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Improving the Science Process Skills and Science Literacy of Primary School Pre-service Teachers with Different Parental Education Levels

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Abstract

This research was undertaken to improve the science process skills (SPS) and science literacy (SL) of primary school pre-service teachers with different family backgrounds in terms of parental education. It was planned with a quasi-experimental design with pretests and posttests in the framework of quantitative research methodology. Eighty-four first-year students from the primary school education departments of two different public universities participated in this 14-week-long study conducted in the spring semester of 2021-2022. Classes were taught with a focus on SPS for the experimental groups and within the scope of a textbook developed for basic science education in primary school for the control groups. Data were collected by administering the SPS Test and SL Test. In the analysis of the data, descriptive statistics, ANOVA, and MANOVA were used. The results showed that SPS-focused education processes significantly increased the SPS and SL of the pre-service teachers. Furthermore, prior to the implementation, participants in both experimental and control groups whose parents were had bachelor degree or high school diploma ranked higher in terms of SPS and SL. While the gap in SPS arising from parental education level was closed in the experimental groups as a result of the implementation, the advantage of having a bachelor degree parent continued for SL. These results are discussed in the context of primary school pre-service teachers regarding parental education levels, SPS, and SL.

Keywords: Scientific Literacy, Scientific Process Skills, Primary School Pre-Service Teacher, Science Education, Parents' Educational Attainment.

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Introduction

Contemporary education systems must undertake strategic efforts to effectively improve the knowledge, skills, habits, and values required to prepare individuals to adapt to rapid economic, environmental, and social changes; to embrace occupations that are yet to exist and technologies that are yet to be invented; and to solve unexpected problems (Organization for Economic Co-operation and Development [OECD], 2018). A high-quality science education is one of the most prominent building blocks in preparing individuals for the future world (World Economic Forum [WEF], 2020; OECD, 2019; Trends in International Mathematics and Science Study [TIMSS], 2020). When schools provide science educations that are tailored to ensure that students gain the skills of the future, students become more involved in the educational process and develop as individuals who are well prepared for life, playing bigger roles in improving both themselves and the modern digital and globally connected world. In line with this, international education indicators shedding light on the status of national education around the world provide important findings. For example, evaluations of the Science Literacy (SL) of individuals via Programme for International Student Assessment (PISA) and TIMSS research are considered to be fundamental. Since the present research is focused on the topic of teacher education, the findings of a recent TIMSS (2020) report on this issue provide key background information for the research questions. According to these findings of TIMSS (2020), the success rates of fourth-grade students in science are directly related to elements such as the experience of the teacher, the use of science resources, the proficiency of the teacher in science education, and the use of experiments in teaching. Therefore, the development of the knowledge, skills, and experience of primary school teachers in science education is a serious topic to be addressed. Questioning is a central strategy in acquiring knowledge and skills in science education (National Research Council [NRC], 1996). In addition, questioning in science education requires the development of Science Process Skills (SPS) (Shahali et al., 2017). When we examine the Science Education Program proposed by the Turkish Ministry of National Education (MoNE), the development SPS in training science-literate individuals is regarded as a skill unique to this field (Turkish Ministry of National Education [MoNE], 2018). Conducting scientific research to address personal or social problems inside or outside of school is also accepted as an integral part of science education in many curricula (Wu & Wu, 2011).

SPS include sensory skills such as curiosity, risk-taking, critical thinking, adapting to reality, and questioning (Yumusak, 2016), as well as cognitive skills such as researching, observing, asking questions, hypothesizing, anticipating, evaluating, classifying, and controlling variables (Meador, 2003). Training students in SPS is important for making it easier for them to learn, supporting critical thinking skills, and increasing their competency in the scientific research process (Erkol & Ugulu, 2014). Therefore, researchers argue that when teachers focus on improving SPS through questioning-based education, their attitudes toward science improve (Kim, 2007) and SL is achieved (Colvill & Pattie, 2002). In today's world where pseudo-scientific and nonscientific claims are rapidly proliferating (Losh & Nzekwe, 2011), the necessity of being able to understand arguments correctly and access scientific information should not be ignored. All societies need science-literate individuals who can read and comprehend scientific information correctly regardless of whether they plan to pursue a career in science or not (Cansiz & Cansiz, 2019). Science-literate individuals can ask questions about things that interest them in their daily experiences and can identify the answers to those questions. Furthermore, they can read scientific articles in popular media publications and can express their opinions regarding the truth of such results (NRC, 1996). UNESCO has suggested nine ideas for substantial activities to conduct today that will improve the education of the future, one of which is ensuring SL within school curricula. It is now the right time to reflect on curricula while fighting against the rejection of scientific information and the spread of misinformation, especially in the context of the COVID-19 pandemic (UNESCO, 2020, p. 6).

Since the 1980s, the development of SL in primary and middle schools has been put forward as a significant goal in many countries (National Academies of Sciences, Engineering, and Medicine, 2016). It is necessary to establish the foundations of science education at earlier ages because the behaviors and skills of individuals are constructed in the primary school period and the perceptions that are shaped during these years affect their future lives and career choices (Özkan et al., 2017). In this regard, we should consider the importance of training individuals who understand scientific information correctly, value science, and possess SPS (Esen et al., 2022). Teachers, who have a major role in training science-literate individuals who understand the processes involved in accessing scientific information (Metin et al., 2020), should use SPS in educational environments in order to effectively teach scientific concepts and phenomena (Fugarasti et al., 2019). Researchers who emphasize the importance of SPS in helping students to learn science argue that students should adopt these skills as early as primary school (Kozcu-Çakır & Sarıkaya, 2010). Ambross et al. (2014) also revealed that the perceptions of teachers regarding SPS influence students. In addition, Kalkan et al. (2020) reported that science education based on research is positively related to the development of SL. As can be seen, teachers should improve their understandings, perceptions, and beliefs about science and should consider how those affect the learning processes of their students (Smith et al., 2012). When the relevant literature is examined, there is very little research to date addressing the SL of pre-service teachers and their SPS or offering suggestions to improve them (Al Sultan et al., 2021; Huyuguzel & Cavas et al., 2013, Karamustafaoğlu et al., 2013). For all of these reasons, the present study is based on a recognition of the importance of training teachers to understand effective SPS and SL. It can be predicted that pre-service teachers who grasp the importance of SPS and SL will educate their students with the same consciousness and awareness.

It is also of interest to consider how pre-service teachers coming from different family backgrounds develop in terms of SPS and SL. Parental education level, for example, is known to affect the acquisition of correct information, appropriate skills, and success (Kaleli-Yilmaz & Hanci, 2016; Monteiro et al., 2012; Ozdemir et al., 2022). The acquisition of conceptual scientific mistakes also changes according to parental education levels (Monteiro et al., 2012). Thus, the extent to which education provided for teachers based on scientific questioning is able to overcome any disadvantages arising from parental education levels is another important research question in this field. The construction of scientific knowledge is not independent of the environment and social world of an individual; it is a process in which individuals organize their experiential worlds (Deng et al., 2011).

The present study, designed in light of the literature cited above, was conducted to explore SPS-centered teaching methods within the scope of a lesson on basic science education in primary school provided in primary school education departments. In this framework, the aim is to improve the SPS and SL of pre-service teachers from different family backgrounds in terms of parental education levels, help them gain experience and a new perspective of teacher training in science education for the future. In this context, research questions are determined as follows:

1. Is there a significant difference between the experimental and control groups in terms of SPS?
2. Is there a significant difference between the experimental and control groups in terms of SL?
3. Is there a significant difference in terms of SPS and SL in the experimental and control groups according to the different parental education levels before the intervention?
4. Is there a significant difference in terms of SPS and SL in the experimental and control groups according to the different parental education levels after the intervention?

Method

Research Model

This research was designed as a quasi-experimental study with pre-tests and post-tests in the framework of quantitative research methodology. In pretest-posttest designs with control groups, there are two groups called experimental and control groups created by random assignment, and pretest and posttest measurements are conducted for these groups (Karasar, 2012). Experimental designs aim to identify the cause-and-effect relationships between variables (Büyüköztürk, 2001). Creswel (2003) drew attention to the importance of random assignment of study participants into experimental and control groups in quasi-experimental research conducted with the implementation of pretests and posttests for experimental and control groups. In this regard, two experimental groups and two control groups were selected from four primary school teacher education classes in two different public universities. Classes were taught with a focus on SPS for the experimental groups and within the scope of a textbook developed for basic science education in primary school for the control groups for 14 weeks.

Participants

The research involved first-year students in the departments of primary education of two different public universities. From these faculties, selected with the convenience sampling method, two experimental groups and two control groups were randomly designated. There were 41 pre-service teachers in the experimental groups and 43 pre-service teachers in the control groups. Demographic information about the experimental and control groups is given in Table 1.

Table 1. Demographic information about the participants

Group	Number of Students		Mother's Educational Level				Father's Educational Level			
	Female	Male	Primary School	Middle School	High School	University	Primary School	Middle School	High School	University
Experimental 1	10	10	10	4	4	2	4	4	6	6
Experimental 2	12	9	11	3	6	1	3	4	7	7
Control 1	13	10	12	3	7	1	4	5	8	6
Control 2	10	10	10	5	3	3	4	3	6	7
Total	45	39	43	15	20	7	15	16	27	26
Percentage (%)	53.6	46.5	50.1	17.8	23.8	8.3	17.8	19	32.2	31

As seen in Table 1, 53.6% of the students participating in the study were female and 46.5% were male. The distribution of students in terms of gender was balanced. The distribution of students in terms of levels of parental education in the experimental and control groups was also balanced. The education levels of fathers compared to mothers, especially in terms of bachelor degree, were higher for students in both experimental and control groups.

Data Collection Tools

In this section, information regarding the measurement tools used for the research questions is provided.

Science Process Skills Test

Within the scope of this research, the Science Process Skills Test (SPST), which was developed by Karslı and Ayas (2013) and the validity and reliability of which have been confirmed, was used for the evaluation of the SPS of the participating pre-service teachers. The test was called

BİSBET by Karslı and Ayas (2013). The test consists of 27 multiple-choice questions and 11 open-ended questions. According to the validity, reliability, and item analysis results, this test can be used for the evaluation of the SPS of pre-service teachers and its validity and reliability are assured. The Cronbach alpha coefficient, which is evidence of the internal consistency of a measurement scale, is 0.78 for the multiple-choice questions (Karslı & Ayas, 2013). The multiple-choice questions of the SPST were prepared based on subjects and concepts from the basic sciences education in primary school lesson for first-year students in departments of primary education. The questions evaluate skills of observation, measuring, classifying, anticipation, identifying, changing and checking variables, hypothesizing, interpreting data, inference, and conducting-designing experiments. Correct answers in the multiple-choice section receive 1 point and all other answers receive 0 points. While the highest score a student can get from this test is 27, the lowest is 0. According to the data gathered from the pretest conducted with the participation of 84 students, the Cronbach alpha value for the internal consistency coefficient of the 27-question multiple-choice section was found to be 0.74. Within the scope of this research, multiple-choice questions from the SPST item pool were used. The Cronbach alpha value of the multiple-choice questions for this study is 0.72.

Science Literacy Test

In the evaluation of the SL of the teachers, the Turkish Society Science Literacy Test, developed by Karataş et al. (2019) within the scope of a TÜBİTAK project, was used. This scale, created using the Delphi technique to develop an appropriate scale in light of the opinions of experts and in line with the definition of literacy in the 21st century, aims to identify the SL of citizens of Turkey aged 18-65 years (Karataş et al., 2019). The test consists of 36 questions. Participants receive 1 point for every correct answer and 0 points for all other answers. According to the data gathered from the pretest conducted with the participation of 84 students, the Cronbach alpha value for the internal consistency coefficient of the Science Literacy Test (SLT) was found to be 0.80.

Data Analysis

In the analysis of the data gathered from the research, the possibility of a difference in the post-test scores for the SPST and SLT according to the independent variable of study group (experimental/control) was examined with one-way MANOVA. MANOVA is a powerful multivariable statistical approach used in experimental and scanning-based research studies (Büyüköztürk, 2007, p. 138). While the number of dependent variables is two or more, there is one independent variable in one-way MANOVA and two independent variables in two-way MANOVA. With the use of a new dependent variable from the best linear combinations of dependent variables, MANOVA, as multivariable variance analysis, enables the examination of differences that might arise for that variable from independent variables (Alpar, 2003). Türkmen (2008) explained that there is always a comparison in research that can be analyzed by ANOVA with one single independent variable, but MANOVA allows for the variance analysis of more than one dependent variable with the same independent variables, and, as a result, findings can be shown in a single table without redundant repetitions. In terms of parental education levels, ANOVA was used in the analysis of the SPST and ST results of the experimental and control groups.

Research Process

This research was conducted with first-year students in a lesson on basic science education in primary school education, which is a compulsory lesson in the undergraduate program. This lesson meets for 3 hours each week and addresses basic subjects and concepts as determined by the Council of Higher Education (CoHE-YÖK) for the undergraduate program for primary education. The units, subject areas, and learning goals determined for the third and fourth grades by the MoNE Sciences Curriculum were also determining factors in creating the lesson content. While developing the lesson, the frameworks provided by CoHE and the MoNE sciences curriculum (2018) were integrated in terms of subjects and goals. During two lesson hours in the first week of the 14-week-long education period, pre-service teachers received training that addressed the following questions: What are SPS? Why are they important? Where does Turkey rank in terms of SPS and SL according to national and international education indicators? What are the features and dynamics of the MoNE sciences curriculum? What is the role of SPS in that curriculum? Why is it important to improve SPS in primary school? For one lesson hour, a practice sheet was given to the pre-service teachers by the researchers and an evaluation was conducted with one example activity ("Why Does an Astronaut Jump on the Moon?"). While conducting SPS-focused education, topics such as understanding nature of science, establishing a relationship between the real world and science, and improving SL were fundamental. The adaptability of the activities to the third and fourth grades was also considered. Thus, we aimed to lay a foundation for science education for pre-service teachers. In the first three weeks of this implementation, the research questions and hypotheses related to the activities were provided by the researchers. After the education was provided in the following weeks, the materials, concepts to be used, and names of the activities were given and responsibilities such as creating research questions and hypothesizing were given to the pre-service teachers. The researchers directed the pre-service teachers with guiding questions and prepared work sheets for every activity. Outside of the classroom, the pre-service teachers also used work sheets to prepare for the next lesson within the scope of the assigned activities. Since some processes such as observation, data collection, and data recording were time-consuming for some activities, these processes continued outside of lesson hours. Five minutes were also given to the pre-service teachers at the end of lessons to share information about SPS regarding the activities and their experiences. The activities completed in this 14-week-long educational plan are listed in Table 2.

Table 2. Weekly Activity Plans in the Science Process Skills-Focused Educational Period

Name of Activity	Content	Skills To Be Improved
A Journey to the Micro World: Why Should We Wash Our Hands?	This activity aims to raise awareness about why we should wash our hands with soap and water and the importance of hygiene rules. Materials: 3 slices of bread, 3 fridge storage bags, and 1 permanent ink marker. Research questions: Why did the bread become moldy? Why are the mold densities on the bread different? What is mold?	Hypothesizing, identifying, and changing variables, experimenting, observation, data collection, recording data, creating graphs, making inferences, and drawing a conclusion.
Floating Like Olive Oil on Water: A Density Story	The mass of a unit volume of a material substance is called density. Density is a feature that separates a material from others and is unique to every material. It is different from mass and volume but not independent. We are familiar with the term density in our day-to-day lives, such as the mass difference while making butter by separating solids from the milk, in jewelry, or in the shipping sector. Our ancestors created a beautiful metaphor by adapting this observation to human characteristics: floating like olive oil on water! Materials: Olive oil, water, rock, coin, plastic bottle lid, milk, corn syrup, honey, beads, corn kernel, lamp oil, and glass bottle or jar. Research question: What kind of a ranking occurs by adding these materials one by one?	Hypothesizing, identifying, and changing variables, experimenting, observation, data collection, recording data, creating graphs, making inferences, and drawing a conclusion.
Which One Goes Farther?	This activity aims to reveal the effects of frictional force on movement on different surfaces. Materials: A toy car, an inclined ramp, sand, a timer, and a ruler. Research questions: Does frictional force make the movement of an object more difficult? How does the frictional force affect the movement of an object?	Hypothesizing, identifying and changing variables, experimenting, observation, data collection, recording data, creating graphs, making inferences, and drawing a conclusion.
Forces We Cannot See: Water Resistance	The frictional force in water that hinders the movement of objects is called water resistance. Just like air resistance, water creates a resistance against the way an object moves. Water resistance also requires contact, just like resistance on solid surfaces. With this activity, the aim is to observe the effect of water resistance on movement. Materials: 2 identical erasers, 2 water bottles of 1.5 L, water, timer. Research question: Do the erasers go the same distance in water and air environments?	Hypothesizing, identifying and changing variables, experimenting, observation, data collection, recording data, creating graphs, making inferences, and drawing a conclusion.

How Does a Balloon Inflate? An Acid-Base Reaction	Acids and bases are important components in many things we use on a daily basis. For example, many foods such as lemons, strawberries, grapes, and yogurt have different acids. On the other hand, many cleaning products such as soap and detergent are basic. Acids and bases have unique features. This activity aims to draw attention to being careful when using chemical reactions and chemical materials, and to observe acid-base reactions and their results in daily life. Materials: Glass bottle, vinegar, 2 tablespoons of baking soda, 1 funnel, 1 balloon, and 1 rubber band/tape. Research questions: Is the vinegar-baking soda reaction an acid-base reaction? Which of our observations is proof for the vinegar-baking soda reaction? How could the balloon on the lid of the glass inflate without someone blowing into it?	Hypothesizing, identifying, and changing variables, experimenting, observation, data collection, recording data, creating graphs, making inferences, and drawing a conclusion.
A Balloon Moving the Ship: Static Electricity	Static electricity is a positive or negative charge that a material or an object has. It can be found in nature on its own and can also result from certain interactions. Static electricity can be seen on metals frequently and is generally short-lived. However, static electricity occurring on nonconductor materials can last a long time. Static electricity occurs when two materials, the same or not, and conducting or nonconducting, come in contact with one another and then separate. Sometimes static electricity might occur with friction processes, as well. For example, when you take your hat off, your hair floats and makes crackling sounds. Moreover, if you do this at night, you can even see sparks from your head. This activity aims to create electricity with friction and observe the effects of static electricity. Materials: Balloon, woolen cardigan and our hair, paper ship, a bucket, and water. Research questions: How can we charge the balloon with electricity? What charges do our hair and balloon have? How can we explain the force that moves the ship with the balloon?	Hypothesizing, identifying and changing variables, experimenting, observation, data collection, recording data, creating graphs, making inferences, and drawing a conclusion.
Ringing Fork and Dancing Black Pepper Flakes: Sound Vibrations and Measuring Sound Volume (TÜBİTAK, 2020)	These activities aim to show the role of sound vibrations in hearing, the relationship between sound vibrations and sound volume, and how different sounds can be created by different vibrations. All sounds consist of vibrations in the air. When these vibrations reach our ears, our eardrums vibrate. This is what enables us to hear. 1- Materials for the Ringing Fork: a fork, knitting yarn, and a desk.	Hypothesizing, identifying and changing variables, experimenting, observation, data collection, recording data, creating graphs, making inferences, and drawing a conclusion.

High-pitched and Low-pitched Sounds: Let's Make a Guitar (TÜBİTAK, 2020)	2- Materials for Measuring Sound Volume: a large glass bowl, plastic wrap, black pepper flakes, and speakers. 3- Materials for High-pitched and Low-Pitched Sounds: Rubber bands of different sizes and thicknesses and, a shoe box Research questions: What is the relationship between the ringing sounds occurring due to hitting the fork on the desk with different levels of force? What is the relationship between the sound coming from the speakers and the movement of the black pepper flakes? Are the sounds coming from rubber bands of different thicknesses and sizes different?	
Weather Observation: Wind Spinner, Pluviometer, and Measuring Air Pressure (TÜBİTAK, 2020)	Weather forecasters record changes in the weather to forecast what the weather will be like using different methods. We will record the way the wind is blowing by making a wind spinner. We will also measure the precipitation with a pluviometer that we design and the air pressure with an air pressure gauge. Materials: Eraser-tipped pencil, glass, play dough, colorful cardboard, and a compass. Materials for Pluviometer: A large plastic bottle, scissors, a ruler, and soil. Materials for Air Pressure Gauge: Balloon, rubber band, a jar, and a straw. Research questions: From which direction does the wind blow on which days (create a table)? What would be the forecast of a meteorologist according to the table? Why is it important to measure and record precipitation? How did the precipitation change over the weeks? How could we evaluate the air pressure according to the length of a straw?	Hypothesizing, identifying and changing variables, experimenting, observation, data collection, recording data, creating graphs, making inferences, and drawing a conclusion.
Family Ties: Can We See Our DNA? (TÜBİTAK, 2020)	All living beings consist of cells, and every cell has genes that come from DNA, which is a chemical compound. Genes carry information that distinguishes every living being from all others. This activity aims to explore our DNA and see what features are inherited from our families. Materials for Exploring the DNA: Alcohol, onion, dishwashing soap, salt, water, and a jar. Materials for Creating a Family Tree: Railroad board and pictures of family members from grandparents to siblings. Research questions: What is the role of DNA in isolating the salt and dishwashing soap? What are the physical features determined by DNA? Whose features did you inherit in your family? What is the role of DNA in inheritance? How is it inherited?	Hypothesizing, identifying and changing variables, experimenting, observation, data collection, recording data, creating graphs, making inferences, and drawing a conclusion.

In the control groups, a textbook included in the basic science lesson in primary school was used. The lessons were carried out according to the theoretical and practical content in the textbook. The pre-tests and post-tests and lesson contents within the scope of the research were planned and implemented by the same instructor.

Findings

In this section we address the findings results of the statistical analysis performed to compare the experimental and control groups before and after the implementation and the assumptions regarding the analysis used in the research.

Findings on Differences Between Experimental and Control Groups Before the Implementation

The pretest results of the Science Process Skills Test and Science Literacy Test were examined to determine any differences between the pre-service teachers in the experimental and control groups prior to the implementation. Data were subjected to normality tests to identify whether pretest scores conformed to normal distribution or not. Examining the values of the experimental and control group students' Scientific Process Skills Pre-test averages on the assumption of normality were examined, the Kolmogorov-Smirnov Coefficient of the experimental group (0.20) and the Kolmogorov-Smirnov Coefficient (0.20) of the control group were higher than the 0.05 significance value. Examining the values of the Scientific Literacy Pre-test averages on the assumption of normality were examined, the Kolmogorov-Smirnov Coefficient of the experimental group (0.16) and the Kolmogorov-Smirnov Coefficient (0.20) of the control group were higher than the 0.05 significance value. According to the results, the data are in accordance with the normal distribution. After providing the assumption of normality, the results of the ANOVA performed to determine the equivalence of the pre-test averages are presented in Table 3.

Table 3. ANOVA Results for Pretest Results of Experimental and Control Groups

Test	Source of Variance	Sum of Squares	*df*	Mean Squares	*F*	*p*
Science Process Skills Test	Between Groups	0.085	1	0.085	0.006	0.951*
	Within Group	605.869	82	14.166		
	Total	605.954	83			
Scientific Literacy Test	Between Groups	2.304	1	2.304	0.507	0.739*
	Within Group	327.659	82	4.544		
	Total	329.963	83			

*p>0.05

When Table 3 is examined, it is seen that there was no significant difference between the experimental and control groups for Science Process Skills Pretest scores (F (1.83) = 0.006, p>0.05) and Scientific Literacy Pretest total scores (F (1, 83) = 0.507, p>0.05). There was no significant difference between the pretest scores of the students who participated in this study. Thus, we can say that the experimental and control groups were equivalent in terms of pretests.

Findings for the First and Second Research Questions

The effects of the SPS-focused education implementation on the SPS and SL of pre-service teachers were tested with one-way MANOVA for the first and second research questions. To avoid any type I errors, the first and second questions were merged and addressed together. The necessary statistical assumptions were tested to conduct one-way MANOVA for one independent variable (education method) and two dependent variables. Box's M test was conducted to examine the distribution of the covariance matrixes. Test results showed that MANOVA could be conducted, and the covariance matrixes of the dependent variables were equally distributed (Box's M 24.845, $p>0.05$). Thus, the assumption of the equal distribution of the covariance matrixes, which is one of the basic assumptions of multivariate analysis, was met. The Levene's test results regarding the homogeneity of the variances are provided in Table 4.

Table 4. Levene's Test Results Regarding Homogeneity of Variances

Dependent Variable	*sd1/sd2*	*F*	*p*
Science Process Skills	1/78	3.056	0.367
Science Literacy	1/78	0.407	0.649

*p>0.05

Examining the values in Table 4, it can be seen that the values of the Levene F test, regarding the assumption of whether variances are equal or not for every dependent variable, were higher than the limit value of 0.05. This shows that there was not a significant difference between the groups in the distribution of the error variances of the dependent variables for the identification of error variances; the variances are homogeneous.

In the collective analysis of the first and second research questions, whether there was a difference for the independent variable of group (experimental/control) in Science Process Skills Test posttest average scores and Science Literacy Test posttest average scores was examined with one-way MANOVA. The MANOVA results for the first and second questions are provided together in Table 5.

Table 5. MANOVA Results of the Science Process Skills Test and Science Literacy Test Scores of the Experimental and Control Groups

Test	Group	*n*	*x*	*SD*	*df*	F	p
Science Process Skills Test	Experimental	41	19.05	2.04	1-82	102.78	0.000
	Control	43	10.80	2.64			
Science Literacy Test	Experimental	41	29.08	5.28	1-82	116.52	0.000
	Control	43	12.60	5.96			

As seen in Table 5, the posttest mean scores of the Science Process Skills Test (Wilks' λ 0.001, F(1, 82) 102.78, $p<0.05$) and posttest mean scores of the Science Literacy Test (Wilks λ 0.001, F(1, 82) 116.52, $p<0.05$) significantly differed according to whether the pre-service teachers were in the experimental groups or the control groups. In other words, pre-service teachers in the experimental groups achieved higher scores for SPS and SL compared to the control groups. Furthermore, to determine the effect size of the independent variable of group, the eta-squared (η2) value was considered. The obtained eta-squared value was interpreted in accordance with the d index proposed by Cohen (1988), which is one of the effect size indexes. Cohen (1988) determined certain thresholds for the interpretation of η2 value (small at η2 0 .01, medium at η2 0.06, and large η2 =0.14). When the eta-squared value obtained in this study in terms of the variable of group is considered (η2 0.068), it is seen that being in the experimental group had a medium effect on the SPS and SL of these pre-service teachers.

Findings for the Third and Fourth Research Questions

For the third research question of this study, the SPS and SL of the pre-service teachers in the experimental and control groups were examined in terms of parental education. Descriptive data are presented first in Table 6.

Table 6. Descriptive Data for Pretest and Posttest Results of SPS and SL of Pre-service Teachers in Terms of Parental Education

Tests			SPS Pretest		SPS Posttest		SL Pretest		SL Posttest	
Groups	Parental Education		x	SD	x	SD	x	SD	x	SD
Experimental	Mother's Educational Level	Primary School(n=21)	3.18	2.68	18.83	2.21	5.36	3.81	28.23	1.81
		Middle School (n=7)	4.74	1.94	19.62	1.89	5.45	3.01	29.10	3.25
		High School (n=10)	6.96	3.12	19.88	2.87	7.75	2.96	30.27	1.96
		Bachelor (n=3)	10.17	2.15	19.14	2.27	10.15	2.48	34.88	1.24
	Father's Educational Level	Primary School(n=22)	2.87	1.21	18.22	3.42	4.55	2.95	28.91	1.95
		Middle School (n=8)	5.06	3.20	19.82	2.56	6.70	2.86	28.20	2.49
		High School (n=10)	7.62	2.75	19.64	2.47	6.92	3.79	29.97	1.69
		Bachelor (n=4)	10.28	3.23	19.84	3.53	11.46	2.91	34.64	1.77
Control	Mother's Educational Level	Primary School(n=21)	3.23	1.68	8.17	3.21	5.35	2.31	10.23	2.92
		Middle School (n=7)	4.53	1.94	10.92	2.19	6.01	1.52	10.67	3.12
		High School (n=10)	5.76	2.12	10.23	2.44	7.28	2.26	10.34	2.32
		Bachelor (n=3)	8.03	1.95	13.48	3.29	11.85	1.68	12.98	3.02
	Father's Educational Level	Primary School(n=22)	2.90	1.78	8.43	1.99	4.79	2.29	9.88	2.22
		Middle School (n=8)	5.13	2.60	10.78	2.16	5.59	1.89	10.29	3.09
		High School (n=10)	6.95	2.17	10.53	2.47	6.12	3.79	10.76	2.42
		Bachelor (n=4)	9.98	2.89	13.65	3.59	12.14	2.95	13.25	3.02

Examining Table 6, we can say that the mean pretest scores are similar between the experimental and control groups in terms of parental education. The ANOVA results for the SPS and

SL scores of the pre-service teachers in terms of parental education are given in Table 7 for the experimental groups.

Table 7. ANOVA Results of SPS and SL Pretests and Posttests of Pre-service Teachers in the Experimental Group According to Parental Education

				Pretests						Posttests				
Group	Education	Test	Source of Variance	KT	df	KO	*F*	*p*	Tukey	KT	df	*KO*	*F*	*p*
EXPERIMENTAL	Mother's Educational Level	SPS Test	Between Groups	1260.66	3 80	420.22			1-2 1-3	429.34	3 80	143.11	1.43	.26
			Within Group	13283.56	83	79.43	5.29	.00	1-4	18363.92	83	100.07		
			Total	14544.22						18793.26				
		SL Test	Between Groups	918.40	3 80	306.13			1-3 2-4	1140.26	3	380.08		
			Within Group	16854.65	83	91.65	3.34	.01	3-4	18001.23	80 83	189.09	2.01	.00
			Total	17773.03						19342.09				
	Father's Educational Level	SPS Test	Between Groups		3 80	279.32			1-2 1-3	332.81	3 80	110.93	1.30	.26
			Within Group	16828.76	83	58.31	4.97	.00	1-4	16078.56	83	85.33		
			Total	17666.74						16411.37				
Experiment		SL Test	Between Groups	798.40	3 80	266.13			1-3	1340.86		446.95		
			Within Group	15888.25	83	89.00	2.99	.01	2-4 3-4	18001.23		89.21	5.01	.00
			Total	16686.65						19342.09				

* 1= Primary School Diploma, 2 = Middle School Diploma, 3= High School Diploma, 4 = Bachelor Degree

For both SPS and SL, pre-service teachers with mothers who were primary school graduates scored much lower on the pretests compared to those with mothers who had completed middle school, high school, or university according to the results of the Tukey test conducted to identify the groups between which differences arose in terms of the mother's educational background. When the SPS posttest results of the experimental groups [$F(3, 80)=1.43$, $p<0.05$] are examined according to the mother's educational background, however, no significant difference is seen. Thus, we can say that the gap in the SPS of the experimental groups in terms of the mother's educational background was closed by the education that was provided. Similarly, the SL posttest results of the experimental groups F(3, 80) 2.01, p 0.05 did not differ significantly in terms of the mother's educational background. The Tukey test was conducted to identify the groups between which differences arose in terms of the mother's educational background for SL posttest results, with the result being in favor of participants whose mothers were bachelor degree. In other words, after the education was provided, the differences in SL arising from the mother's educational background continued.

When Table 7 is examined according to the father's educational background, the pretest results for the SPS [$F(3, 80)=4.97$, $p<0.05$] and SL [$F(3, 80)=2.99$, $p<0.05$] of the pre-service teachers in the experimental group are seen to reflect a significant difference. For both SPS and SL, pre-service teachers with fathers who were bachelor degrees scored much higher in both pretests compared to participants with fathers who had completed primary school, middle school, or high school according to the results of the Tukey test, which was conducted to identify the groups between which differences arose in terms of the father's educational background. When SPS posttests were considered for the experimental groups in light of the father's educational background F(3, 80) 1.30 , p<0.05], there were no significant differences. Thus, we can say that the pretest difference in the SPS of the experimental group based on the father's educational background disappeared after the implementation. The SL posttest results [F(3, 80)=5.01, p<0.05] of the pre-service teachers did not differ significantly in terms of the father's educational background. In other words, the differences in SL arising from the father's educational background after the educational process continued. We can accordingly say that the father's education levels increased the pretest scores of the experimental group, as well as subsequent scores for SPS and SL. In terms of posttests, in spite of no overall difference in the posttest scores for the experimental group regarding parental education, a specific difference continued in favor of those with parents who were bachelor degree regarding SL. This difference existed only for participants with parents who were bachelor degree. There was no significant difference between the SPS and SLT posttest scores of pre-service teachers who had parents with primary school, middle school, or high school diploma. The ANOVA results for SPS and SL pretest scores of participants in the control groups according to parental education are provided in Table 8.

Table 8. ANOVA Results of SPS and SL Tests for Pretest and Posttests of Pre-service Teachers in the Control Group According to Parental Education

				Pretests						Posttests				
Group	Education	Test	Source of Variance	KT	df	KO	*F*	*p*	Tukey	KT	df	*KO*	*F*	*p*
CONTROL	Mother's Educational Level	SPS Test	Between Groups	1089.23	3	363.07			1-2	1328.39	3	442.79		
					80				1-3		80			
			Within Group	14253.86	83	90.76	4.83	.00	1-4	18499.27	83	103.69	4.27	.01
			Total	15343.09						19827.66				
		SL Test	Between Groups	1828.26	3	609,42			1-3	1253.20		417.73		
					80				2-4		3			
			Within Group	13874.45	83	161.22	3.78	.00	3-4	16387.22	80		3.51	.00
											83	119.01		
			Total	15702.71						17640.42				
	Father's Educational Level	SPS Test	Between Groups	1237.98	3	412.66			1-2	1342.88	3	447.62	4.11	.00
					80				1-3		80			
			Within Group	15878.16	83	95.30	4.33	.00	1-4	16078.56	83	108.90		
			Total	17116.14						17421.44				
		SL Test	Between Groups	2098.40	3	699.46				1140.46		380.15		
					80				1-3		3			
			Within Group	15888.25	83			.01	2-4	17441.73	80		3.27	.00
						176.63	3.96		3-4		83	116.25		
			Total	16686.65						18582.19				

* 1= Primary School Diploma, 2 = Middle School Diploma, 3= High School Diploma, 4 = Bachelor Degree

When Table 8 is examined, the pretest scores for SPS [F(3, 80)=4.83, p<0.05] and SL [F(3, 80)=3.78, p<0.05] of the pre-service teachers showed significant differences in terms of the mother’s educational background. In both cases, the pre-service teachers with mothers who were primary school graduates had a lower mean score from the pretests compared to the other groups according to the results of the Tukey test conducted to identify the groups between which differences arose regarding the mother’s educational background. Examining the SPS F(3, 80) 4. 27, p 0 .05 and SL F(3, 80) 3.51, p 0.05 posttest scores according to the mother’s educational background, we see a significant difference. From this point of view, the differences in success for both SPS and SL as reflected by posttests according to the mother’s educational background continued for the experimental group. The results of the Tukey test conducted to identify the groups between which differences arose showed an advantage in terms of the mother’s educational background for the control group in posttests favoring bachelor degree mothers.

When Table 10 is examined according to the father’s educational background, the SPS [F(3, 80)=4.33, p<0.05], and SL [F(3, 80)=3.96, p<0.05] pretest scores of the pre-service teachers in the control groups are seen to have created a significant difference. In both cases, pre-service teachers with fathers who were bachelor degree scored higher than pre-service teachers with fathers who were high school, middle school, and primary school graduates according to the results of the Tukey test conducted to identify the groups between which differences arose in terms of the father’s educational background. When the SPS [F(3, 80)=4.11, p<0.05], and SL [F(3, 80)=3.27, p<0.05] posttest scores of the pre-service teachers in the control group are examined according to the father’s educational background, a significant difference is seen. The differences arising from the father’s educational background for the mean scores of the control group continued for both SPS and SL. In contrast to the pretests, this difference exists in favor of participants whose parents were bachelor degree.

Discussion

The results of the analysis conducted for the first research question showed that the SPS of the pre-service teachers in the experimental groups significantly improved compared to the control groups after SPS-focused education. Shalia et al. (2017) showed that, during teacher training sessions, importance should be attached to both the conceptual and the operational dimensions of SPS. Both the research results and the functional implementations of the SPS activities addressed throughout this study support this finding. In their research, Molefe and Aubin (2021) evaluated the opinions of pre-service teachers regarding SPS through freshwater activities and gradual science processes. They concluded that the pre-service teachers were associating SPS with hypothesizing but having difficulties in observations, drawing conclusions, and making inferences. However, in this research, an educational approach with theoretical and practical implementations related to SPS was designed for the first week of the class, with the aim of avoiding the limitations encountered by Molefe and

Aubin, and a platform was created for the pre-service teachers to discuss their activities. Subsequently, responsibilities were largely transferred to the pre-service teachers, giving them an opportunity to use different SPS. Within this scope, the results also revealed the development of pre-service teachers regarding skills measured by the test of SPS. In the literature we can find other studies addressing the development of SPS using experiments conducted in inverted classes (Cakiroglu et al. 2020), contemporary education methods, and technologies applied in inverted classes (Artun et al., 2020; Ozkul & Ozden, 2020). However, studies addressing SPS-focused education are still very limited. The present study is accordingly a pioneer in the field in terms of discussing both conceptual and operational dimensions of SPS and enabling pre-service teachers to acquire knowledge and skills on the basis of scientific questioning and research in their first year of an undergraduate program. When we consider that all kinds of information, skills, and behaviors are acquired at early ages (Özkan et al., 2017), it is necessary to improve the SPS of pre-service teachers and to encourage them to improve those skills over time.

When we examine the results from the analysis performed for the next research question, it is seen that SPS-focused education practices significantly improved the SL of the pre-service teachers in the experimental groups compared to the control groups. As Kalkan et al. (2020) stated, there are many factors affecting the improvement of SL. However, this study clearly reveals that practices that aim for the improvement of SPS also improve SL. On top of that, as stated in many studies in the literature, the SL of pre-service teachers is generally satisfying (Huyuguzel Cavas et al., 2013; Karamustafaoğlu et al., 2013). Therefore, implementations within the scope of the present research are essential in terms of improving and shaping the SL of pre-service teachers. In terms of improving SL, there are also studies that address argumentation methods that focus on critical thinking instead of reading scientific information (Deng et al., 2011) or addressing the understanding of the nature of science (Al Sultan et al., 2021). What is common between our research and these previous studies is that the implementations were based on scientific questioning and research. Deviating from the framework of scientific questioning and research can cause changes that affect the future of individuals and societies and also daily life. Turgut (2011) highlighted how wrong and inappropriate perceptions can lead to the integration of nonscientific and false information in scientific fields and their popularization. In fact, the importance of SL on a societal level became more apparent during the COVID-19 pandemic, when extremely unscientific claims lacking scientific methodologies and proofs were publicly considered against correct information (Buarque, 2022; Teovanović et al., 2021). A science- literate individual who is exposed to faulty evaluations of science based on passive information from books, television, social media, or web sites (Irwin et al., 2016) will be much more careful about adopting information without scientific proof. Therefore, it is obvious that there is a need for implementation-based research that prioritizes the SL of teachers who will train science-literate individuals for the society of the future. In this regard, the present research has made a contribution to the field.

The third and fourth research questions of the present study focused on the improvement of the SPS and SL of pre-service teachers from different family backgrounds in terms of parental education levels. When we consider the results for the pretests, pre-service teachers in both the experimental and control groups with parents who had high school or university education had the highest scores. Thus, national and international factors highlight the positive outcomes of high-quality active participation of children in educational processes on individual and societal levels. When we examine the findings for Turkey from the OECD (2020) Education at a Glance report, while the percentage of young-adults who did not graduate from secondary education is 15% in the OECD on average, this rate is 41% in Turkey. Furthermore, Turkey is the OECD country with the second highest rate after Mexico in terms of young-adults who did not complete secondary education. These data shed light on the influence of parental education for young adults in Turkey today. On the other hand, the TIMSS (2020) Turkey findings showed that children who participate in scientific activities, think about science, do activities based on arithmetical calculations, and enjoy support in terms of resources at home with their parents rank much higher in terms of TIMSS averages for the 4th and 8th grades (TIMSS, 2020). Nevertheless, it is seen that children who lack attentive parents at home, accounting for approximately 50% of all children in Turkey, cannot succeed at even the most basic competence level (TIMSS, 2020). "Both the results of international research and the pre-test results of this study reveal that individuals with lower education levels in terms of parental education levels are more disadvantaged in terms of scientific inquiry and skills. The scientific process skills-oriented teaching process results given to the experimental group pre-service teacher candidates from different households in terms of their parental education levels are remarkable. Because it was also seen here that the gap in SPS arising from the parental education levels of the experimental groups vanished while the difference in success arising from parental education in the control groups continued. Within this framework, the results obtained in this study are important in terms of providing educational opportunities that will enable pre-service teachers to develop SPS in the context of the disadvantages arising from parental education levels."

Moreover, even though the SL level increased significantly following the implementation in experimental groups, the difference arising from parental education continued. This difference was in favor of participants with parents who were bachelor degree. It is essential to interpret the differences arising from parental education in the context of SL, as SL is based on mental habits (Lin, 2014) and the development of the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity (NRC, 1996). Making inferences from the present results in light of these previous findings, the development of a scientific understanding indicates a longer-running process and background compared to simply developing skills. It is obvious that, in developing scientific understandings and habits, it is necessary to provide more educational opportunities to individuals to overcome the disadvantages arising from particular socio-demographic variables.

From this perspective, the aim of this research was to enable pre-service teachers to acquire SPS and SL with a positive outcome for society in terms of investments in the basic dynamics of improving science teaching skills. "While students from well-off families will often find a path to success in life, those from disadvantaged families have generally only one single chance in life, and that is a great teacher and a good school. If they miss that boat, subsequent education opportunities will tend to reinforce, rather than mitigate, initial differences in learning outcomes" (OECD, 2019, p. 4). The present study will contribute to this academic field, education policies, and practical implementations for 21st century science-teaching dynamics among primary school teachers, who are educating the citizens of the future.

Credit Author Statement

The authors contributed equally to this research.

Conflict of Interest

No potential conflict of interest was declared by the authors.

Ethical Statement

This research was carried out with the approval of Selcuk University Scientific Ethics Evaluation Committee dated 17.05.2022 and numbered E.286287.

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