODE-based laboratory experiments (see Table 2) and also prompt questions or sub-questions for inquiring theirs views were included. In the third part, the evaluation questions to measure or be aware of how the pre-service science teachers' initial thoughts have changed at the end were included. In the control group, the traditional laboratory activities, namely cook-book type (Prescott & Anger, 1970), were used. In this approach, an experiment paper consists of "name of experiment", "subject", "inquiry question", "tools and equipment", "procedure", "observation", "results" and "what we learnt?" was presented to the pre-service science teachers.

The laboratory activities applied to the experimental and control groups were designed by the authors, but the applications were carried out by the instructor of the courses (except from the authors). The authors and the instructor came together, and the first author interactively gave training to the instructor on how to do laboratory activities and what to pay attention while performing. The instructor is an expert on science education, and he has lots research papers with the inclusion of POE and PDEODE. Therefore, it was believed to have a sound understanding and pedagogy to perform these lab activities.

Table 2. The content of the laboratory activities applied to in both groups

Worksheets	Lab Activity	Contents of Activity	Time
Evaporation-1	Lab task-1	Factors affecting evaporation; • temperature • surface space of the liquids • air flow on surface of the liquids	2 hours
	Lab task-2	Factors affecting evaporation; • humidity of the air	
Evaporation-2	Lab task-1	Evaporation in different liquids; • evaporation of alcohol	2 hours

		• evaporation of water • evaporation of oil	
	Lab task-2	Evaporation in different systems; • in an opened system • in a closed system	
	Lab task-3	Heat exchange during evaporation; • heat transfer and drop of the temperature	
Condensation	Lab task-1	Condensation in closed container; • two systems: room temperature and cooled condition	2 hours
	Lab task-2	Condensation in opened container; • two systems: room temperature and cooled condition	
	Lab task-3	Condensation in opened container; • two systems: cooled condition and surrounded cold condition	
Boiling-1	Lab task-1	Boiling water at a temperature below 100°C • reduced external pressure with a syringe • boiling water at 70°C	2 hours
	Lab task-2	Boiling water with ice cubes reducing gas pressure with ice cubes boiling water lower temperature	
Boiling-2	Lab task-1	Boiling water at a temperature above 100°C • increasing external pressure with a syringe • boiling water above 100°C	2 hours
Dissolution	Lab task-1 Lab task-2	The dissolution of a gas into a liquid; • pressure effect (with a syringe) • temperature effect (heating)	2 hours
Gas Pressure	Lab task-1	Gas pressure in a closed beaker increasing gas pressure with heating	2 hours
	Lab task-2	Recognizing atmospheric pressure rising up colored water in a glass tube (like Torricelli experiment)	
	Lab task-3	Gas pressure in a beaker decreasing gas pressure with cooling	
Liquid Pressure	Lab task-1	Factors affecting liquid pressure; observing liquid pressure increasing liquid pressure by immersing depth	2 hours
	Lab task-2	Factors affecting liquid pressure; liquid pressure in different liquid (water and vinegar)	
Raoult's Law	Lab task-1	Colligative properties of solutions; • boiling point elevation & vapor pressure lowering • Raoult's Law & boiling point of a emulsion (water-olive oil emulsion) • boiling point of water-olive oil emulsion	2 hours

As stated before, the PEODE-based laboratory activities were presented to pre-service science in worksheets. Each worksheet contains one or more PEODE tasks in it. The PEODE tasks comprised of five steps. In the first step (P: Prediction), the instructor presented an experiment about fundamental science concepts and asked the pre-service science teachers to make a prediction individually as to what would happen. After that, they wrote their predictions in blanks in the worksheet. In the second step (E: Explain), they justified their predictions via reasoning. In the third step (O: Observe), the pre-service science teachers again worked in their groups to experiment, and individually wrote their observations in the worksheet about what would happen. In this step, the students also observed changes in the experiment and the instructor guided them to focus on observations. In the fourth step (D: Discuss), they were asked to discuss in their groups, and then to reconcile their predictions with the actual observations made in the science laboratory. After that, they were asked to analyze, evaluate, and review their friends' works in the other groups. In the last step (E: Explain), they compared all inconsistencies between observations and predictions. The pre-service science students in each group were asked to attain a concurrence and consequence about experiment, and to present their ideas to other group members through whole-class debates. The role of the instructor was to challenge students and to enable discussions. Moreover, the instructor asked challenging questions, and did warrant that they did observations carefully.

Data Collection

To determine the effects of the intervention on the experimental group, the "Scientific Process Skills Test (SPST)" developed by Burns, Okey & Wise (1985) and adapted to Turkish by Geban, Aşkar, & Özkan (1992) was used to collect the data in this research. The test consisted of 36 multiple choices and Turkish version was conducted to the sample. It also measure different scientific process skills. These skills are given with the question items in Table 3.

Table 3. Distribution of the Questions in the Scientific Process Skills Test

Sub-Scientific Process Skills	Questions in SPST
1. Defining Variables	1, 3, 13, 14, 15, 18, 19, 20, 30, 31, 32, 33
2. Forming and Defining Hypothesis	4, 5, 8, 12, 16, 17, 26, 29, 36
3. Making Operational Comments	2, 7, 22, 23, 24, 34
4. Designing the Research	10, 21, 25
5. Interpreting Graph and Data	6, 9, 11, 27, 28, 35

The internal consistency reliability coefficient of the original of the SPST was found to be KR-21 = 0.82 (Okey, Wise, & Burns, 1985). The reliability coefficient of the test adapted to Turkish language was calculated (Geban, Aşkar, & Özkan, 1992) and found as 0.81. Also, a pilot research was carried out by applying SPST to 141 pre-service science teachers, and the Cronbach Alpha reliability constant was calculated as 0.729. The data about reliability coefficients were evaluated as an adequate test in terms of the reliability of SPST.

Data Analysis

SPST in both tests was scored by giving "1 point" for correct question and "0 point" for incorrect or left blank question. Subsequently, it was determined whether the scores were distributed according to the normal distribution in order to determine whether the answers given to the test were analyzed with parametric or non-parametric tests. For this purpose, the Shapiro-Wilk Test results were used since the total sample size in the experimental and control groups was less than 50 (Shapiro & Wilk, 1965; Demir, Saatçioğlu & İmrol, 2016).

RESULTS

Each pre-service science teachers' total scores in both pre- and post- SPST test were calculated for both groups in the experimental and control groups. The total results were presented in Table 4.

Table 4. Total scores of pre- and post- SPST in both the experimental and control groups

Science Teachers' Code	Experimental Group			Control Group		
	Pre-test	Post-test	Changes	Pre-test	Post-test	Changes
S1	33	34	+1	25	32	+7
S2	29	31	+2	32	32	0
S3	33	35	+2	29	34	+5
S4	30	33	+3	32	32	0
S5	20	30	+10	29	30	+1
S6	26	33	+7	28	33	+5
S7	29	34	+5	31	31	0
S8	33	36	+3	29	33	+4
S9	34	34	0	26	26	0
S10	31	33	+2	26	28	+2
S11	31	34	+3	27	31	+4
S12	29	33	+4	32	32	0
S13	34	35	+1	25	32	+7
S14	32	35	+3	33	34	+1
S15	26	34	+8	33	33	0
S16	20	28	+8	26	26	0
S17	23	30	+7	32	35	+3
S18	35	36	+1	22	24	+2
S19	27	32	+5	30	30	0
S20	31	34	+3	24	32	+8
S21	25	34	+9	29	29	0
S22	28	31	+3	30	30	0
S23	-	-	-	28	29	+1
S24	-	-	-	28	30	+2
Mean	**29.05**	**33.14**	**+4.09**	**28.58**	**30.75**	**+2.17**

In order to decide whether analyzed using parametric tests or non-parametric tests, a statistical analysis was used to determine whether the data in Table 4 showed a normal distribution. For this purpose in the research, Shapiro-Wilk Test results were used because the total sample size in each of the experimental and control groups was less than 50. The total scores pre-tests of the pre-service science teachers in the experimental and control groups showed a normal distribution based on the Shapiro-Wilk test results ($p = .394 > .05$ for the control group and $p = .129 > .05$ for the experimental group). The pre-service science teachers' in both groups total scores indicated a normal distribution ($p > .05$) according to the Shapiro-Wilk test results ($p = .118 > .05$ for the control group and $p = .058 > .05$ for the experimental group). Since the pre-tests scores in both groups showed normal distribution, the results of independent group t-test analysis of the parametric tests were used (see Table 5 and Table 6).

Table 5. Comparison of Pre- SPST Scores of Experimental and Control Groups with Independent Group t-test

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TEST	GROUP	n	$\bar{X}$	sd	t-Test	
					t	p
Pre-Test	Control Group	24	28.58	3.02	.674	.138
	Experimental Group	22	29.05	4.33		

From Table 5, there was no a significant statistical difference between the pre-SPST scores of the experimental and control groups ($t = 0.674$, $p = 0.138 > .05$). This implied that the SPST scores of the experimental and control groups were close to each other before the intervention.

Since the post- SPST of the experimental and control groups showed normal distribution, the results of the independent group t-test analysis of the parametric tests were used.

Table 6. Comparison of Post- SPST Scores of Experimental and Control Groups with Independent Group t-test

TEST	GROUP	n	$\bar{X}$	sd	t-Test	
					t	p
Post-Test	Control Group	24	30.75	2.72	.002	.216
	Experimental Group	22	33.14	2.05		

From Table 6, there was no a significant statistical difference between the post-SPST scores of the experimental and control groups ($t = 0.002$, $p= 0.216 > .05$). This result showed that the post-SPST scores of the experimental and control groups were close to each other after the intervention. The result also showed that the intervention in the experimental group (i.e. the PEODE-based laboratory) and the traditional laboratory approach performed in the control group increased pre-service teachers' scientific process skills to a very similar level.

Although there was no significant difference between the total score of SPST, it was statistically analyzed whether there was a significant difference between the pre- and post-tests in both groups as regards sub-scientific process skills. Hence, firstly, Shapiro-Wilk Test results were used whether each sub-skills showed normal distribution.

Table 7. Shapiro-Wilk results of the sub-skills of SPST

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Sub-Skills	Test	Experimental Group (n=22)		Control Group (n=24)	
		Statistic	p	Statistic	p
Defining Variables	Pre-	.941	.207[b]	.776	.000[a]
	Post-	.873	.009[a]	.722	.000[a]
Forming and Defining Hypothesis	Pre-	.877	.011[a]	.898	.020[a]
	Post-	.782	.000[a]	.853	.003[a]
Making Operational Comments	Pre-	.867	.007[a]	.872	.006[a]
	Post-	.875	.010[a]	.693	.000[a]
Designing the Research	Pre-	.613	.000[a]	.721	.000[a]
	Post-	.590	.000[a]	.316	.000[a]
Interpreting Graph and Data	Pre-	.768	.000[a]	.828	.001[a]
	Post-	.684	.000[a]	.702	.000[a]

[a]: Since $p < 0.05$ does not show normal distribution
[b]: Since $p > 0.05$ shows normal distribution

From Table 7, all sub-skills (except for the first sub-skill) did not show the normal distribution in both tests and both groups ($p < 0.05$). Therefore, the nonparametric Mann-Whitney-U test was used for statistical comparison (Hollander, Wolfe & Chicken, 2013). Statistical results are given in Table 8 for the pre-test and in Table 9 for the post-test.

Table 8. Comparison of Pre-test Scores with the Mann-Whitney U Test

Sub-Skills	Group	N	Mean Rank	Sum of Ranks	U	p
Defining Variables	Experimental	22	18.70	411.50	158.500	.018*
	Control	24	27.90	669.50		
Forming and Defining Hypothesis	Experimental	22	27.27	600.00	181.000	.053
	Control	24	20.04	481.00		
Making Operational Comments	Experimental	22	22.59	497.00	244.000	.645
	Control	24	24.33	584.00		
Designing the Research	Experimental	22	24.68	543.00	238.000	.506
	Control	24	22.42	538.00		
Interpreting Graph and Data	Experimental	22	25.27	556.00	225.000	.354
	Control	24	21.88	525.00		

From Table 8, there was no significant difference that was found between the pre-service teachers in the experimental and control groups in all sub-skills except for the "Identifying Variables" ($p > 0.05$). In this sub-dimension, a significant difference was found between the pre-service teachers in both groups ($p < 0.05$).

From Table 9, there was no significant difference between the pre-service teachers in the experimental and control groups in all sub-skills ($p > 0.05$) except for three sub-skills namely, "Identifying Variables", "Making Operational Comments" and "Designing the Research" subdimensions. In the three sub-skills, there was a significant difference between the pre-service teachers in the experimental and control groups (p < 0.05). These findings showed that the intervention in the experimental group was more effective to enhance these three sub-skills compared to the traditional group.

Table 9. Comparison of Post-test Scores with the Mann-Whitney U Test

Sub-Skills	Group	N	Mean Rank	Sum of Ranks	U	p
Defining Variables	Experimental	22	19.45	428.00	175.000	.038*
	Control	24	27.21	653.00		
Forming and Defining Hypothesis	Experimental	22	23.32	513.00	260.000	.924
	Control	24	23.67	568.00		
Making Operational Comments	Experimental	22	18.52	407.50	154.500	.010*
	Control	24	28.06	673.50		
Designing the Research	Experimental	22	20.68	455.00	202.000	.047*
	Control	24	26.08	626.00		
Interpreting Graph and Data	Experimental	22	23.86	525.00	256.000	.838
	Control	24	23.17	556.00		

From Table 8 and Table 9, in the sub-skills of "Identifying Variables", there were significant differences between the experimental and control groups in both pre- and post-test. To specify the significant differences in these sub-skills, statistical analyzes were made. For this, firstly, the Shapiro-Wilk Test results were taken into consideration, as the differences show normal distribution or not. The obtained data ($p=0.000<0.05$ for the experimental group; $p = 0.001< 0.05$ for the control group) revealed that it did not show a normal distribution ($p < 0.05$). Therefore, pre-test and post- test differences of Identifying Variables' scores were compared via nonparametric statistical tests.

Table 10. Mann-Whitney U Test Results of the Differences in the "Identifying Variables" Sub-Skill

TEST	GROUP	n	Mean Rank	Sum of Ranks	Mann-Whitney U Test U	P
Difference (Pre- and Post)	Control Group	24	23.42	562.00	262.000	.963
	Experimental Group	22	23.59	519.00		

From Table 10, there was no significant difference between the pre- and post- tests of the experimental and control groups in the "Identifying Variables" ($U = 262,000$ $p = 0.963 > 0.05$).

DISCUSSION

This research sought to investigate the effectiveness of the PEODE-based laboratory works on pre-service science teachers' science process skills. For this purpose, the main problem of the research was; "What is the effect of the PEODE based laboratory activities on pre-service science teachers' scientific process skills?" To answer the question, we used a quasi-experimental research model with pre- and post- test via control group. While the control group participated in traditional laboratory work activities, the experimental group took part in the PEODE-based laboratory work activities. Laboratory works activities were carried out in both groups for a total of 18 hours in total 9 weeks, two hours a week. To assess pre-service science teachers' science process skills, a science process skills test (SPST) test including thirty-six multiple-choice test items was presented to them as pre- and post-test.

The data of this research revealed that the PEODE-based laboratory works (the experimental group) positively contributed to the development of pre-service science teachers' scientific process skills compared to the traditional laboratory works (the control group). As known from the literature, science laboratories are one of the most important learning environments in the development of scientific process skills in science (Karslı, 2011). However, even if science laboratory is essential, the related studies have shown that traditional laboratory approaches, which are widely used, do not develop the scientific process skills of students and teacher candidates at the desired level (Aydoğdu, 2006; Farsakoğlu et al., 2008; Hazır & Türkmen, 2008; Kanlı, 2007; Karslı, 2011; Temiz, 2001; Temiz & Tan, 2009). Since traditional laboratory works mainly emphasized the implementation of the experiments without satisfactory inquiries about the experiment, they are generally inefficient for the development of students' scientific process skills (Kanlı, 2007; Karslı, 2011). Hence, the laboratory works were designed to meet the necessities and inquiry, which enable them to develop the scientific process skills and to provide retention learning (Coştu, 2008; Kanlı, 2007; Karslı, 2011). In this context, the PEODE-based laboratory works could be used in science education as an alternative to the traditional laboratory approach to improve scientific process skills.

The origin of the PEODE-based laboratory works is POE based one, and it also indicated that the POE-based laboratory works also contributed affirmatively to scientific process skills (Bilen & Aydoğdu 2012; Çakır, Güven, & Özdemir, 2017; Sarı, 2017; Tokur, 2011). To sum up, it could be expressed that counterpart approaches make positive contributions to the development of scientific process skills similarly. For instance, one type of the enriched discussions with POE, i.e. PDEODE, where there were additions of discussions before and after the observation phase (Coştu, 2008; Coştu et al., 2010; 2012; Demircioğlu, 2017) indicated similar results to another type of the enriched discussion with POE, i.e. PEODE, used in this research. In this respect, the whole POE-based approach made positive contributions to the development of scientific process skills. However, unlike the POE, the alternative method contributed to the fact that pre-service science teachers in the experimental group were inquired and pondered their thoughts by reviewing the different thoughts of the students in the experimental group (Coştu, 2008; Coştu et al, 2010; 2012; Demircioğlu, 2017).

The second important result revealed that this research was related to the sub-skills of the scientific process skill. At the end of the research, there were significant statistical differences between the experimental and control groups in "Making Operational Comments" and "Designing the Research". This result might stem from the PEODE-based laboratory works that brought their predictions together with the plausible reasons before the experimental activities, and then they discuss in their groups and reconcile their predictions after the observation. It is possible to evaluate that pre-service science teachers made predictions before the experiment and having discussions with other classmates in the groups after the experiment enable them to develop in the two sub-skills.

CONCLUSION

The research results revealed that the PEODE-based laboratory works contributed more to the development of pre-service science teachers' scientific process skills compared to the traditional laboratory. This finding indicated that there were significant differences between the experimental and control groups in "Making Operational Comments" and "Designing the Research". In other words, the pre-service teachers in the experimental group more enhanced the "Making Operational Comments" and "Designing the Research" sub-skills of scientific process skills compared to the control group. To sum up, the PEODE-based laboratory works activities, evaluated as successful in promoting scientific process skills, should be utilized as an effective way of achieving pre-service science teachers' scientific process skills. Since the PEODE-based laboratory works only added "predict" "explain" and "discuss" steps to the traditional laboratory works, it should be utilized in schools and universities to enhance effective teaching due to ease to adapt to the existing science laboratory.

This research has one major limitation. The development of scientific process skills for pre-service teachers in a short time could be difficult. In this research, the experiments in both groups were conducted two hours a week for nine weeks. The development of scientific process skills might be acquired in longer periods. Therefore, future research papers on enhancing scientific process skills may be recommended to use longer time by taking this limitation into account.

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