

# Explicit Teaching of Science Process Skills: Learning Outcomes and Assessments of Pre-service Science Teachers

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**Abstract:** Science process skills (SPSs) are one of the most important skills possessed by students in conducting scientific activities. Therefore, it is crucial for science teachers to understand and practice these skills. Considering the role of teachers in developing students' SPSs, the focus of this study is on developing pre-service science teachers' SPSs. This study aims at determining the effects of explicit teaching of SPSs upon pre-service teachers' SPSs. To accomplish this, action research was employed. The study involved 10 pre-service science teachers who voluntarily participated in the study and were from Science Education Departments at a state university in Türkiye. Data were collected by using two methods: quantitative and qualitative. The quantitative data were obtained by using the Science Process Skills Scale. Meanwhile, the qualitative data were obtained from semi-structured interviews and diaries. The Wilcoxon Signed Rank Test was utilized in the quantitative data, and a content analysis technique was used in the analysis of the qualitative data. The results of the study indicated that explicit teaching of SPSs contributes to the development of pre-service teachers' SPSs, and that all pre-service teachers prefer explicit teaching in the teaching or development of SPSs.

**Keywords:** explicit teaching, science process skills, science education, pre-service teachers, learning outcomes, learning assessment

## 1. Introduction

Due to the diversity and richness of modern science, the scientific method as a unifying factor is occasionally overlooked. However, the scientific method is fundamental to science, and science process skills (SPSs) enable anyone to conduct research and draw conclusions (Tifi et al., 2006). SPSs can be defined as a set of skills used in structuring and organizing scientific knowledge. Scientists use these skills to study and explore the world (Bentley et al., 2007; Martin, 2009; Mulyeni et al., 2019). They are a means by which to produce content and create concepts (Aslan et al., 2016, p. 1; Funk et al., 1985; Harahap et al., 2019).

### 1.1. Problem Statement

Students need SPSs when they conduct scientific research and learn (Karslı et al., 2009). Process skills enable students to view the world from a scientific perspective and apply scientific methods. Scientific ways of thinking are also referred to as SPSs (Rezba et al., 2007). These skills are tools that students use to explore the world around them and construct scientific concepts. Therefore, it is crucial for teachers to understand and use these skills for the purpose of teaching scientific facts effectively (Afandi et al., 2019; Darmaji et al., 2019; Harahap et al., 2019). On the other hand, science is not only about knowledge but also about a systematic understanding of the environment. SPSs are necessary for students to learn more about the world of science and technology (Suryanti et al., 2020; Turiman et al., 2012). When someone can understand a topic by developing possible explanatory ideas, making predictions, using them to test the predictions, or gathering evidence to ask and answer questions, and checking the results through interpretation; he or she practices SPSs. If these skills are not well developed, relevant evidence will not be collected. For example, findings that confirm initial biases and ignore contrary evidence will not contribute to understanding the world. Therefore, SPSs should be the primary goal of scientific education (Harlen, 1999).

## 1.2. Related Research

In reality, there are still students and teachers who do not master SPSs. For this reason, the development of SPSs should continue to be carried out at every level of education (Darmaji et al., 2019). Studies on exploring the level of students' basic and integrated SPSs show that the students' basic and integrated SPS levels are considered medium and low respectively (Duruk et al., 2017; Inayah et al., 2020; Irwanto et al., 2019; Tilakaratnea & Ekanayakeb, 2017).

Following a literature review, it is seen that the SPSs of pre-service teachers and teachers need to be improved (Aktaş & Ceylan, 2016; Cañete et al., 2017; Duruk et al., 2017; Rintayati et al., 2020). Furthermore, it is also revealed that the teachers' basic knowledge on SPSs are higher than their integrated knowledge (Swe & Oo, 2018). Özdemir and Işık (2015) state that pre-service teachers do not use skills such as measuring, interpreting data, forming hypotheses, identifying and testing variables, making predictions, and drawing conclusions very often. In order to use SPSs, the learning environment should be in a way that accommodates students' active participation (Duran et al., 2011).

In general, the research literature suggests that students can learn SPSs if they are the target of a scientific program within a specific plan (Padilla, 1990). The importance of teaching and learning SPSs is emphasized explicitly in the science curricula of many countries (Arnold et al., 2018). Appropriate understanding and application of SPSs are considered to be important aspects of scientific learning. Students' performance in scientific activities may not help them to achieve all of the required learning objectives, due to a large amount of scientific content. However, a mixture of explicit instructions from teachers to teach basic concepts and develop the necessary skills may provide a more successful learning approach for students to conduct research (Holidays, 2006). In explicit teaching, the emphasis is on teaching in small steps, providing practice for students after each step, guiding them during initial practice, and providing them with a high level of successful practice (Rosenshine, 1987). Although the implicit teaching of SPSs has been actively researched, studies on explicit teaching of SPSs are less discussed (Durmaz & Mutlu, 2012; Gess-Newsome, 2002; Lederman et al., 2019).

## 1.3. Research Objectives

Considering the responsibility and role of science teachers in developing students' SPSs, the focus of this study was on developing pre-service science teachers' SPSs. These skills were taught implicitly in previous years in undergraduate courses' physics, chemistry, and biology laboratories. This study aims at teaching them explicitly and with scientific content in different contexts in a separate course. The purpose of the study is to determine the impact of explicit teaching of SPSs upon the development of pre-service science teachers' SPSs and their views on the explicit teaching of SPSs. An explicit instruction should never be understood detachedly of content as it is concerned with the explicit teaching of SPSs as different skills and skill combinations in the various contexts mentioned.

For this purpose, the following research questions were posed:

1. Does the explicit teaching of SPSs make a difference in the pre-service science teachers' SPSs at the end of the SPSs course?
2. What are the pre-service science teachers' views about the explicit teaching process of SPSs?

## 2. Theoretical Framework

### 2.1. Basic and Integrated Science Process Skills

According to studies in the literature, SPSs are generally studied in two groups, namely basic and integrated (Aslan et al., 2016, p. 3; Rezba et al., 2007). Basic SPSs are actively used by students in exploring the natural world, serving as the basis of integrated process skills. Observing, classifying, communicating, measuring, predicting, and inferring are basic SPSs (Rezba et al., 2007). Meanwhile, integrated skills are multifaceted. They can be called experimental skills because variables are identified, hypotheses are formed, data are

accessed (to confirm or reject) and recorded, and judgment is made. These more complicated skills are based on core skills. For example, predictive capabilities are used to form hypotheses. Integrated processes encompass asking more questions and conducting more experiments (Gultepe, 2016; Kujawinski, 1997; Rezba et al., 2007). Furthermore, process-integrated skills include identifying variables, hypothesizing, analyzing research findings, tabulating data and creating graphs from the data, describing data, exploring, and designing (Aslan et al., 2016, pp. 3-4; Rezba et al., 2007).

## **2.2. Explicit Teaching of Science Process Skills**

Two processes are recognized in the development of cognitive skills, namely explicit and implicit processes which are employed to varying degrees in different educational settings (Sun et al., 2007). When we consider the teaching or development of SPSs, we can speak of explicit and implicit processes (as with other skills). For example, when elementary students are taught process skills directly, they learn to use those processes and, thus, benefit from them in the future. Students cannot be expected to master skills that they do not know or are not allowed to practice. It is not logical to expect students to gain experience in experimental skills after only a few trials. It can be stated that students need more than one opportunity to practice these skills in different content areas and contexts (Padilla, 1990).

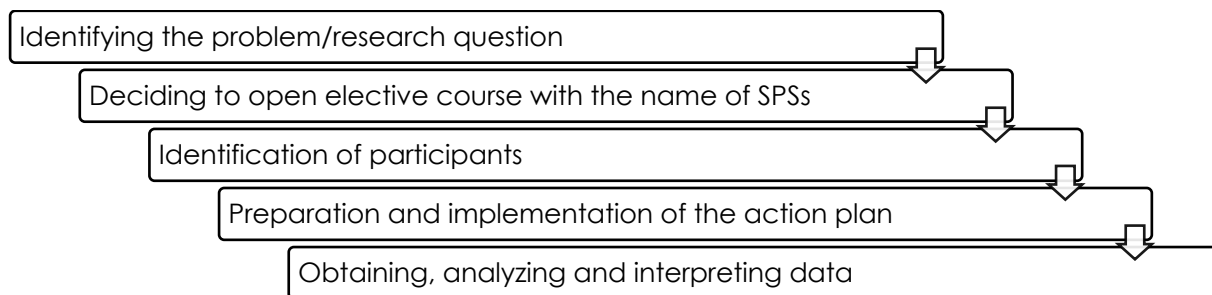
Another, more general explanation for the effectiveness of explicit instruction and task structuring derives from cognitive learning theories. Proponents of this instructional paradigm argue that students should receive clear guidance on the concepts and procedures that they need to learn. Without this support, the search for and processing of new information is slow and hindered by memory limitations. Explicit instruction is considered to be the most effective and efficient way that helps students to adopt the content and organization of long-term memory. The newly stored information can be easily retrieved after solving new problems or performing new tasks (Lazonder & Egberink, 2014; Mayer, 2004; Sweller, 2004).

Developing and implementing scientific research can be complex, and guiding students can manage such complexity effectively. It is essential to broaden students' experience and help them to develop the knowledge necessary to conduct successful research. In this regard, Germann et al. (1996) emphasize the importance of working with students according to skills or a combination of skills. SPSs are not always applied to specific scientific content. However, they can be applied to all scientific content, and this content plays a central role in learning with understanding. Therefore, it is instrumental to consider them separately (Harlen, 1999). It would be impossible to teach students the content of an entire subject, be it biology, chemistry, earth science, or physics. Therefore, those who want to learn science should learn the means of science. Teachers have the task of teaching skills with which to access content (Kujawinski, 1997).

## **3. Method**

### **3.1. Research Design**

The action research method was employed in this study (Johnson, 2015, pp. 29-41). Action research is considered to be a type of research that helps educators to better understand their research and improve the quality of educational practice (Aksoy, 2003). Individuals who conduct action research can find opportunities to observe, gain knowledge, generate ideas, and gain experience regarding their practice through direct participation in the research process (Başarrı, 2019, p. 28).



**Figure 1.** Research Process

The action research process applied in the study is summarized in Figure 1 as the explanations about the research process are as follows.

### **3.2. Identifying the Problem/Research Question**

The researchers' experience in the General Chemistry and General Physics Laboratory courses that they have obtained previously have been effective in the emergence of the subject of this study. The researchers deemed that the pre-service teachers who took these laboratory courses had deficiencies in terms of SPSs. The first of the said deficiencies was observed in the performance of pre-service teachers in experimental studies (for example, in measuring, experimenting, determining variables). The second one was observed in the experimental reports prepared by the pre-service teachers every week after the laboratory course. During the examination of these reports, it was found the reports contained deficiencies or errors related to SPSs. For example, confusing prediction and inference, inability to make hypotheses or making mistakes, creating an incorrect table, inability to establish a relationship between variables, making an incorrect graph, etc. The researchers observed the pre-service teachers during the laboratory courses and examined the experimental reports they prepared every week. As a result, it was concluded that the laboratory courses were insufficient to resolve these deficiencies and improve students' SPSs at the desired level. These results led the researchers to the question: "How can the science process skills of pre-service science teachers be improved?". Thereafter, the question "Is explicit teaching of science process skills an effective approach in improving the science process skills of pre-service science teachers?" determined the research question of the study. In order to solve the aforementioned problems, it was decided to develop SPSs via an explicit approach, rather than implicitly (as in laboratory courses).

### **3.3. Deciding to Open Elective Course with the Name of SPSs**

The researchers had planned to open an elective course in which SPSs will be taught explicitly. For this purpose, the Head of Science Education Department was contacted and the request and reasons for opening an elective course under the name Science Process Skills were conveyed. The documents required to open an elective course were prepared and submitted to the Head of the Department. After the request to open an elective course was granted, the SPSs elective course was opened to be conducted by the first researcher. The SPSs course was conducted for fourteen weeks, two hours per week.

### **3.4. Identification of Participants**

In the selection of the participants, pre-service teachers who took General Physics Lab I, General Chemistry Lab I, and Biology Lab I courses were designated as the target group, particularly participants who had experience in teaching implicit science process skills. In order to reach the determined target audience, the advisors of the pre-service science teachers who studied in the 2nd, 3rd, and 4th grades joined in a meeting and were informed about the study. The pre-service teachers who took the aforementioned courses were informed about the Science Process Skills elective course by sharing the course information package. Consequently, ten students in the Science Education Department of a state college in Türkiye voluntarily participated in the study. The ages of the participant group, consisting of second-,

third- and fourth-grade pre-service teachers, ranged from 19 to 24 years old. It was determined that all of the pre-service teachers who participated in the study had taken the General Physics Lab II and General Chemistry Lab II courses, in addition to the three aforementioned laboratory courses. While some of them continued with Biology Lab II and Science Lab Applications courses during the study, some had already taken all of these courses. Therefore, it can be assumed that all of the participants had much experience in implicit teaching of SPSs.

### 3.5. Preparation and Implementation of the Action Plan

In accordance with SPSs described in the literature in the context of the study, the skills of observing, classifying, predicting, inferring, communicating, measuring, forming data tables, drawing graphs, identifying variables and establishing relationships between the variables, defining operationally, changing and controlling variables, formulating hypotheses, designing experiments, experimenting, and interpreting data were discussed. Explicit SPSs teaching courses were focused on skills, thus the meaning and importance of each skill, its intended use, and its correct and effective application were explored interactively with the pre-service teachers. Thereafter, activities were conducted to facilitate the use of each skill. The process was conducted with the activities selected by the pre-service teachers from those prepared by the researchers and those designed by the pre-service teachers. Content from different disciplines (such as physics, chemistry, biology, geography, and environmental science) contextualized the activities. During the implementation, attention was paid to the autonomy of the students.

### 3.6. Data Collection Tools

Both quantitative and qualitative methods can be used in action research (Kock Jr, 1997). The present study consists of two parts: quantitative and qualitative. The Science Process Skills Test (SPST) was used as the data collection tool for the quantitative part of the study, while participant diaries and semi-structured interviews were used as data collection tools for the qualitative part.

**Table 1.** Data Collection Tools

| Data collection tools              | Question to be answered   | Application time                         |
|------------------------------------|---|--|
| Science process skills test (SPST) | Does the explicit teaching of SPSs make a difference in the pre-service science teachers' SPSs at the end of the SPSs course? | At the beginning and end of the research |
| Participant diaries                | What were the experiences/views of the pre-service science teachers concerning the explicit SPS teaching process?             | Throughout the research process          |
| Semi-structured interviews         | What were the opinions of pre-service science teachers concerning teaching SPSs through an explicit approach?                 | At the end of the research               |

Keeping diaries and interviews are the main data collection tools in action research (Borgia & Schuler, 1996; Johnson, 2015, pp. 81-106). In addition, quantitative data obtained from test scores, as in the SPST, can be used in action research because they can provide a different perspective (Borgia & Schuler, 1996). Table 1 provides information on the data collection instruments used in the study, the questions that these tools were designed to answer, and the application time.

#### 3.6.1. Science Process Skills Test (SPST)

The Science Process Skills Test (SPST) was developed by Burns et al. (1985), and a Turkish adaptation was developed by Geban et al. (1992). The Cronbach's alpha coefficient of the adapted version of the instrument is 0.81. The test consists of 36 multiple-choice items, encompassing integrated science process skills under five subsections: identifying variables (12

items), defining operationally (6 items), formulating hypotheses (9 items), graphing and interpreting data (6 items), and designing investigations (3 items). This test is a frequently preferred scale for measuring the SPSs of students (Chabalengula et al., 2012; Çakiroğlu et al., 2020; Dirks & Cunningham, 2006; Fugarasti et al., 2019).

### **3.6.2. Participant Diaries**

The pre-service teachers were asked to keep a diary in which they recorded their thoughts, feelings, experiences, and opinions with regard to the explicit SPSs teaching process. Prior to writing the diaries, the importance of the diary for the study was explained to the pre-service teachers. Some of them stated that they might not know exactly what to write, therefore a diary form was given to them. The form, which was prepared with the opinions of two experts, included questions that guided pre-service teachers about what they could write while writing their diaries. While writing a diary, the participants were asked to write in a way to include the answers to the questions in the form. The questions in the participant diary form are as follows: *What did today's SPSs course make you think about? What are your feelings about today's SPSs course? What have you learned in today SPSs course? Did you find anything important in today's SPSs course? If so, explain what it was. Did you find anything unusual in today's SPSs course? If so, explain what it was. What are your views on the activities that you and your friends did in today SPSs course?*

### **3.6.3. Semi-structured Interview**

A semi-structured interview form with two open-ended questions was prepared for the interview with the pre-service teachers. The first question on the form aims to elicit the pre-service teachers' opinions with regard to teaching SPSs through an explicit approach. Meanwhile, the second question compares their experiences of explicit and implicit teaching of SPSs (especially in laboratory courses) and finds out which of these two approaches they prefer for developing SPSs. To assess the relevance of the questions on the interview form, the opinions of two science education experts were sought, and the form was finalized by means of the experts' feedback.

## **3.7. Data Analysis**

In analyzing the study's quantitative data, given the number of participants and non-normal distribution of the data, non-parametric statistics were used (Büyüköztürk, 2012, p. 145). In this regard, when analyzing the data obtained from the sub-dimensions of the SPST and all sub-dimensions, a comparison was made with the Wilcoxon Signed Rank Test. For this purpose, the software SPSS (Statistical Package for the Social Sciences) 20.0 was used. Meanwhile, content analysis was conducted to analyze the qualitative data of the study. It aims to find concepts and relationships that can explain the data obtained from the semi-structured interview and the participants' diaries (Yıldırım & Şimşek, 2011, p. 227). For this purpose, coding was carried out based on the concepts extracted from the data. Thereafter, themes were created based on the resulting codes, which allowed the codes to be grouped under specific categories and explain the data at a general level (Strauss & Corbin, 1990). To ensure consistency in coding, the researchers coded the data separately (Weber, 1990, p. 12). Following the initial coding, a reliability test was applied to assess functioning (Robson, 2015). In this context, a consensus between the coders was determined using the formula proposed by Miles and Huberman (2015, p. 64). The points of agreement and disagreement between the coders were identified and it was found that the disagreement was found in only a few codes. These disagreeing codes were negotiated, and an agreement was reached. Once the coding process was completed, the results were tabulated.

## **3.8. Procedure**

In accordance with SPSs described in the literature in the context of the study, the skills of observing, classifying, predicting, inferring, communicating, measuring, forming data tables, drawing graphs, identifying variables and establishing relationships between the variables, defining operationally, changing and controlling variables, formulating hypotheses, designing

experiments, experimenting, and interpreting data were discussed. Explicit SPSs teaching courses were focused on skills, thus the meaning and importance of each skill, its intended use, and its correct and effective application were explored interactively with the pre-service teachers. Thereafter, activities were conducted to facilitate the use of each skill. The process was conducted with the activities selected by the pre-service teachers from those prepared by the researchers and those designed by the pre-service teachers. Content from different disciplines (such as physics, chemistry, biology, geography, and environmental science) contextualized the activities. During the implementation, attention was paid to the autonomy of the students. Learner autonomy in this context means that students take responsibility for their learning, set goals, select tasks and materials, direct their actions, and are independent in doing so (Cotterall, 1995; Littlewood, 1996).

## 4. Results

In this section, the quantitative and qualitative data obtained from the study are presented.

### 4.1. Quantitative Results

Quantitative data were obtained via the SPST. The scale was used as a pre-post measure. Pre-service science teachers' scores before and after the explicit SPSs teaching process were compared using the Wilcoxon Signed Rank Test. The results of the analysis are presented in Table 2.

**Table 2.** The Results of the Wilcoxon Signed Rank Test for the SPST

| Science process skills         | Post-test-pre-test | N | Rank average | Rank total | $z^a$ | p     |
|--------------------------------|--------------------|---|--------------|------------|-------|-------|
| Identifying variables          | Negative rank      | 2 | 4.25         | 8.50       | .93   | .348  |
|                                | Positive rank      | 5 | 3.90         | 19.50      |       |       |
|                                | Equal              | 3 |              |            |       |       |
| Operationally defining         | Negative rank      | 3 | 4.33         | 13.00      | .72   | .470  |
|                                | Positive rank      | 5 | 4.60         | 23.00      |       |       |
|                                | Equal              | 2 |              |            |       |       |
| Formulating hypotheses         | Negative rank      | 4 | 2.63         | 10.50      | .59   | .550  |
|                                | Positive rank      | 3 | 5.83         | 17.50      |       |       |
|                                | Equal              | 3 |              |            |       |       |
| Graphing and interpreting data | Negative rank      | 1 | 1.00         | 1.00       | 2.22  | .026* |
|                                | Positive rank      | 6 | 4.50         | 27.00      |       |       |
|                                | Equal              | 3 |              |            |       |       |
| Designing investigations       | Negative rank      | 0 | .00          | .00        | 2.12  | .034* |
|                                | Positive rank      | 5 | 3.00         | 15.00      |       |       |
|                                | Equal              | 5 |              |            |       |       |
| Total                          | Negative rank      | 2 | 3.75         | 7.50       | 2.04  | .041* |
|                                | Positive rank      | 8 | 5.94         | 47.50      |       |       |
|                                | Equal              | 0 |              |            |       |       |

<sup>a</sup>Based on negative ranking; \*  $p < .05$

Table 2 shows that there was no significant difference between the SPST pre-test-post-test results of the pre-service teachers in terms of identifying variables ( $z = .93$ ,  $p > .05$ ), operationally

defining ( $z=.72, p>.05$ ), and formulating hypotheses ( $z=.59, p>.05$ ). Meanwhile, there was a significant difference between the sub-dimensions of graphing and interpreting data ( $z=2.22, p<.05$ ) and designing investigations ( $z=2.12, p<.05$ ). What is more, it is noteworthy that there was a significant difference between the pre-test-post-test scores of the pre-service teachers on the overall test ( $z=2.04, p<.05$ ).

## 4.2. Qualitative Results

This section presents the findings obtained from the participants' diaries and the semi-structured interview. In the case of direct quotations from the semi-structured interview, the names of the pre-service teachers were indicated by coding.

### 4.2.1. Participant Diaries

Table 3 shows that six themes were expressed in the pre-service teachers' diaries: learning through explicit SPSs teaching, thinking processes, acquisition of scientific knowledge, self-assessment, self-efficacy perception, and affective influence.

**Table 3.** Themes and Codes Obtained from the Participants' Diaries

| Themes                                  | Codes  |
|---|--|
| Learning through explicit SPSs teaching | Deep learning  |
|   | Skills-focused learning                              |
|   | Efficient learning                                   |
|   | Learning by doing                                    |
|   | Learner autonomy                                     |
|   | Group & cooperative learning                         |
| Thinking processes                      | Questioning  |
|   | Further thinking                                     |
|   | Focusing   |
| Acquisition of scientific knowledge     | Scientific research                                  |
|   | Systematic study                                     |
| Self-assessment                         | Realizing one's learning difficulties                |
|   | Realizing and correcting one's inadequacies/mistakes |
| Self-efficacy perception                | Using SPSs correctly                                 |
| Affective influence                     | Curiosity  |
|   | Enjoyability   |
|   | Liking   |
|   | Satisfaction   |
|   | Level of importance                                  |
|   | Contentment  |

The pre-service teachers expressed learning through explicit SPSs instruction, i.e., the first theme, with statements corresponding to the codes for deep learning, skills-focused learning, efficient learning, learning by doing, learner autonomy, and group & cooperative learning. Below are examples of the statements from the pre-service teachers that were assessed under this theme:



- *"We did the experiments that we designed ourselves. We collected data, made a table, and drew graphs. My friend and I examined the dissolution rate of sugar at different temperatures. This way, learning by doing and working together in a group becomes more efficient and permanent."* (S9)
- *"In today's lesson, I completely learned how to make a data table. I learned that the table has a name and how to determine dependent and independent variables. [...] I learned how to make a table clear."* (S5)
- *"For example, observations should not be made randomly, it should serve a specific purpose. I understood and learned that I need to use my senses (not just my eyes) when I observe and that I should observe for a specific purpose."* (S8)
- *"I realized something essential today: I did not really know the meaning of variable. When I did the activities, I (finally) understood it."* (S1)
- *"Observation is something very different from what I thought it was. I always defined observation as just seeing and touching [...]. By the end of the course, [however], I realized that the definition of observation I knew was very different from the scientific definition."* (S2)
- *"As part of today's communication topic, my friend and I decided to experiment on optics [...]. We decided to explain the data we obtained in a table because we thought that the best way to explain it was with a table. Each group did their experiment individually and presented their data the way they wanted to express themselves."* (S9)
- *"I learned that while there are no strict rules for creating data tables, there is a consensus, widely accepted rules."* (S3)

The second theme that emerged from the analysis of the diaries is that of thinking processes. The pre-service teachers expressed their views on this theme via the use of expressions corresponding to three codes: questioning, further thinking, and focusing. Below are examples of expressions from the pre-service teachers that were assessed with regard to this theme:

- *"We thought a lot about designing an experiment today. It is not easy to design an experiment without help. We did it by questioning and thinking independently."* (S10)
- *"Even though it looks very simple to draw a diagram, (in reality) it is not so easy. I used to write the horizontal and vertical axes according to my head. But it wasn't like that — it's not that easy. I have to think carefully [...]. If the data is not proportional and integer, our task in drawing graphs becomes complicated."* (S2)
- *"Usually I get distracted easily, but in this class that's not the case — I can concentrate."* (S1)
- *"While I was observing, I was careful to focus on the details [...]. After observing, I inferred why the water in the glass is rising."* (S3)

The third theme that emerged from the analysis of the diaries is that of the acquisition of scientific knowledge. The pre-service teachers expressed this theme via the use of expressions corresponding to two codes: scientific research and systematic study. The following are examples of expressions from the pre-service teachers that were assessed with regard to this theme:

- *"Today we covered the last of our SPSs lessons [...]. I learned what steps to follow before starting an experiment and how to conduct an experimental study. I learned what scientific research is."* (S5)
- *"This course showed me how important it is to work systematically and regularly."* (S10)

The fourth theme that emerged from the analysis of the diaries is that of self-assessment. Within this theme, the pre-service teachers expressed themselves using expressions that correspond to two codes: realizing one's learning difficulties and realizing and correcting one's

inadequacies/mistakes. Below are examples of expressions from the pre-service teachers that were assessed under this theme:

- "Today's topic of our SPSs course was classifying. Before we examined classifying, we did an exercise. After we dealt with the topic, we did the same classifying exercise again. We compared the two. In this exercise, I realized that I had difficulty in determining the criteria for classifying." (S10)
- "I was a little lacking in making inferences. Fortunately, after the activities and experiments that my friends and I have done, I think (I) totally understand how to make inferences." (S5)
- "I can see that I am improving day by day thanks to the SPSs course." (S2)
- "Today we examined the (creation of) data tables. According to my previous knowledge, I did not know that dependent and independent variables should be taken into account while creating a table. I think another important point is that the name you give the table should fit the table." (S8)

The fifth theme that emerged from the analysis of the diaries is that of self-efficacy perception. Concerning this theme, the pre-service teachers expressed themselves using expressions corresponding to a single code: using SPSs correctly. The following are examples of expressions from the pre-service teachers that were evaluated with regard to this theme:

- "We tabulated the data from our experiment today and then transferred it to a graph. While I was making the tables and drawing the graphs, I realized that I understood the SPSs and could use it correctly." (S4)
- "There was an experimental setup: NaOH (aq) dripped phenolphthalein with a pink solution and pipette, vinegar, and baking soda. Our teacher asked us for our predictions about this mechanism and we answered. One of the strong predictions was mine." (S6)
- "We held an activity about what communication method we could use to better explain a topic. I preferred to explain through graphing. I explained by drawing three different graphs." (S7)

The sixth theme that emerged from the analysis of the diaries is that of affective influence. The pre-service teachers expressed their views on this theme via the use of expressions corresponding to six codes: curiosity, enjoyability, liking, satisfaction, level of importance, and contentment. The following are examples of the pre-service teachers' expressions that were assessed under this theme:

- "This course has reminded me that giving importance to one's task is an important virtue. I need to give importance to everything I do. I need to do what is worth doing and I think I should do it with care." (S6)
- "I really feel like I'm learning something, and that gives me satisfaction." (S10)
- "SPSs courses are fun. I don't understand how time flies, because we practice all the time." (S1)
- "I'm happy. I'm lucky enough to learn a lot in this course." (S2)
- "[...] and we had the last week of the course, which was fun, where I learned something new at the end of every course and I am glad I took this course." (S3)

#### **4.2.2. Semi-structured interview**

Table 4 shows that the pre-service teachers' views were categorized under four themes, i.e., understanding/using science process skills, acquisition of scientific knowledge, thinking process, and effective influence.

**Table 4.** The Pre-Service Teachers' Views on the Explicit SPS Teaching Process

| Themes  | Codes   |
|---|---|
| Understanding/applying science process skills | Drawing graphs<br>Forming data tables<br>Predicting<br>Observing<br>Inferring<br>Designing an experiment<br>Identifying variables<br>Hypothesizing<br>Defining operationally<br>Data collection |
| Acquisition of scientific knowledge           | Scientific research<br>Access to information<br>Attempt<br>Systematic study   |
| Thinking processes                            | Systematic thinking<br>Looking from different perspectives<br>Interpreting differently  |
| Affective influence                           | Enjoyability<br>Contentment<br>Liking   |

The pre-service teachers expressed their views on the theme of understanding/using science process skills by emphasizing eight codes: drawing graphs, forming data tables, predicting, observing, inferring, designing an experiment, identifying variables, hypothesizing, defining operationally, and data collection. Below are examples of the views of the pre-service teachers with regard to this theme:

- *"I can design an experiment on any topic by myself. With the experiment I designed, I can gain data and make graphs or tables to make that data more understandable." (S4)*
- *"I learned a lot in this course. Before, I used to mix dependent and independent variables. Now, I understand it better. I learned how to design an experiment, how to formulate a hypothesis, how to conduct an observation, what factors affect the observation, and the differences between prediction and inference." (S9)*
- *"I think I learned a lot in this course. I do not have difficulties with the scientific processes anymore. For example, in designing experiments, I only have difficulty now because I lack science knowledge, not because of my skills in the scientific process." (S1)*
- *"I feel competent in terms of science process skills. I learned how to estimate, observe, draw conclusions, make tables and graphs, design experiments, and what points to consider in an experiment. I only struggle because the content knowledge (related to science) is inadequate." (S2)*

The pre-service teachers expressed their views on the theme of acquisition of scientific knowledge by emphasizing four codes: scientific research, access to information, attempt, and systematic study. Examples of the pre-service teachers' views on this theme are as follows:

- "Science process skills are the skills that scientists use in their work. I also learned to use the scientific process when conducting a study." (S7)
- "I learned that scientific knowledge is not so easy to obtain." (S3)
- "I have learned to experiment more regularly and gain scientific knowledge by trying." (S5)
- "I have learned the importance of being punctual and systematic in my work." (S6)

The pre-service teachers expressed their views on the theme of thinking processes by emphasizing three codes: systematic thinking, looking from different perspectives, and interpreting differently. Examples of the pre-service teachers' views on this theme are as follows:

- "I am glad that I chose this course. It has enabled me to think in a more systematic and planned way." (S4)
- "Systematic thinking is critical in experimental studies. I think I have learned that." (S6)
- "I have learned to look at some events in daily life from different perspectives and interpret them differently." (S3)
- "I have learned to look at life from many perspectives, not just one way." (S8)

The pre-service teachers expressed their views on the theme of affective influence by emphasizing three codes: enjoyability, contentment, and liking. Examples of the pre-service teachers' views on this theme are as follows:

- "I have learned many things. I enjoyed the courses very much. The applications were educational and fun." (S1)
- "The practices were effective. I learned better. I was happy. I enjoyed it." (S3)
- "I liked that we experimented by ourselves. I really felt that I was learning something." (S6)

The study also sought the pre-service teachers' opinions on the comparison of their experiences with explicit and implicit teaching of SPSs (especially in laboratory courses) and which of these approaches they preferred for developing their SPSs. The pre-service teachers compared this context because they encountered implicit teaching of SPSs mainly in laboratory courses (physics, chemistry, biology, and science laboratory applications). In this context, the opinions of the pre-service teachers are summarized in Table 5, along with examples of expressions.

**Table 5.** Views of Pre-Service Teachers on the Explicit and Implicit Teaching of SPSs

| Explicit SPS teaching codes  | Implicit SPS teaching codes   |
|--|---|
| <ul style="list-style-type: none"> <li>•Deep learning</li> </ul>   | <ul style="list-style-type: none"> <li>•Surface learning</li> </ul> |
| <p>"Thanks to this course, I became aware of what we do and write." (S5)</p> <p>"I have taken many laboratory courses. However, even though we did scientific studies in those courses, I did not know what a dependent or independent variable was. I learned that thanks to the science process course." (S10)</p> <p>"I can plan experiments on a topic more easily than before and I can make tables and graphs." (S4)</p> <p>"We learned science process skills superficially in the lab courses before, but in this course we learn them in depth." (S6)</p> |   |

**Table 5.** Views of Pre-Service Teachers on the Explicit and Implicit Teaching of SPSs

| Explicit SPS teaching codes   | Implicit SPS teaching codes   |
|---|---|
| <ul style="list-style-type: none"> <li>•Systematic learning</li> </ul> <p><i>"In other lab courses, we did the steps like hypothesis, observation, etc. randomly without knowing them completely." (S5)</i></p> <p><i>"In other courses, the teachers assumed that we knew the scientific processes, and the lessons were taught accordingly. However, we do not all have those skills. I fully learned science process skills in this course." (S6)</i></p>  | <ul style="list-style-type: none"> <li>•Random learning</li> </ul>      |
| <ul style="list-style-type: none"> <li>•Active studying</li> </ul> <p><i>"In our other lab courses, we were told what to do and given instruction procedures. In this course, we used our science process skills. We determined science process activities ourselves. We designed experiments, made observations, made predictions, drew conclusions, [created] tables and graphs." (S2)</i></p> <p><i>"It was different from the lab courses we saw in school because in the lab we were always given the experimental procedures and told to do them, but now we did everything ourselves — we designed the experiment — and that made it easier for me to learn." (S8)</i></p> | <ul style="list-style-type: none"> <li>•Passive studying</li> </ul>     |
| <ul style="list-style-type: none"> <li>•Clear/more understandable</li> </ul> <p><i>"In other lab courses, we did not formulate hypothesis when writing reports and we did not consider dependent and independent variables when making tables and graphs. In report writing, this was not very appropriate for the content of the report. We made a lot of mistakes. In this course, I realized (these mistakes)." (S3)</i></p> <p><i>"With the knowledge I learned in this course, it is more understandable, clear and systematic. I can conduct an experiment and interpret the data about (that) experiment easily." (S4)</i></p>   | <ul style="list-style-type: none"> <li>•Complex/incompatible</li> </ul> |
| <ul style="list-style-type: none"> <li>•Effective questions for reflection</li> </ul> <p><i>"This course was very different from other lab courses. First of all, in other courses, we did not design experiments and we were not asked constructive and effective questions about the experiment we conducted (during and after the experiment). Also, in other lab courses we wrote reports and I think the questions and, therefore, the answers were repeated in those reports." (S6)</i></p>   | <ul style="list-style-type: none"> <li>•Repetitive questions</li> </ul> |
| <ul style="list-style-type: none"> <li>•Skill priority</li> </ul> <p><i>"In this course, we learned the ways of a scientific study, rather than the topic (scientific content) — that was different." (S7)</i></p> <p><i>"In the first grade, we went straight to the lab. We did not have enough knowledge about dependent and independent variables, observing, and making tables and charts. That was pretty difficult for us. I learned that in science process course." (S10)</i></p>  | <ul style="list-style-type: none"> <li>•Topic priority</li> </ul>       |

From Table 5 it can be observed that in explicit teaching of SPSs deep learning is enabled, skills are taught systematically, active study is undertaken, learners' autonomy is taken into account, skills are taught clearly, teaching is carried out with effective questions that make students think, and skill learning is at the core of this approach. Concerning implicit SPS teaching, meanwhile, it can be stated that they believe that it provides superficial learning, skills are learned randomly (without a specific sequence), students are passive due to prefabricated procedures, repetitive questions are used in teaching, and the focus is on learning the topic. In this regard, the pre-service teachers expressed their views by emphasizing six codes when comparing the two approaches. Finally, after summarizing their views in Tables 4 and 5, the participants were asked which of the two approaches they would prefer for developing SPSs. All of the pre-service teachers responded to this question by stating that they preferred the explicit approach.

## 5. Discussion

The development of SPSs through explicit teaching of SPSs is the focus of this study. From this perspective, an attempt was made to determine the impact of explicit teaching of SPSs on pre-service teachers' development of SPSs. To this end, pre-service teachers' SPST scores and their views on explicit teaching of SPSs were evaluated.

The SPST results showed a significant difference between the pre-test and post-test scores of the whole test. As for the sub-dimensions, although there was no statistically significant difference between the pre-test and post-test results regarding identifying variables, defining operationally, and formulating hypotheses, a significant difference was found in the sub-dimensions of graphing and interpreting data and designing investigations. The results suggest that explicit teaching of SPSs can effectively improve the SPSs of pre-service teachers in general. As for the sub-dimensions of the SPST, it is noteworthy that more complex skills (such as graphing and interpreting data and designing investigations) were achieved in comparison to others. Considering that data analysis, drawing graphs (Ateş & Bahar, 2002; Leinhardt et al., 1990), and research design (Watson, 1990) are among the most challenging processes for students, it can be concluded that pre-service teachers' development of these skills is deemed crucial. There are many studies in the literature on the development of SPSs (Yıldırım et al., 2016). While SPSs are taught explicitly in a relatively small proportion of these studies (Durmaz & Mutlu, 2012), they are implicit in a relatively large proportion of them (Bodur & Yıldırım, 2018; Çakiroğlu et al., 2020; Harahap et al., 2019; Özkul & Özden, 2020; Uysal & Cebesoy, 2020). In both approaches to teaching skills, it was found that the SPSs of the participants mostly improved. On the other hand, it is stated that the explicit approach was more effective for teaching skills in some studies on explicit (skill-based) teaching of various skills (e.g., critical thinking) (Aybek, 2007; McLaughlin & McGill, 2017; Plath et al., 1999; Yıldırım & Yalçın, 2008). Considering the aforementioned contexts, the results of this study are similar. In fact, it is a predictable result of this study that the participants are enabled to develop their SPSs through the explicit teaching of skills. It is essential how this result can be explained based on the implementation process. At this point, the pre-service teachers' opinions on explicit teaching of SPSs become more critical. Since the participating pre-service teachers consisted of second-, third- and fourth-grade students, they informally stated that they had possessed a great deal of experience with implicit teaching of SPSs prior to the study. This was the first time they had been exposed to explicit teaching of SPSs. Therefore, after the study, they were able to compare explicit and implicit teaching of SPSs and evaluate explicit teaching of SPSs. The study attempted to acknowledge the pre-service teachers' views, for which diaries and semi-structured interviews were used. It was found that the pre-service teachers mainly wrote in their diaries about what they had done in the SPS lesson on that day, and in these expressions, they shared their views, experiences and feelings with regard to explicit teaching of SPSs. Reading this, the general impression is that all of the pre-service teachers had positive thoughts regarding explicit teaching of SPSs. When the results of the two data collection instruments were analyzed together, the pre-service teachers indicated that the explicit SPS teaching approach facilitated better learning of SPSs by means of deeper, skill-focused, more applied, autonomous, and collaborative learning through group work. They emphasized that they were able to better understand and use SPSs. In addition, they indicated that it supported their thinking processes by encouraging them to be more reflective, questioning, focused, and implementing systematic thinking; that it taught them scientific and systematic study, which is important for acquiring scientific knowledge; that they noticed and corrected their learning difficulties and deficiencies/mistakes related to SPSs; that it contributed to the development of different perspectives; that explicit teaching of SPSs was enjoyable and they were pleased and satisfied with their learning; and that they learned to take care of their work.

The study's most striking finding was regarding the pre-service teachers' views on explicit and implicit teaching of SPSs. One of the views was that in explicit teaching of SPSs, skills are learned in-depth, while in implicit teaching, skills are learned superficially. Another view was that in explicit teaching of SPSs, skills are learned systematically, whereas in implicit teaching, skills are learned randomly. Since explicit teaching of SPSs emphasizes student autonomy, it is also assumed that students are active, whereas they are passive in implicit teaching, due to the

predetermined procedures, resulting in low student autonomy. A further view was that in explicit teaching of SPSs, skills are taught clearly and more understandably. In implicit teaching, in contrast, skills are taught in a complex manner without considering the relationships between the skills. Finally, the pre-service teachers believed that explicit teaching of SPSs asked practical questions that stimulated thinking, while implicit teaching asked repetitive questions; explicit teaching of SPSs focused on skills, while implicit teaching focused on topics. The pre-service science teachers' views about explicit teaching of SPSs are crucial because revealing students' thoughts and emotions for an object or a phenomenon can give clues about their attitudes or motivation towards the relevant object or phenomenon (Tegmark et al., 2022; Ültay & Alev, 2017), and attitudes (Aslan, 2017) and motivation (Ferreira et al., 2011; Schunk, 2011, p. 453) affect learning (Guido, 2013; Jufrida et al., 2019). The qualitative data revealed that pre-service science teachers had positive thoughts and emotions for explicit teaching of SPSs. This suggests that the course design using explicit teaching of SPSs can motivate pre-service science teachers to learn SPSs and help them develop a positive attitude towards learning the SPSs.

## 6. Conclusion

All of the findings summarized above show that the pre-service teachers prefer an explicit approach when it comes to teaching/developing SPSs. Moreover, they point out that laboratory courses alone are not sufficient to teach/develop SPSs. One of the pre-service teachers who participated in the study stated this clearly: *"I think the SPSs course should definitely be compulsory, because SPSs is like a building block for our lab courses, as a foundation. I think there should be an SPSs course that comes before the lab courses."* The views of the pre-service teachers indicated that it is possible to overlook the teaching of skills, as teachers and/or learners tend to focus on the content in implicit SPSs instruction where the focus is on the content. However, SPSs are necessary and used in every area of life. For this reason, they should be taught in such a way that they can be transferred to any situation/subject.

## Limitation

The findings of this study draw attention to the fact that explicit teaching of SPSs can be an effective way to teach and develop SPSs, with an understanding that is independent of content, focuses on skills, recognizes the place of SPSs in all aspects of life, and learns skills from a broad perspective. However, it should be emphasized that learner autonomy should be considered in explicit teaching of SPSs. This matter was taken into account in the study.

## Recommendation

It is suggested that designing explicit SPS instruction that considers student autonomy will lead to more effective outcomes.

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## Conflict of Interest

The authors declare no competing interests.

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