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Investigating the Impact of Activities Based on Scientific Process Skills on 4th Grade Students' Problem-Solving Skills*

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Abstract

The purpose of this research is to examine the impact of activities based on scientific process skills on problem-solving skills of 4th grade students in science lessons. In the study a non-equivalent control group pre-test and post-test design type of quasi-experimental method was used. The research study group was composed of 30 students with 15 each in the experimental study group and control group. In the experimental and control groups, for scientific process skills, the "Scientific Process Skills Test (SPS)",and for problem-solving skills, the "Problem Solving Inventory for Children at Elementary Education Level (PSIC)" were used as pre-test and post-tests. Activities including scientific process skills in the experimental group were applied for 8 weeks and 16 lesson hours, while no intervention was made to the control group. In the data analysis process, the Mann-Whitney U test and Wilcoxon Signed-Rank test were used. According to the data obtained from the research, it was observed that there was a significant difference in the post-test scores in the Scientific Process Skills Test (SPST) and the Problem-Solving Inventory for Children (PSIC) of the students in the experimental group compared to the students in the control group. According to these findings, it can be stated that activities including scientific process skills develop problem-solving skills of students in primary science education.

Keywords:

Scientific Process Skills, Science Lesson, Problem Solving, Elementary School Students.

Introduction

In daily life, humankind is faced with various problems all the time. Humans have to think of ways to solve these problems (Fredics, 2003). Individuals try to find solutions to problems they are confronted with at various times. In rapidly changing communities, in order to solve and eliminate problems, there is a need to improve scientific process skills (NSTA, published in 1971, Padilla, Okey & Garrard, 1984). Hence, acquiring scientific process skills and developing them is not unique to scientists (Carin & Bass, 2001; Rillero, 1998).

Scientific process skills include skills which a person can use in all stages of his daily life to become science literate and to improve his life quality by internalizing the nature of science (Bağcı-Kılıç, 2003; Harlen, 1999; Rillero, 1998; Tifi, Natale & Antonnietta, 2006). Individuals ask questions, they make observations and measurements, they gather data, they interpret data, they collect and predict the probable impact of variables, they make a hypothesis and test it, they obtain test results and they use scientific processes during the process of gaining access to information (Opara, 2011; Renner & Marek, 1990).

In addition to gaining access to information, individuals having scientific process skills can become good citizens who inquire about technological developments around them (Rubin & Norman, 1992).

Scientific process skills (SPS) play a key role in the development of skills such as communication and evaluation and provide opportunities to students to solve problems, to take decisions and to think in a critical way (Harlen, 1999; Myers, 2006; Pekmez, 2000). Competency in these skills enables students to produce new information and to find solutions to problems (Burns, Okey & Wise, 1985). It is expected that individuals who have gained these skills at a significant level will use them to solve problems they are faced with in daily life and to solve problems related with science (Aldridge, published in 1991, Smith, 1997, p. 4). While solving a problem, content information and scientific process skills complement each other in the solution process (Rillero, 1998). Scientific process skills are effective in learning content information because students are motivated to learn, they gain access to information with their own experiences and this is important for them to remember the information (Myers, 2006). In this process, students who use scientific process skills can create knowledge in a more effective way. Students make observations and measurements related with a case or an event, they collect data, they interpret the data they collect and they make a generalization based on the data collected. This process has a positive impact on the permanence of learning and makes learning become more permanent (Bahadır 2007; Preece & Brotherton, 1997; National Research Council [NRC], 1996; Rehorek, 2004).

The Science curriculum based on scientific process skills (2017) aims for all individuals to become science literate. Some of the objectives of the program are to adopt scientific process skills and a scientific research approach and to find solutions to problems faced in these areas, to take responsibility for problems faced in daily life, and during the problem solution process, to ensure the usage of scientific process skills, information related with sciences and other life skills (Ministry of National Education [MONE], 2017). These skills help students to think logically and ask logical questions, and develop their ability to solve problems they face in daily life (German, 1994). Individuals with good scientific process skills can solve problems they encounter in their daily lives both in a short time and by using an appropriate method (Smith & Scharman, 1999). In the light of these benefits, scientific process skills do not only enable acquisition of research, questioning and problem-solving skills while learning lessons in formal learning, but they also enable individuals to attain skills to solve problems faced in their daily lives. These skills are skills that are also used in daily life besides education life. In addition to many aspects, increasing the permanence of learned content and transferring this content to new and different situations (Tifi et al., 2006) makes it important for individuals to gain scientific process skills.

In studies conducted in relation to scientific process skills, it was concluded that education focused on scientific process skills develops the attitudes of students towards science, science literacy, scientific process skills, academic success, problem solving, reflective thinking, and scientific and creative thinking skills (Aktamış, 2007; Batı, 2010; Brotherton & Preece, 1996; Hızlıok, 2012; Karahan, 2006; Kuhn & Dean, 2005; Kurnaz, 2013; Mutlu, 2012; Suryanti, İbrahim & Lede, 2018; Yıldırım, 2012). In fact, according to the results of a meta-synthesis study including 200 studies related to scientific process skills, as there was only one study examining the relationship between scientific process skills and problem-solving skills and as they were limited in relation to elementary school students, this situation constitutes one of the reasons why this study was carried out (Yıldırım, Çalık & Özmen, 2016). As there are few studies examining the impact of scientific process skills on problem-solving skills of students and as studies conducted at elementary school level are limited, this can be said to constitute a deficient aspect of the literature. In the literature, there are opinions stating that the individual attaining scientific process skills can be successful in solving problems he faces in daily life. In this study that was conducted the aim was to examine the impact of activities focused on scientific process skills on problem-solving skills. For this reason, this research was carried out in a science course based on scientific process skills.

Aim of the Study

The aim of this study is to examine the effects of activities including scientific process skills on students' problem-solving skills in the Primary School Science course. In this context, the study sought answers to the following questions:

1. Is there a significant difference in the pre-test scores and post-test scores of the students in the experimental group to which the activities including science process skills were applied?
2. Is there a significant difference in the pre-test and post-test scores of the students in the control group obtained from the SPST?

3. Is there a significant difference between the post-test scores of the students in the experimental group and the control group, which they obtained from the SPST, after the SPS-focused activities were applied to the experimental group students?

4. Is there a significant difference between the pre-test scores and post-test scores of the students in the experimental group, in which activities involving scientific process skills were applied, obtained from the Problem Solving Inventory for Children (PSIC)?

5. Is there a significant difference between the post-test scores of the students in the experimental and control groups obtained from the PSIC, after SPS-focused activities were applied to the experimental group students?

Method

Research Model

The pre-test and post-test control group design type of quasi-experimental method was used in this study, which was conducted to examine the effect of activities focused on scientific process skills on the problem-solving skills of primary school 4th grade students. Since the experimental and control groups were selected from the classes in the school, the quasi-experimental design was used. In this design, the experimental group and the control group were selected without random assignment. The experimental and control groups are pre-tested and post-tested. The experimental procedure was done only in the experimental group. Pre-tests allow the similarity between groups to be known before the application (Büyüköztürk et al., 2012; Creswell, 2013; Fraenkel & Wallen, 2003; Karasar, 2006). The independent variable in the research was activities focused on scientific process skills while the dependent variable was problem-solving skills. In the study, before determining the effect of the independent variable, the SPST and PSIC were applied to the experimental group and control group students as pre-tests. It was determined whether there was a significant difference between the scores. Activities focused on scientific process skills were applied in the experimental group, and there was no intervention to the students in the control group during this process. At the end of the application in both groups, the SPST and PSIC were applied as a post-test and it was examined whether there was a significant difference between the results.

Study Group

The study group of the research consists of 30 fourth grade students studying at an elementary school in the fall semester of the 2017-2018 academic year. The distribution of the experimental and control group students by gender is presented in Table 1 below.

Table 1.
Distribution of Control and Experimental Group Students as per Gender

Group	Gender	*N*	Total
Experimental	Female	8	15
	Male	7	
Control	Female	8	15
	Male	7	

Before the application, teachers working in the 4th grade in a primary school in the city center were interviewed and a volunteer teacher's branch was determined in the studies to be carried out in the experimental group. After the experimental group was determined, a class equivalent to the group was determined as the control group. The scientific process skills pre-test results of the groups are also included in the Table 2.

SPST Pre-Test Scores of Students in Experimental and Control Groups

The difference between the experimental group and control group students' SPST pre-test scores was analyzed with the Mann-Whitney U test and the results are presented in Table 2.

Table 2.
SPST Pre-Test Scores of Students in Experimental and Control Groups

Group	*N*	Mean rank	Rank sum	*U*	*p*
Experimental	15	13.27	199	79	0.163
Control	15	17.73	266		

According to the SPST pre-test results in Table 2, it was found that there was no significant difference between the SPST scores of the students in the experimental and control groups ($U = 79$, $p > 0.05$). According to this finding, it can be said that the scientific process skills of the groups were equivalent.

Data Collection Tools

In the study, the "Scientific Process Skills Test (SPST)"and "Problem Solving Inventory for Children (PSIC)" were used as data collection tools for the purpose of the research. The necessary permission was obtained from the relevant researchers in order to use the data collection tools in the study. As pre-test and post-test to measure scientific process skills in the experimental and control groups the "Scientific Process Skills Test" prepared by Kurnaz (2013) was used. The internal consistency coefficient of the SPST was found to be 0.82 (Kurnaz, 2013). Since the activities involving scientific process skills and the skills in the SPST coincide, the SPST scale developed by Kurnaz (2013) was used as a measurement tool. The skills included in the questions in the scale are presented in Table 2.

March 2022, Volume 14, Issue 4, 491-500

Table 3.
Distribution of Questions in SPST as per Scientific Process Skills Dimension

Scientific scale skills dimension	Question number
Making observations	3, 4, 5, 6, 18, 25, 27, 31, 36 and 38
Classification and ranking	1, 2, 11, 17, 28, 29 and 32
Measurement	13, 14, 15 and 22
Making predictions	20 and 30
Establishing a hypothesis	19, 21, 23 and 35
Experiment planning and execution	8, 9, 10, 16, 24, 33, 34, 37 and 39
Interpretation of results	26
Explaining results	7 and 12

In order to measure the problem-solving skills in the experimental and control groups, the "Problem Solving Inventory for Children (PSIC)" developed by Serin et al. (2010) was used as a pre-test and a post-test. According to the factor analysis, 24-itemed measurement tool that consists of three factors (self confidence related to problem solving skill, self-control, avoidance). The Cronbach Alpha reliability coefficient was found to be 0.80 (Serin et al., 2010).

Data Collection Process

There are two basic approaches in teaching scientific process skills. The first of these approaches is the acquisition of scientific process skills simultaneously with the teaching of concepts within the scope of any subject in a given course. Studies show that this approach contributes to acquisition of skills; however, it is emphasized that it has limiting aspects. The most important of these limitations is that the context becomes more intense in the acquisition of skills (Lawson, 1995; Reif, 1991). The second approach to teaching skills is to prepare programs based on the thinking styles of scientific process skills. In these kinds of programs, the course of the subject progresses in an order depending on the scientific process skills. According to the results of research studies, such programs have a positive effect on the scientific processes (Carin & Bass, 2001). In this study, it was intended to carry out instruction that was separate from the context; however, since the preparation of such teaching activities requires experience and a lot of accumulated knowledge, the context was adhered to. For this reason, in the science course, an attempt was made to foster skills in parallel with the teaching of the acquisitions in the "Getting to Know Matter" unit. In the preparation of the lesson plans, the acquisitions belonging to the unit of "Getting to Know Matter" in the Science Curriculum (MONA, 2017) were associated with the scientific process skills they contain and determined by obtaining expert opinion. In the control group, however, the process was carried out by following the science textbook. In the observations made in the control group, it was observed that the teacher taught the lesson with the presentation method of teaching strategy using the training platform.

Designing SPS Activities

The source of scientific process skills is based on the constructivist approach (Padilla, 1990; Roth, cited in 1989, Roth, 1993, p. 128). Many studies have found a positive relationship between scientific process skills and Piaget's developmental stages (Brotherton & Preece, 1995; Chiappetta, 1976; Padilla, Okey, & Dillashaw, 1983; Tobin & Capie, 1982). While designing the activities related with scientific process skills by considering the studies conducted, the age levels of the students were considered and they were planned within the framework of the constructivist approach. While creating classroom activities, the principles of learning by discovery were taken into account. The lesson plans prepared by the researcher and including the SPS teaching activities were put into practice after obtaining expert opinion. Lesson plans were shared with the experimental group teacher, and it was ensured that the lessons were carried out within the plan. In order to get used to the researcher's presence in the classroom, the researcher was present in the science course for 3 weeks before the application. The researcher took part in the class as an observer. The application took 8 weeks and 16 lesson hours with the pre-test and post-test. An example of two achievements is presented in Table 3.

In Table 4, activities prepared for some learning objectives in the Getting to Know Matter unit are presented. In parallel with the teaching of the outcomes, the focus of the activities is on the teaching of scientific process skills. For example, in the "Market Place" activity prepared to improve the measurement skills of students, a small market counter was set up in the classroom, enabling students to measure the mass and volume of different substances.

Analysis of Data

In order to determine whether the activities focused on scientific process skills were effective on students' problem-solving skills, the SPST and PSIC pre-test and post-test scores of the groups were used. The data were analyzed using the analysis program. To see whether there was a significant difference between the scores of the experimental and control groups, analysis was made with the Mann-Whitney U test. The Mann-Whitney U test is the equivalent of the independent t-test in nonparametric statistics (Ekiz, 2015). This test is used to compare data obtained from two independent sample groups (Çepni, 2014). The difference between the pre-test and post-test scores of the experimental and control groups was analyzed using the Wilcoxon Signed-Ranktest. The Wilcoxon

Signed-Rank test is used to examine whether there is a significant difference in the post-tests and pre-tests when the number of two sample groups is less than 30 (Sümbüloğlu & Sümbüloğlu, 2010).

Findings

In this section, the findings related with the objectives and sub-objectives of the research are presented.

SPST Pre-Test and Post-Test Scores of Experimental Group

The difference between the SPST pre-test and post-test scores of the experimental group students was analyzed with the Wilcoxon Signed-Rank test and the results are presented in Table 6.

Looking at the results in Table 5, a significant difference was found between the pre-test and post-test scores of the experimental group (z = 3.42; p < 0.05). Considering the sum of the difference scores and the mean rank, it is seen that this difference is in favor of the post-test scores. The experimental group pre-test-post-test SPST effect size value was calculated as 0.88. The eta square ranges between 0 and 1, and as it approaches 1, the effect size increases (Can, 2016). It is seen that the effect size is large according to the value obtained as a result of the calculation. Based on this finding, it can be said that the activities based on SPS improved students' scientific process skills.

Control Group SPST Pre-Test and Post-Test Scores

The difference between the SPS pre-test and post-test scores of the control group students was analyzed with the Wilcoxon Signed-Rank test and the results are presented in Table 6.

According to the results in Table 6, it is seen that there is a significant difference between the pre-test and post-test scores of the control group (z = 3.309, p <0.05). It is seen that the difference is in favor of the post-test scores according to the sum of the difference scores and the mean rank. This situation shows that the post-test scores of the control group students increased. The control group pre-test-post-test SPST effect size value was calculated as 0.85. It is seen that the effect size is large according to the value obtained as a result of the calculation.

Within the scope of the research, a significant difference was found in the SPST pre-test and post-test scores of both the experimental group students and the control group students. In this case, it can be said that both the program in the experimental group, in which the activities focused on scientific process skills were carried out and the program in the control

Table 4.
Learning Objectives and SPS Activities

Objectives	Activities	Scientific process skills contained in the activities
Compares by measuring the mass and volume of different substances.	Shopping time	Making observations, making predictions, establishing a hypothesis, interpretation of results, explaining results
Defines the substance using its measurable properties.	Market place	Measurement, experiment planning and execution, making predictions, establishing a hypothesis, interpreting results, explaining results
	Covered particulars	Making observations, establishing a hypothesis, making predictions, experiment planning and execution, interpreting results, explaining results

Table 5.
Pre-Test and Post-Test Scores Obtained by Students in Experimental Group from SPST

Pre-test and post-test	N	Mean rank	Rank sum	z	p	η^2
Negative ranks	0	0	0	-3.42	0.001	0.88
Positive ranks	15	8	120			
No difference	0					

Table 6.
SPST Pre-Test and Post-Test Scores of Students in Control Group

Pre-test and post-test	N	Mean rank	Rank sum	z	p	η^2
Negative ranks	0	0	0			
Positive ranks	14	7.5	105	3.309	0.001	0.85
No difference 1	1					

group, where the current application was carried out, improved the scientific process skills of the students. Based on these results, the post-test scores of the groups were compared in order to determine whether the activities applied in the experimental group were more effective than the current instruction given in the control group. The relevant results are presented in Table 7

Experimental and Control Group SPST Post-Test Scores

The difference between the SPST post-test scores of the students in the control and experimental groups was analyzed with the Mann-Whitney U test and the results are presented in Table 7.

Looking at the results in Table 7, it is seen that there is a significant difference in the post-test scores of the experimental and control groups ($U = 45.5$, $p < 0.05$). According to this finding, the experimental group students achieved more success in the post-test than the students in the control group. Based on these findings, it can be said that the activities focused on scientific process skills were effective in the experimental group. The post-test SPST effect size value in the experimental and control groups was calculated as 0.52. According to the value obtained as a result of the calculation, it is seen that the effect size is medium.

Experimental Group PSIC Pre-Test and Post-Test Scores

The difference between the PSIC pre-test and post-test scores of the experimental group students was analyzed with the Wilcoxon Signed-Rank test, and the results are presented in Table 8.

Considering the results in Table 8, a significant difference was found between the pre-test and post-test scores of the experimental group ($z = 3.32$, $p < 0.05$). According to this finding, it can be said that the activities including scientific process skills improved students' problem-solving skills. The experimental group pre-test-post-test PSIC effect size value was calculated as 0.86. It is seen that the effect size is large according to the value obtained as a result of the calculation.

Experimental and Control Group PSIC Post-Test Scores

The difference between the post-test scores of the students in the experimental and control groups was analyzed with the Mann-Whitney U test and the results are presented in Table 9.

Looking at the results in Table 9, it is seen that there is a significant difference between the post-test scores of the control and experimental groups ($U = 62.5$, $p < 0.05$). Considering the results of the U Test, the experimental group was more successful in the post-test than the control group. The experimental and control groups' post-test PSIC effect size value was calculated as 0.38. It is seen that the effect size is small according to the value obtained as a result of the calculation. According to these findings, it can be said that the activities focused on scientific process skills also had an effect on improving students' problem-solving skills.

Discussion

In this study, it was examined whether the application of activities focused on scientific process skills in primary school science education had an effect on problem-solving skills. In this section, an attempt has

Table 7.

SPST Final Test Scores of Students in Experimental and Control Groups

Group	*N*	Mean rank	Rank sum	*U*	*p*	η^2
Experimental	15	19.97	299.5	45.5	0.005	0.52
Control	15	11.03	165.5			

Table 8.

PSIC Pre-Test and Post-Test Scores of Students in Experimental Group

Pre-test and post-test	*N*	Mean rank	Rank sum	*z*	*p*	η^2
Negative ranks	1	1.5	1.5	3.32	0.001	0.86
Positive ranks	14	8.46	118.5			
No difference	0					

Table 9.

PSIC Post-Test Scores of Students in Experimental and Control Groups

Group	*N*	Mean rank	Rank sum	*U*	*p*	η^2
Experimental	15	18.83	282.5	62.5	0.038	0.38
Control	15	12.17	182.5			

been made to associate the conclusions reached on the basis of the findings with the relevant literature (Batı, 2010; Kurnaz; 2016). There was no statistically significant difference between the experimental and control group students' SPST pre-test scores in the findings of the experimental and control group pre-test results. This finding can be interpreted as that the students developed SPS at a similar level with the current curriculum. In other words, it can be said that the current curriculum develops almost the same skills in students. This may be due to the fact that the 2017 Science Curriculum explicitly considers and emphasizes SPS as a learning area (MONA, 2017).

When the findings for the second research question are examined, it is thought that the statistically significant difference between the experimental group students' SPST pre-and post-test scores and the large effect size were due to the effectiveness of SPS-based instruction. In other words, the planning of the activities and the emphasis on SPS dimensions may have caused this difference. This result coincides with the results of studies involving student-centered activities based on SPS (e.g. Aktamış, 2007; Karahan, 2006; Kuhn & Dean, 2005; Kurnaz, 2013).

When the findings for the third research question are examined the fact that there was a statistically significant difference in favor of the post-test in the control group in the pre-test and post-test scores of the SPST and the large effect size may be due to the fact that SPS are taken as a basis in the instruction carried out in accordance with the current curriculum. In other words, teaching SPS by associating them with the subject in both experimental and control groups may have caused this difference to emerge. The acquisition of skills simultaneously with the teaching of concepts in a given course in any subject contributes to the acquisition of skills. However, it is emphasized that it has limiting aspects. The most important of these limitations is that the context becomes more intense in the acquisition of skills (Lawson, 1995; Reif, 1991).

When the findings for the fourth research question are examined a significant difference in the SPST post-test scores of the experimental and control groups and the medium effect size may be due to the effectiveness of the SPS-based activities applied in the experimental group. This result coincides with the results obtained by Aktamış (2007), Kurnaz (2013). In addition to the situations discussed above, it should be noted that a long period of time may be needed for the development of scientific process skills (Tifi et al., 2006). In this study, an attempt was made to foster scientific process skills in parallel with the teaching of the acquisitions in the Getting to Know Matter unit in the science course and the context was adhered to. Therefore, this situation may have led to the development of scientific process skills in students depending on the context (Lawson, 1995; Reif, 1991).

When the findings related with the fifth research question are reviewed, as the PSIC pre-and post-test results of the experimental group were significantly different and as the effect size was big, it can be stated that the activities prepared in accordance with SPS developed the problem-solving skills of students. This finding overlaps with the results of a study that examined the effect of SPS-focused activities on problem-solving skills (Batı, 2010).

Considering the findings for the sixth research question, a statistically significant difference was found in the experimental and control groups 'PSIC post-test scores, while the effect size was small. The fact that the lesson plans planned for the experimental group did not differ greatly from those given in the current books or known activities and the limited time of application may have caused this situation. The reason for the limited time is that the activities are designed as much as the unit time, as the application adheres to the context. In addition, the reason why the activities are known are the skills expected from children in the younger age group; this is due to the fact that they are simple skills such as measuring or classifying (Kuhn, Black, Keselman & Kaplan, 2001). This situation can be considered as a limitation of the study.

Conclusions

The results obtained from the discussion are stated in the items in this section.

1. The fact that there was no significant difference between the experimental and control group students'SPST pre-test scores leads to the conclusion that the current curriculum develops similar SPS in students.
2. The fact that there was a significant difference in favor of the post-test between the SPST pre-test and post-test scores of the experimental group students reveals that the scientific process skill-based instruction is effective.
3. The fact that there was a significant difference in favor of the post-test between the SPST pre-test and post-test scores of the control group students indicates that the current curriculum effectively improves their scientific process skills.
4. The fact that there was a significant difference in the SPST pre-test and post-test scores of the experimental and control group students in favor of the post-test leads to the conclusion that SPS are learned on a context-based basis.
5. The fact that there was a significant difference between the PSIC pre-test and post-test scores of the experimental group students in favor of the post-test leads to the conclusion that SPS-based instruction improves students' problem-solving skills.

6. The presence of a significant difference in the pre-test and post-test scores of the students in the experimental and control groups in favor of the post-test leads to the conclusion that the activities prepared for SPS are not different from those in the current curriculum and known activities.

Suggestions

On the basis of the conclusions reached in the study, the following recommendations can be made:

Suggestions Regarding the Results of the Research

1. Scientific process skills can be taught in two ways. The first one is that only SPS is taught as inherent in the nature of science and the other one is that SPS is taught depending on the subject. In this study, the second type was preferred. In studies to be conducted in the future, activities that are directly focused on SPS can be designed.

2. The ability of teachers and prospective teachers to use scientific process skills effectively can affect the level of students' use of these skills. For this reason, studies can be conducted to ensure that both prospective teachers and teachers participate in activities that will positively affect the development of scientific process skills.

3. The students in the study group of the research consist of 4th grade students. By applying the research to students at different grade levels and age groups, the differences in students' skill levels can be examined.

Suggestions Regarding Studies that Can Be Conducted in the Future

1. Studies on different methods and techniques that can improve students' problem-solving skills can be done.

2. The effectiveness can be investigated by developing activities that make direct associations between problem solving and SPS.

3. The effectiveness of this research carried out in the science course can be investigated by conducting it in different subjects (Turkish, mathematics and social studies) in primary school.

4. Other sub-dimensions of SPS, which are not included in this research, can be included in future studies.

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