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A Teacher Training Program for Learning and Teaching About Scientific Reasoning Skills

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Abstract

This study aims to improve science teachers' scientific reasoning skills (SRS) in using and teaching these skills through a professional development program, Scientific Reasoning Skills Teacher Training Program (SRSTP). Forty-five middle school science teachers participated in the study, which was on convergent parallel design. "Scientific Reasoning Skills Assessment Form (SRSAF)" and "Scientific Reasoning Skills Test for In-service and Pre-service Science Teachers (SRSTIPST)" were used to determine the improvement in teachers' use of scientific reasoning skills. Besides, "Self-efficacy Perceptions towards Teaching Scientific Reasoning Skills Assessment Form (SEPSRSAF)" and "Self-efficacy Perceptions towards Teaching Scientific Reasoning Skills Scale (SEPSRS)" were used to determine teachers' self-efficacy perceptions towards teaching them. Findings from SRSAF and SRSTIPST pointed out that teachers' scores in using specific scientific reasoning skills and their ways of making claims, presenting evidence, and reasoning differed significantly after SRSTP. Findings from SEPSRS showed that teachers got significantly higher scores in creating SRS based learning environment, academic proficiency, using SRS in the classroom, assessment of SRS, and instructional ways for teaching SRS after the professional development program. SEPSRSAF supported these findings by revealing that SRSTP allowed teachers to change their efficacy sources from indirect experience to active experiences and improve personal characteristics such as showing empathy. It was also found that teachers' perceptions of teaching SRS shifted towards teacher-related factors after SRSTP. These findings were discussed, and the contribution of the results was explained.

Keywords

Science teachers, Scientific reasoning skills, Professional development, Teacher training.

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INTRODUCTION

Increasing inclusion of technology into everyday lives makes societies educate appropriate individuals, such as individuals with 21st-century skills for future lives. 21st century skills require communication and collaboration skills, mastery of technology, innovative and creative thinking skills, and problem-solving skills (Larson & Northern Miller, 2011). Inquiry-based learning (IBL) pedagogy is suggested as an effective method for these skills (Chu et al., 2012; Kuhlthau et al., 2015), and scientific reasoning skills (SRS), the main subject of this study, are seen as the functioning way of IBL (Han, 2013; Hogan & Fisherkeller, 2005; Kuhn, 2002; Kuhn & Pearsall, 2000; Zimmerman, 2000). Therefore, SRSs are important for educating students as future citizens.

In the scientific inquiry process, students ask, refine, and evaluate questions; design, refine, and interpret experiments; make observations; collect, represent, organize, analyze, and discuss data; learn and refine theories and models to explain the phenomena (Duschl & Grandy, 2008). However, scientific reasoning skills include asking a scientific question, finding a solution, analyzing data, and interpreting findings (National Research Council [NRC], 1999). This definition of scientific reasoning skills shows their place and importance in IBL. When a student faces a problem, he/she engages in an inquiry process. In this process, he/she determines many possible solutions through hypothetical-deductive reasoning and selects one as a hypothesis to test. Then, he/she makes observations, identifies variables, designs experiments, and collects data. Here, while kinesthetically conducting experiments correspond to using science process skills (SPS), mental skills about inferring causal relations through controlling which variable is dependent/independent correspond to scientific reasoning skills (Chen & Klahr, 1999). When analyzing data, he/she uses causal or correlational reasoning to determine the data patterns or possible causal relationships between variables. Then, tentative conclusions from data patterns are made through inductive, deductive, or causal reasoning. Like controlling variables, while writing a conclusion corresponds to science process skills, mental processes for concluding correspond to scientific reasoning skills. After concluding, if he/she still has questions about the problem, then the cycle, which includes both SPS and SRS, begins with hypothesis generation again. Scientific reasoning skills are required to learn the content of inquiry-based activities (Stender et al., 2018). Because scientific reasoning skills are used in the inquiry process, researchers stated a common view that these skills consist of hypothetical deductive reasoning, inductive reasoning, probabilistic reasoning, proportional reasoning, causal reasoning, correlational reasoning, and control of variables strategy (Lawson, 1978; Zimmerman, 2007).

Although SRSs are important indicators for future societies (Osborne, 2013), according to research findings, students still need to understand how data can be used as evidence (Abdelkareem, 2008; Ibrahim et al., 2016; Sadler et al., 2004; Schimek, 2012). Furthermore, they need to be more capable of using learning when reasoning in authentic contexts (Sadler & Donnelly, 2006). They tend to make and evaluate their arguments based on prior knowledge and beliefs rather than epistemological commitments (Choi et al., 2010). Teachers also need some help with scientific reasoning skills, especially in relation to teaching them. For example, they cannot emphasize some characteristics of IBL, such as evaluating explanations and associating experiment's findings with theoretical knowledge, which corresponds to using scientific reasoning directly (Kang et al., 2008) and creating a classroom culture where the assumption and proof language is used (Geist, 2004; Osborne et al., 2004). Besides, they do not have solid content knowledge (Hilfert Ruppell et al., 2013), and they are incapable of performing some behaviors to promote students' thinking and reasoning (Diezmann et al., 2002; Schwartz et al., 2004).

One way to eliminate these problems is through professional development of teachers. Studies that reported the effect of teacher training on the improvements of teachers' and students' SRS supported this view (Gillies, 2011; Kocagul & Unal Coban, 2022; Smit et al., 2018). However, although the results of some studies informed about the need for training of teachers (Kocagul Saglam & Unal Coban, 2020; Khan & Krell, 2021), teachers' training studies on SRS were rare and existing studies were conducted extensively with teachers in the pre-service (Alonzo & Kim, 2018; Chowning et al., 2012; Gillies, 2011; Hogan et al., 1999; Jacops et al., 2007; Sedova et al., 2016). Furthermore, studies on teachers' training regarding SRS focused heavily on only one reasoning skill (Chowning et al., 2012; Jacops et al., 2007; Wilhelm et al., 2018) or reasoning skills that are different from the skills in the context of this study (Koenig et al., 2012; Tadesse et al., 2017; Wilhelm et al., 2018) or were conducted with different branches of teachers out of science (Jacops et al., 2007).

This study aims to improve the SRS of science teachers in using and teaching these skills through a professional development program, the Scientific Reasoning Skills Teacher Training Program (SRSTP). The study variables are teachers' knowledge about using SRS and self-efficacy perceptions towards teaching them. Knowledge about using SRS was considered mainly by other teacher training studies (Jacops et al., 2007; Koenig et al., 2012; Tadesse et al., 2017; Wilhelm et al., 2018); however, this study also focuses on teachers' self-efficacy perceptions, an important barrier to reflect on their learning in the classroom environment. Furthermore, this study differs in terms of the included SRS. It consists of basic SRS (inductive reasoning, hypothetical-deductive reasoning, causal reasoning, correlational reasoning, proportional reasoning, and control of variables strategy), which researchers agreed on (Lawson, 1978; Zimmerman, 2007). It also includes analogical reasoning, because analogies can be used to promote the understanding of inquiry (Flick, 1991). Seven basic SRSs were taught in different content through various methods such as observation, field trips, modeling, experiments, calculation-based, game-based, and group work.

In this context, the following research problem was considered:

- How does SRSTP affect science teachers' use of SRS and their self-efficacy perceptions toward teaching them?

METHOD

Research Design

This mixed method study addresses determining the impact of SRSTP on teachers' use of scientific reasoning skills and their self-efficacy perceptions towards teaching them. The convergent parallel mixed method design is used and it is a type of design in which qualitative and quantitative data are collected for the same variable simultaneously, analyzed separately, and then merged to provide a comprehensive analysis of the research problem (Creswell & Plano Clark, 2011). In this study, quantitative data for both independent variables (teachers' use of SRS and their self-efficacy perceptions toward teaching them) explain teachers' status, while qualitative data provide justifications. For example, teachers' use of the SRS variable was quantitatively measured through a multiple choice test, and their reasoning style was qualitatively determined using open questions based on scenarios. The reason for choosing this method is that quantitative and qualitative data have the same value to understand the research problem in a comprehensive way.

Participants

The selection of participants was carried out based on purposive sampling. An online application form was created and shared with science teachers through social media groups to determine volunteer teachers. The teachers were then selected based on their gender, professional experience, and geographic region of work where they work. Finally, 45 science teachers working in state or private middle schools participated in the study.

Table 1

Demographic Information on Teachers

Region[a]	*Experience*								
	0-5 years		*6-10 years*		*11-15 years*		*16+ years*		*Total*
	F	*M*	*F*	*M*	*F*	*M*	*F*	*M*	
Aegean	2	-	1	3	2	2	3	1	14
Mediterranean	-	-	-	1	1	-	1	1	4
Black Sea	1	1	1	-	-	-	-	-	3
Marmara	1	-	2	1	1	1	2	-	8
Central Anatolia	-	2	1	1	1	-	2	-	7
East Anatolia	-	3	1	1	-	-	-	-	5
Southeastern Anatolia	2	-	-	1	-	1	-	-	4
Total	6	6	6	8	5	4	8	2	45

Note. N=45

a: Reflects the geographic region of the participants in their work

F: Female and M: Male

Table 1 showed that there were 25 female (55.56%) and 20 male (44.44%) teachers and most of them were from the Aegean region (31.11%). The study was located in Izmir, a city in the Aegean Region. The highest attendance from this region may be due to the ease of transportation in terms of cost. In addition, there was a nearly equal number of teachers in terms of professional experience.

Data Collection Tools

The main aim of this study is to determine whether SRSTP has an impact on ensuring that science teachers learn and teach scientific reasoning skills. Therefore, this study has two independent variables to measure. One is about teachers' content knowledge, which is related to learning about SRS.

Therefore, the first two data collection tools aim to quantitatively and qualitatively measure the knowledge of science teachers about SRS. The other variable is teachers' self-efficacy perception, which is related to the teaching of SRS. The third and fourth data collection tools (2.3.3 and 2.3.4) aim to quantitatively and qualitatively measure the perceptions of self-efficacy of science teachers towards teaching SRS.

Scientific Reasoning Skills Test for In-service and Pre-service Science Teachers (SRSTIPST)

This test, developed by Kocagul Saglam and Unal Coban (2018), aims to determine whether science teachers can use SRS. The test includes 27 items, 4 for inductive reasoning, 3 for deductive reasoning, 5 for causal reasoning, 6 for correlational reasoning, 2 for analogical reasoning, 3 for proportional reasoning, and 4 for control of variables strategy. Expert views confirmed the validity of the content, while factor and item analysis provided evidence for the validity of the construct. Therefore, SRSTIPST, which has only one dimension, is suitable with moderate item difficulty (p=0.523) and high discrimination index (rjx=0.480). The KR-20 reliability coefficient is .812. A sample item is presented in Figure 1.

Figure 1

A Sample Proportional Reasoning Item from SRSTIPST

Deniz is a bike-rider and wants to live the one of X, Y or Z cities. Finally, he decided to live in city Y with the thought of having more chance to ride against car traffic. According to this, which choice is belonged to city Y?

A. 15 hectare area and 12560 cars
B. 3 hectare area and 2502 cars
C. 17 hectare area and 14212 cars
D. 10 hectare area and 7136 cars

Scientific Reasoning Skills Assessment Form (SRSAF)

This form, developed by Kocagul Saglam (2019), aims to determine science teachers' use of SRS in detail based on the "Claim-Evidence-Reasoning Framework" proposed by McNeill and Krajcik (2011). The reason for choosing this framework was to describe the reasoning process in detail. The form includes seven scenarios, each representing a different scientific reasoning skill. Expert opinions confirmed the validity of the content with some revisions. A sample question is presented in Figure 2.

Figure 2

A Sample Proportional Reasoning Question from SRSAF

Two friends want to prepare an orange-juice for other friends in the picnic. They have four different recipes for the best flavor.

A	B	C	D
2 cups of orange juice and 3 cups of water	1 cup of orange juice and 4 cups of water	4 cups of orange juice and 8 cups of water	3 cups of orange juice and 5 cups of water

Based on the information above, which mixture has the most intense orange flavor?

What evidence do you have for your answer?

What is your rationale for the evidence you present?

Self-efficacy Perceptions toward Teaching Scientific Reasoning Skills Scale (SEPSRS)

This scale, developed by Kocagul Saglam (2019), aims to reveal science teachers' self-efficacy perceptions toward teaching SRS. Expert views shed light on content and face validity while explanatory and confirmatory factor analyses for construct validity. The scale includes 20 items under five dimensions entitled creating an SRS-based learning environment, academic proficiency, using SRS in the classroom, assessment of SRS, and instructional ways of teaching SRS, respectively. The Cronbach alpha value for the scale is .947.

Self-efficacy Perceptions Toward Teaching Scientific Reasoning Skills Assessment Form (SEPSRSAF)

This form, developed by Kocagul Saglam (2019), aims to reveal science teachers' self-efficacy perceptions toward teaching SRS. The questions were created based on some components of the Teacher Efficacy Model proposed by Tschannen Moran et al. (1998). The form asks for teachers' efficacy information, personal teaching competence, and analysis of teaching tasks, respectively. The consequences of teacher efficacy and performance are separate from the form because collecting data regarding them is possible only when the teacher teaches. Expert views confirmed the validity of the content and the form, which includes three questions, was implemented for teachers.

Scientific Reasoning Skills Teacher Training Program (SRSTP)

According to Mizell (2010), the success of a professional development program depends on its content related to teachers' classroom problems. Therefore, the Scientific Reasoning Skills Teacher Training Program (SRSTP) was created based on teachers' need to teach SRS (Kocagul Saglam & Unal Coban, 2020). It aimed to increase teachers' awareness about SRS, which they already used without awareness, and their efficacy for promoting SRS-based instructional practices without guidance in their classrooms. In addition, SRSTP activities were organized to allow teachers to experience them as if they were students to contribute to empathy development and communication skills.

SRSTP activities were designed based on the learning principle from simple to complex. In the first part of SRSTP, "Introduction to Scientific Reasoning Skills," teachers engaged in activities to explore the claim, evidence, and reasoning and their similarities and differences. In this part, the terms claim and evidence were presented by constructing the concepts systematically before teaching the term scientific reasoning directly. In the second part, "Defining Scientific Reasoning Skills," teachers engaged in activities to define each reasoning skill independently. Activities in this part aimed to help teachers assess their students' status in each scientific reasoning skill. In the third part, "Development of Scientific Reasoning Skills," teachers experienced pedagogical methods for developing these skills by engaging in activities about three approaches to inquiry-based learning (structured, guided, and open inquiry), transforming existing activities into the inquiry by making small changes, and question types that engage students into the inquiry process. Activities in this part aimed to help teachers understand the role of scientific reasoning in the inquiry process and the interaction between inquiry-based learning, questioning, and scientific reasoning. In the fourth part, "Designing learning environment," teachers used all learning from training in a different subject matter. They visited a water treatment plant and designed an SRS-based learning environment based on the content learned there. The activities in this part aimed to contribute to teachers' awareness of factors related to designing a scientific reasoning-based learning environment. Detailed information on SRSTP activities is shown in Table 2.

Table 2

Dimensions of SRSTP and Activities

Dimensions	*Activity Name*	*Activity Purpose*
Part 1. Introduction to Scientific Reasoning Skills	Role of Evidence in a Claim	Exploring what the evidence is and which data can be used as evidence to support a claim.
	Evidence use in competing theories	Importance of evidence to determine which claim is best and the use of competing theories to develop students' reasoning skills
	Role of Reasoning in a Claim	Emphasizing what the reasoning is and the role of reasoning in making a claim more convincing.
	Similarities and differences between evidence and reasoning	Explaining the differences in the roles of both evidence and reasoning in a claim.
	Assessment of Reasoning	Exploring how teachers give feedback to students about the use of evidence and reasoning and how they guide them.

	Learn-Design-Share-I	Determining the possible difficulties of students with evidence and reasoning taught before five activities and developing an activity to overcome these difficulties.
Part 2. Defining scientific reasoning skills	Inductive reasoning	Experiencing an activity based on inductive reasoning in the context of shadows.
	Deductive reasoning	Experiencing a deductive reasoning-based activity in the context of the Bernoulli principle.
	Causal reasoning	Experiencing causal reasoning from simple to complex processes in the context of electrical circuits.
	Correlational reasoning	Experiencing correlational reasoning through drawing graphs about velocity-time and position-time.
	Control of variables strategy	Experiencing control of variables strategy in the context of factors that affect fermentation.
	Proportional reasoning	Experiencing proportional reasoning in the context of the gold rate.
	Analogical reasoning	Experiencing analogical reasoning in the context of homeostasis.
Part 3. Development of scientific reasoning skills	Assessing the "wh" questions	Analyzing investigable and non-investigable "wh" questions to engage students in the inquiry process.
	Learn-Design-Share-II	Developing "asking questions" activities to promote students inquiry and reasoning skills by strengthening learning in the previous activity.
	Three Approaches to Inquiry	Experiencing structured, guided, and open inquiry approaches and their similarities and differences.
	Adaptation of existing activities to inquiry	Exploring that there is no need to develop specific activities to engage students in inquiry and adapt an existing activity into inquiry.
Part 4. Creating a learning environment	Field trip	Experiencing the stages of the water treatment process.
	Learn-Design-Share-III	Creating and designing a learning environment based on scientific reasoning skills through learning in the previous activity.

The first part of the SRSTP activities lasted 5 hours 15 minutes, the second for 8 hours, the third for 5 hours 15 minutes and the fourth for 12 hours 15 minutes in total. The SRSTP activities included at least one method among observation, experimentation, field trips, calculation-based, game-based, art-based, group work, and modeling activities. For example, in the correlational reasoning activity, teachers read an article about "What should the walking speed be for a healthy life?" and then engaged in the activity to calculate their walking speed. In the proportional reasoning activity, teachers explored the Fibonacci sequence with a calculation-based activity and then investigated the gold rate of the Mona Lisa with an art-based activity. Finally, in the deductive reasoning activity, teachers conducted experiments to explore Bernoulli's principle and then engaged in a game-based activity to create the farthest-flying aircraft.

Setting

Before implementing SRSTP, an online application form was created and shared in teacher social media groups to determine volunteer teachers. Then, 45 teachers were selected to form a heterogeneous group regarding their gender, years of professional experience, and geographical region where they work. First, teachers completed all data collection tools as pre-tests. Then, the teachers participated in SRSTP activities for four days between 09.00-18.30 hours. Teachers worked in groups of five; however, they individually completed activity worksheets based on the Predict-Observe-Explain (POE) technique. After each activity, whole-class discussions were held on important points emphasized by the activity and how the learning from the activities could integrate into the classes. Finally, after completing all activities, teachers again completed all data collection tools as post-tests.

Data Analysis

SRSTIPST and SRSAF were independently analyzed to answer the research problem. First, the scores were checked for normal distribution to analyze the data from SRSTIPST through statistical programs. The results of the Shapiro-Wilks test showed that the scores did not normally distribute (Zpretest=.863, p=.000; Zposttest=.773, p=.000; Zpre-ir=.638, p=.000; Zpost-ir=.660, p=.000; Zpre-dr=.745, p=.000; Zpost-dr=.776, p=.000; Zpre-cr=.893, p=.001; Zpost-cr=.859, p=.000; Zpre-cor=.881, p=.000; Zpost-cor=.772, p=.000; Zpre-pr=.796, p=.000; Zpost-pr=.618, p=.000; Zpre-cov=.782, p=.000; Zpost-cov=.715, p=.000; Zpre-ar=.613, p=.000; Zpst-ar=.485, p=.000) based on the significance criteria .05 (Buyukozturk, 2012), so the Wilcoxon signed-rank test was used to test if there was a significant difference in SRSTIPST scores after the training. However, next, descriptive analysis was used for the data from SRSAF. The Claim-Evidence-Reasoning Rubric, developed by McNeill and Krajcik (2011), was adapted to Turkish by Kocagul Saglam (2019). The reliability of the adapted rubric was provided by Miles and Huberman's interrater reliability formula (1994). It was found to be 76.35% for the pre-test and 78.35% for the post-test. After that, the rubric scores were checked for normal distribution. The results showed that the total scores before and after the test had a normal distribution (Zpretest=.985, p=.814; Zposttest=.959, p=.111), while the scores of the SRSAF components did not (Zpre-claim=.911, p=.002; Zpost-claim=.903, p=.001; Zpre-evidence=.977, p=.014;. Zpost-evidence=.894, p=.001; Zpre-reasoning=.943, p=.029; Zpost-reasoning=.933, p=.012; Zpre-ir=.879, p=.000; Zpostir=.890, p=.001; Zpre-dr=.819, p=.000; Zpost-dr=.834, p=.000; Zpre-cr=.795, p=.000; Zpost-cr=.837, p=.000; Zpre-cor=.920, p=.005; Zpost-cor=.864, p=.000; Zpre-cov=.823, p=.000; Zpost-cov=.829, p=.000; Zpre-pr=.835, p=.000; Zpost-pr=.918, p=.004; Zpre-ar=.891, p=.001; Zpost-ar=.920, p=.005 Therefore, paired sample t-test was used for total pre and post-test scores, while the Wilcoxon signed-rank test was for SRSAF components. The IzI / sqrt N formula was used to calculate the effect size values for Wilcoxon signed rank test results and was interpreted as small for .10, medium for .30, and large for .50 (Corder & Foreman, 2014). After analysis, the findings of SRSTIPST and SRSAF were interpreted together.

SEPSRS and SEPSRSAF data were also independently analyzed. First, the scores were checked for normal distribution. The results showed that the scores had a normal distribution (Zpretest=.970, p=.295; Zposttest=.941,p=.124; ZpreF1=.974, p=.416; ZpostF1=.909, p=.372; ZpreF2=.958, p=.100; ZpostF2=.958, p=.102; ZpreF3=.963, p=.155; ZpostF3=.917, p=.103; ZpreF4=.973, p=.377;

ZpostF4=.920, p=.107; ZpreF5=.978, p=.551; ZpostF5=.967, p=.079; therefore, paired sample t test was used for all SEPSRS scores. Cohen's formula d was used to calculate the effect size values and was interpreted as small for .20, medium for 50, and large for .80 (Cohen, 1988). However, next, the SEPSRSAF data were analyzed via content analysis. All teachers' answers were coded first and categories were created based on these codes. Then, the frequency value of each code was calculated to interpret teachers' tendencies in their self-efficacy perceptions toward teaching scientific reasoning skills for both pre and post-test answers. After analysis, the findings of SEPSRS and SEPSRSAF were interpreted together.

Ethical Principles

The ethics committee permission for this study was obtained from the Ethics Committee of the Dokuz Eylül University Institute of Educational Sciences Directorate with the decision dated 18.05.2018 and numbered 05.

FINDINGS

SRSTIPST Findings

Wilcoxon signed-rank test results are presented in Table 3.

Table 3

Wilcoxon-signed Rank Test Results for SRSTIPST Scores

Posttest-Pretest	*N*	*Mean Rank*	*Sum of Ranks*	*Z*	*p*	*ES*
Negative rank	12	16.04	192.50	-2.936	.003**	0.44
Positive rank	28	22.41	627.50			
Ties	5					

Note. **p<.01

ES: effect size

Table 3 showed that the total scores of SRSTIPST differed significantly in support of the post-test scores (Z=-2.936; p=.003<.01) with a medium effect. For detailed analysis, the pre- and post-scores of each reasoning skill were also analyzed, and the results are presented in Table 4.

Table 4

Wilcoxon-signed Rank Test Results for Each Reasoning Skill in SRSTIPST

Reasoning Skill	*Posttest-Pretest*	*N*	*Mean Rank*	*Sum of Ranks*	*Z*	*p*	*ES*
Inductive (IR)	Negative rank	12	16.04	192.50	-2.936	.003**	0.44
	Positive rank	28	22.41	627.50			
	Ties	5					
Deductive (DR)	Negative rank	15	12.67	190.00	-.798	.425	0.12
	Positive rank	10	13.50	135.00			
	Ties	20					
Causal (CR)	Negative rank	7	12.21	85.50	-3.094	.002**	0.46
	Positive rank	23	16.50	379.50			
	Ties	15					
Correlational (CoR)	Negative rank	10	14.00	140.00	-2.576	.010*	0.38
	Positive rank	23	18.30	421.00			
	Ties	12					
Proportional (PR)	Negative rank	7	13.71	96.00	-1.890	.059	0.28
	Positive rank	18	12.72	229.00			
	Ties	20					
Analogical (AR)	Negative rank	3	6.33	19.00	-1.303	.193	0.19
	Positive rank	8	5.88	47.00			
	Ties	34					
Control of variable (CoV)	Negative rank	7	8.71	61.00	-1.130	.258	0.16
	Positive rank	11	10.00	110.00			
	Ties	27					

Note. *p<.05, **p<.01

ES: effect size

Table 4 showed significant differences with medium effects in inductive, causal, and correlational reasoning skills in support of post-test scores (Z_{CR}=-3.094; p=.002<.01; Z_{CoR}=-2.576; p=.010<.05).

SRSAF Findings

The paired sample t-test was used for pre and post-total scores, while the Wilcoxon signed-rank test was used for each component and reasoning skill score.

Table 5

Paired Sample t-Test Results for SRSAF Scores

Parameter	*M*	*SD*	*t(44)*	*p*	*Cohen's d*
Pre-test	21.42	4.69	-6.162	.000***	0.97
Post-test	26.13	5.07			

Note. ***p<.001

ES: effect size

According to Table 5, there was a significant difference between pre and post-test total scores of SRSAF in support of post-test scores (t=-6.162; p=.000<.001). The results for detailed analysis are presented in Table 6 and Table 7, respectively.

Table 6

Wilcoxon Signed-rank Test Results for SRSAF Components

Components	*Posttest-Pretest*	*N*	*Mean Rank*	*Sum of Ranks*	*Z*	*p*	*ES*
Making claim (C)	Negative rank	5	13.40	67.00	-4.123	.000***	0.61
	Positive rank	30	18.77	563.00			
	Ties	10					
Presenting evidence (E)	Negative rank	9	15.28	137.50	-4.075	.000***	0.60
	Positive rank	34	23.78	808.50			
	Ties	2					
Reasoning (R)	Negative rank	13	14.69	191.00	-3.288	.001**	0.49
	Positive rank	29	24.55	712.00			
	Ties	3					

Note. ** p<.01, ***p<.001

ES: effect size

Table 6 indicated that the pre- and post-test scores of the teachers of all components of SRSAF differed significantly in support of the post-test scores (Z_C=-4.123, p=.000<.001; Z_E=-4.075, p=.000<.001; Z_R=-3.288, p=.001<.01) with large effects in all components.

The teachers' statements in SRSAF also showed this significance. The difference between the pre- and post-test scores of each component for each teacher was calculated, and the best statements were presented to provide the best examples. For example, in making a claim component, teacher Si. Ak. *(First two letters from name and surname*) gave a wrong answer (0 points) to the deductive reasoning question in the pre-test, but he got 2 points by giving the correct answer in the post-test. Similarly, teacher Sa. Ar. gave a wrong answer (0 points) to the control of variables strategy question in the pre-test, but he could write a complete and correct claim in the post-test. In the presenting evidence component, teacher Gu. Es. provided evidence that did not support her claim (0 points) in the pre-test of the control of variables strategy question, and she provided appropriate and sufficient evidence for her claim (2 points) in the post-test. In the reasoning component, teachers tended to repeat the claim or evidence in the pre-test, but they could link the claim and evidence in the post-test. The best example of reasoning in the control of variables strategy is as follows:

Pre and post-test claim: Materials in different colors absorb different amounts of light (2 points).

Pre and post-test evidence: When equal light is exposed to the same amount of ice, the melting times for ice that has different colors are different (2 points).

Pre reasoning: Materials having different colors absorb different amounts of light (0 points, repeating the claim)

Post reasoning: Colors close to ultraviolet light have a short wavelength and more energy. Therefore, these colors can absorb more light. Because the purple box absorbs more light than other boxes, its temperature increases, and more amount of ice can melt (2 points, relating claim and evidence by using appropriate scientific principles)

Table 7

Wilcoxon Signed-rank Test Results for Each Reasoning Skill in SRSAF

Reasoning Skill	*Posttest-Pretest*	*N*	*Mean Rank*	*Sum of Ranks*	*Z*	*p*	*ES*
Inductive (IR)	Negative rank	4	20.13	80.50	-3.888	.000***	0.58
	Positive rank	31	17.73	549.50			
	Ties	10					
Deductive (DR)	Negative rank	10	14.80	148.00	-1.008	.313	0.15
	Positive rank	17	13.53	230.00			
	Ties	18					
Causal (CR)	Negative rank	8	11.06	88.50	-2.699	.007**	0.40

	Positive rank	20	15.88	317.50			
	Ties	17					
Correlational (CoR)	Negative rank	8	14.63	117.00	-3.762	.000***	0.56
	Positive rank	30	20.80	624.00			
	Ties	7					
Proportional (PR)	Negative rank	14	14.64	205.00	-1.847	.065	0.27
	Positive rank	21	20.24	425.00			
	Ties	10					
Analogical (AR)	Negative rank	12	14.29	171.50	-1.533	.125	0.23
	Positive rank	19	17.08	324.50			
	Ties	14					
Control of variable (CoV)	Negative rank	8	14.29	114.00	-3.524	.000***	0.52
	Positive rank	28	17.08	552.00			
	Ties	9					

Note. **p<.01, ***p<.001 ES: effect size

According to Table 7, the inductive, causal, and correlational reasoning skills of the teachers in addition to control of variables strategy improved significantly (Z_{IR}=-3.888, p=.000<.001; Z_{CR}=-2.699, p=.007<.01; Z_{CoR}=-3.762, p=.000<.001 and Z_{CoV}=-3.524, p=.000<.001). There was a small effect on deductive, proportional, and analogical reasoning and a medium effect on causal reasoning, while there were large effects on inductive and correlational reasoning skills in addition to the control of variables strategy.

In sum, the analysis of teachers' use of SRS indicated significant differences in teachers' pre and post-test total scores and causal and correlational reasoning scores in SRSTIPST. Although it was not significant, teachers' post-test scores for deductive reasoning skills were lower than the pre-test. The SRSAF findings supported significant developments in teachers' use of inductive, causal, and correlational reasoning skills and the control of variables strategy. Unlike the SRSTIPST findings, the SRSAF findings showed an increase, but not significant, in the deductive reasoning scores. In addition, the ways of making claims, presenting evidence, and reasoning of the teachers differed significantly. For example, teachers could justify their claim while they presented evidence of the claim example before training.

Similarly, they could associate their claim with evidence by generally using insufficient scientific principles after training. The SRSAF data verified the significant developments in teachers' use of causal and correlational reasoning skills and revealed the significant differences in other reasoning skills. In addition, they shed light on the developments in teachers' ways of making claims, presenting evidence, and reasoning. As shown in the SRSAF findings, improvement in the ways of reasoning of teachers could explain the significant differences in some specific reasoning skills.

SEPSRS Findings

The results of the paired sample t-test are presented in Table 8.

Table 8

Paired Sample t-Test Results for SEPSRS Scores

Parameter	*M*	*SD*	*t(44)*	*p*	*Cohen's d*
Pre-test	148.75	22.73	-9.543	.000***	1.48
Post-test	177.26	15.28			

Note. ***p<.001

Table 8 indicated that the total SEPSRS scores differed significantly in support of the post-test scores (t (44)=-9.543, p<.05) with a large effect. Pre and post-scores of each dimension of SEPSRS were also analyzed for detailed analysis. The results are presented in Table 9.

Table 9

Paired Sample t-Test Results for SEPSRS Dimensions

Dimensions	*Parameter*	*M.*	*SD*	*t(44)*	*p*	*Cohen's d*
Creating an SRS-based learning environment (F1)	Pre-test	39.73	5.73	-	.000**	0.97
	Post-test	44.71	4.59	6.501		
Academic proficiency (F2)	Pre-test	26.91	6.17	-	.000**	1.71
	Post-test	35.22	3.16	9.660		
Using SRS in the Classroom (F3)	Pre-test	31.35	4.64	-	.000**	1.27
	Post-test	36.31	3.05	7.294		
Assessment of SRS (F4)	Pre-test	28.60	5.76	-	.000**	1.20
	Post-test	34.64	4.24	7.850		
Instructional ways to teach SRS (F5)	Pre-test	22.15	4.41	-	.000**	1.17
	Post-test	26.37	2.67	7.583		

Note.***p<.001

Table 9 showed that there were significant differences with large effects in all dimensions of SEPSRS dimensions (t_{F1}(44)=-6.501, p=.000<.001; t_{F2}(44)=-9.660, p=.000<.001; t_{F3} (44)=-7.294, p=.000<.001; t_{F4} (44)=-7.850, p=.000<.001, and t_{F5}(44)=-7.583, p=.000<.001).

SEPSRSAF Findings

To compare the results, Tables 10, 11, and 12 presented the pre-and post-test findings for each question.

Table 10

Teachers' Efficacy Sources

Before SRSTP				*After SRSTP*			
Category	*Cod*	*f*	*f%*	*Category*	*Cod*	*f*	*f%*
Vicarious experience	Undergraduate courses	5	11.11	Mastery experience	Learning by doing and living	8	11.9
	Graduate courses	3	6.67		Experiencing conducting a sample lesson	8	11.9
	Seminars, etc.	4	8.89		Introducing each reasoning skill independently	9	13.4
	Social media / Internet	4	8.89		The high number of activities	3	4.4
	Books	3	6.67	Vicarious experience	Discussion sessions held after each activity	4	5.9
Mastery experience	Professional experience	7	15.55		Gaining knowledge about SRS	18	26.9
Other	No answer	19	42.22	Verbal persuasion	Emphasis on the relationship between curriculum and SRS	1	1.5
					Emphasis on the roles of teachers and students	6	8.9
				Psychological/ emotional arousal	Aware that he/she has already taught based on SRS	6	8.9
				Other	No answer	4	5.9

Most teachers (42.23%) pointed out vicarious experiences as the source of existing SRS knowledge before SRSTP, while they mainly benefited from SRSTP through mastery experiences (41.6%) and vicarious experiences (32.8%).

According to Table 11, teachers tended to consider the factors related to them mostly after SRSTP, while they considered student-related factors (32.7%) the most influential factor before training. Furthermore, 72.6% of them considered instructional factors, which only 22.1% of teachers considered before training, the most important factor after SRSTP.

Table 11

Teachers' Instructional Task Analysis

Before SRSTP				*After SRSTP*			
Category	*Cod*	*f*	*f%*	*Category*	*Cod*	*f*	*f%*
Student-related factors	Individual differences	10	13.1	Instructional factors	Asking investigable questions	15	14.4
	Developmental characteristics	10	13.1		Integration of technology	6	5.8
	Content knowledge	3	3.9		Use of analogies	2	1.9
	Knowledge about technology	2	2.6		Emphasis on the relationship between science and daily life	1	0.9
Academic proficiency	Content knowledge	3	3.9		Multisensory instruction	2	1.9
	Pedagogical knowledge	6	7.8		Group work	2	1.9
	Knowledge of science process skills	2	2.6		Inquiry-based learning	7	6.7
	Experimentation skills	2	2.6		Conducting experiments	3	2.8
Environmental factors	Socio-economic factors	11	14.4		Discussion sessions	1	0.9
	Physical status of the classroom	7	9.2		Justifying knowledge	4	3.8
	Attitudes of the school administrator	1	1.3		Teaching claim-evidence-reasoning terms	7	6.7
Instructional factors	Asking questions/inquiries	6	7.8		Teacher's content knowledge	1	0.9
	Use of technology	1	1.3		Behaviors of teachers to promote SRS	20	19.2
	Interdisciplinary teaching	1	1.3		Presentation of clear instructions to students.	5	4.8
	Problem-solving	1	1.3	Student	Readiness	13	12.5

	Making observations	1	1.3		Developmental level	1	0.9
	Allowing students to be active	3	3.9		Demographical characteristics	3	2.8
	Associating science with daily life	2	2.6		Misconceptions	1	0.9
	Expressing thinking freely	2	2.6		Motivation	8	7.7
	No answer	1	1.3	Other	No answer	21	46.7
Other	No knowledge	1	1.3				

According to Table 12, 22.75% of the teachers felt adequate for teaching SRS, needed development in instructional design (26.31%), and personal factors (43.85%) to feel adequate for teaching SRS before training. However, after training, they stated that SRSTP changed their perceptions about instructional design (64%) and personal factors (36%).

Table 12

Assessment of Personal Teaching Skills of Teachers

Before SRSTP				*After SRSTP*			
Category	*Cod*	*f*	*f%*	*Category*	*Cod*	*f*	*f%*
Instructional design	Promoting students to be an inquirer	3	5.26	Instructional design	Designing an inquiry-based learning environment	13	26
	Active students	2	3.51		Using appropriate Wh questions to promote SRS?	12	24
	Transferring learning	2	3.51		Using analogies	1	2
	Promoting the use of the scientific method	2	3.51		Creating SRS-based activities	6	12
	Asking questions to promote thinking	2	3.51	Personal factors	Showing empathy toward students	2	4
	Designing an SRS-promoted learning environment	4	7.01		Providing guidance	2	4
Personal factors	Gaining SRS	18	31.58		Classroom behaviors to promote SRS	5	10
	Training needs for TPACK[a]	2	3.51		Increased level of SRS knowledge	9	18
	Taking into account individual differences.	1	1.75				
	Guide students	1	1.75				

Other	Problem-solving skills	1	1.75
	Use of technology	2	3.51
	Enough materials and equipment	1	1.75
	No answer	3	5.26

In summary, teachers expressed that their efficacy sources were primarily based on indirect experiences, and only 17.5% of teachers' efficacy sources were based on active experiences. However, after training, the teachers stated that their sources of efficacy were based on active experiences due to SRSTP activities. To support this, teachers rated themselves as having high efficacy in the SEPSRS items on developing students' reasoning skills, knowing about SRS, and coping with problems faced during SRS teaching. Therefore, the finding that reported sources of teacher efficacy that evolved strongly into active experiences could explain and confirm the significant development in the dimension of academic proficiency of SEPSRS.

Before training, teachers determined student-related factors as the most influential factor in developing students' SRS; however, after training, this view evolved into instructional factors. This finding could explain and confirm the significant differences in creating an SRS-based learning environment and using SRS in the SEPSRS classroom dimensions.

Although 77.25% of teachers felt inadequate to teach SRS before training, all teachers gained efficacy in instructional design and personal factors to promote these skills. This finding could also explain and confirm significant developments in instructional ways to teach SRS and the dimensions of academic proficiency of SEPSRS.

DISCUSSION

This study aimed to improve the SRS of science teachers in the use and teaching of these skills. In this context, teachers participated in the SRSTP. Data on their use of SRS and self-efficacy perceptions toward teaching these skills were collected qualitatively and quantitatively for detailed analysis and interpretation.

Findings related to teachers' use of SRS showed significant differences in SRSTIPST total scores, especially in correlational and causal reasoning skills. Additionally, there were significant differences in the total SRSAF scores, especially in the inductive, causal, and correlational reasoning skills, in addition to the control of variables strategy. Some studies indicated that training and transfer could improve scientific reasoning skills (Adey & Shayer, 1994; Chen & Klahr, 1999). Therefore, the improvements in specific reasoning skills may stem from the second part activities of SRSTP. In this part, each scientific reasoning skill was introduced to the teachers and whole-group discussions were held about how each reasoning skill could be developed. For example, teachers engaged in deductive reasoning through a Bernoulli principle activity. In the activity, the teachers made Bernoulli principle experiments first, and then they played a game about the farthest flying aircraft using deductive reasoning skills. Teachers can transfer their learning by answering the questions in data collection tools. This obtained finding was supported by other studies that reported that scientific reasoning skills could be developed and improved through instructional practices (Piraksa et al., 2014; Vass et al., 2000).

The first finding pointed out an interesting thing. Although each scientific reasoning skill was introduced to teachers, only inductive, causal, correlational reasoning skills, and control of variables strategy were found to be improved significantly. This may be due to the commonality of the processes among these reasoning skills. According to Gopnik et al. (2004), knowing causality allows people to predict future events and facilitates understanding the outcome of an event. Based on this, knowing causality or understanding causal reasoning may affect the development of inductive and correlational reasoning skills in addition to the control of variables strategy. Other studies supported that knowing causality affected inductive reasoning skills (Hayes & Thompson, 2007; Opfer & Bulloch, 2007). A similar statement can be used for the control of variables strategy. According to Zimmerman (2005), defining and isolating causal relations is the heart of understanding the control of variables strategy. Although correlation and causation differ, knowing causality implies knowing correlation because causation may occur between correlated variables. The Harrington study (2019) showed that intervention in causality could improve the understanding of causal relationships. On the basis of this, learning causal reasoning may affect the improvement of correlational reasoning.

The second finding was that teachers performed better in making claims, presenting evidence, and describing the reasoning components in SRSAF. Before training, the teachers presented evidence as an example of the claim. This finding may stem from insufficient classroom discussions not focused on experiments' results or on data that could be used as evidence, as Jimenez Aleixandre et al. (2000) said. Similarly, Schimek (2012) reported that students from all grade levels could not use scientific evidence or know-how data could be used as evidence. Furthermore, before training, the reasoning of teachers was based on repeating the claim or evidence. This finding was also a common problem reported in SRS studies (Abdelkareem, 2008; Bell & Linn, 2000; Ibrahim et al., 2016; Lindahl & Lundin, 2016). However, after training, teachers could present the appropriate evidence for the claim and justify their evidence using appropriate but insufficient scientific principles. This finding may stem from the first part activities of SRSTP. In these activities, teachers learned the claim, evidence, and reasoning, their differences and similarities, and the roles of reasoning and evidence in a claim. The obtained finding followed Loch's (2017) study, which reported that the Claim-evidence-reasoning framework promoted students' use of evidence and reasoning in their claims but had no effect on using scientific principles in their reasoning. Furthermore, according to the National Academies of Sciences, Engineering, and Medicine (2018), gaining knowledge through experience facilitates new and related knowledge gain. Therefore, the learnings from the first part of SRSTP can lead to significant differences in the SRSTIPST and SRSAF scores.

Related to the other important finding, Vass et al. (2000) stated that proportional reasoning skills cause developments in correlational reasoning skills. However, although there were significant differences in causal, correlational reasoning, and the control of variables strategy, no significant differences were found in proportional reasoning skills. Therefore, an inconsistency between the two studies occurred.

Another important finding was related to deductive reasoning skills. Although the SRSTIPST findings showed a decrease in the post-test scores for deductive reasoning, the SRSAF findings showed developments in this skill. This inconsistency may be due to the type of data collection tool. SRSTIPST includes long multiple-choice questions, while SRSAF includes short answers. Teachers may struggle with the length of the questions. This finding is supported by other studies that reported difficulties using SRS (Park & Han, 2002; Wooley et al., 2018). These studies informed that when using deductive reasoning, individuals could not read premises carefully in multiple-choice questions and could try to answer questions based on their beliefs and knowledge, not on premises. One of these reasons may be related to deductive reasoning questions.

SEPSRS findings showed that teachers' total post-test scores were significantly higher than total pre-test scores. Additionally, post-test scores of SEPSRS dimensions also differed significantly from the pre-test scores. The SEPSRSAF findings supported these findings. Teachers stated that mainly vicarious experiences (42.23%) caused their efficacy in teaching SRS before training; however, their sources of efficacy consisted of mastery experiences (41.6%). In SRSTP, teachers first experienced introductory claims-evidence-reasoning activities. Then, each reasoning skill identification, instructional ways, and promoting questions for teaching SRS, and finally, they designed a sample lesson at the end of the training. Teachers engaged in all activities by living and doing and worked collaboratively with other teachers. Researchers said that gaining mastery experiences is the strongest source of self-efficacy beliefs (Bandura, 1977; Brand & Wilkins, 2007). Therefore, the finding that the sources of efficacy reported from teachers consisted mainly of mastery experiences may be the reason for another finding that, while a percentage of 77.25 of teachers said they felt inadequate before training, all stated that they had efficacy for teaching SRS after training. Koponen et al. (2021) also concluded that explicit support of mastery experiences and social persuasion were positively associated with self-efficacy perception.

Another finding was that teachers considered student-related factors mostly for teaching SRS before training. In contrast, the most considered factor was instructional factors, such as asking investigable questions or teacher behaviors, after the training. In other words, the factors considered by teachers in teaching SRS evolved into self-related factors. This may be due to an increase in their knowledge of SRS. Before training, teachers explained that they learned a lot about scientific reasoning skills through vicarious experiences, while nearly half knew nothing about them. Teachers with little or no knowledge might perceive student-related factors, such as developmental level or readiness, and differences, as obstacles to teaching SRS. However, after training, teachers who gained knowledge and efficacy in teaching SRS may think that they can develop students' reasoning skills through well-designed instruction. Other studies reported the effect of instruction on improving SRS (Bezci & Sungur, 2021; Kocagul & Unal Coban, 2022; Yanto et al., 2019).

Conclusion

This study aimed to improve the SRS of science teachers in using and teaching these skills through SRSTP. This study proved that:

- SRSTP is an effective training program to develop teacher knowledge and efficacy in teaching SRS.
- SRSTP allows teachers to improve their use of SRS, especially in causal, correlational, inductive, and deductive reasoning skills and control of variables strategy.
- SRSTP can improve the way teachers make claims, present evidence, and reason.
- SRSTP can develop teacher self-efficacy perceptions toward teaching SRS.

The results obtained have some implications. The most important value of this study is to present an original training program on teaching scientific reasoning skills. In this way, other researchers will be informed about a new teacher training program to improve the status of scientific reasoning skills. Furthermore, the detailed information about SRSTP presented in this study will help other researchers implement the training program in their countries. This may improve students' scientific reasoning skills worldwide and provide authentic evidence of SRSTP effectiveness. This study also presents a solution to the problem of "not coordinating theory with evidence" that is reported mostly in studies related to scientific reasoning skills. Because teachers could perform better at making claims, presenting evidence, and reasoning when proposing scientific explanations after the SRSTP. Another contribution of this study was the data collection tools. They are all original and can provide rich data. Other researchers should also use these data collection tools.

Recommendations

This study showed that SRSTP was effective in most of the reasoning skills. Therefore, SRSTP may be included at the beginning and end of teachers' seminars to provide more teachers with experience in this training program. In addition, investigable questioning, three inquiry approaches, and adaptation of existing activities to inquiry activities were included in SRSTP. However, it was observed that most teachers still needed a solid understanding of inquiry and argumentation, although curriculums emphasized these instructional ways. Therefore, more teacher training programs focused on inquiry-based learning may be held.

It was also found that SRSTP improved teachers' ability to make claims, present evidence, and reason. Therefore, teachers should engage them in discussion after conducting experiments on how and which data can be used as evidence, comparing groups' results and possible differences between them to develop students' claim-evidence-reasoning skills.

This study considered teachers' use of SRS and their perceptions of self-efficacy towards teaching SRS. Other researchers may test the effect of SRSTP activities on other variables.

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Author Contributions

All authors contributed equally to the manuscript.

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