# A CASE STUDY FOR EVALUATING SCIENTIFIC REASONING SKILLS TRAINING PROGRAM[1]

# AKIL YÜRÜTME BECERİLERİ EĞİTİM PROGRAMININ DEĞERLENDİRİLMESİNE YÖNELİK BİR DURUM ÇALIŞMASI

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*Araştırma Makalesi*

**Abstract:** Current educational reforms consider scientific reasoning skills as significant to engage students into generate scientific explanations. The primary aim of this study is to evaluate the effectiveness of a teacher-training program, which is based on gaining knowledge, instructional strategies and skills for science teachers to promote students' scientific reasoning skills. The participants of this research, which was in holistic single case study design, were an in-service science teacher who had attended to Scientific Reasoning Skills Training Program (SRSTP) and his thirty-two 5th grade students. Teaching Scientific Reasoning Skills Observation Form (TSROF), and Force and Motion Scientific Reasoning Skills Test (FMSRT) were used as data collection tools. Results indicated that the trained teacher showed success at the rate of maximum %61,06 of observed phenomena with %47,76 of them in behaviors dimension and the students showed significant developments both in total score of FMSRT and especially in inductive, deductive, causal, analogical reasoning skills and control of variables strategy.

Keywords: *Scientific reasoning, professional development program, reasoning skills test, reasoning skills observation*

**Özet:** Güncel eğitim reformları, öğrencilerin bilimsel açıklamalar üretebilme sürecine dâhil olmalarında akıl yürütme becerilerini önemli görmektedir. Bu çalışmanın temel amacı, öğrencilerin akıl yürütme becerilerini teşvik etmek için bilgi kazanımı, öğretimsel stratejiler ve becerilere dayalı bir öğretmen eğitimi programının etkililiğini değerlendirmektir. Bütüncül tekli durum çalışmasına dayalı yürütülen çalışmanın katılımcıları, Akıl Yürütme Becerileri Eğitimi Programına (AYBEP) katılan bir fen bilimleri öğretmeni ve onun 32 beşinci sınıf öğrencisidir. Akıl Yürütme Becerileri Öğretimi Gözlem Formu (AYBÖGF) ve Kuvvet ve Hareket Akıl Yürütme Becerileri Testi (KUHAYBET) veri toplama araçları olarak kullanılmıştır. Çalışmadan elde edilen sonuçlar, eğitim alan öğretmenin gözlenen olgulardan %47,76'sı davranış boyutunda olmak üzere maksimum %61,06'sını başarabildiğini ve öğrencilerin hem KUHAYBET toplam puanlarında hem de özellikle tümevarımsal, tümdengelimsel, nedensel ve analojik akıl yürütme becerileriyle değişkenlerin kontrolü stratejisinde anlamlı gelişmeler olduğunu göstermiştir.

Anahtar Kelimeler: *Akıl yürütme, mesleki gelişim programı, akıl yürütme becerileri testi, akıl yürütme becerileri gözlemi*

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## Introduction

People wonder about questions like "Is there a possibility of living on another planet?, Can a less-damaging treatment be found for cancer? or Which covid-19 vaccine do we prefer?" and so on. In order to cope with such questions, societies need individuals having next-generation science standards (National Research Council [NRC], 2012). These standards aim to ensure individuals to have the skills such as asking scientific questions, developing and using scientific models, planning and conducting scientific investigations, analyzing and interpreting data, constructing scientific explanations and finding solutions to problems, making arguments from evidence, obtaining, evaluating and communicating the information in four basic disciplinary. Parallel to this, countries make curriculum reforms to have students gain these skills required to construct knowledge effectively. Therefore for decades, educational researches have focused on developing students' "nature of science understandings" (Bilican, Tekkaya & Çakıroğlu., 2012; Hacıeminoglu, 2014; Sangsa-ard, Thathong & Chapoo, 2014; Schiefer, Golle, Tibus, Trautwein & Oschatz, 2017), "argumentation skills" (Çetin, Kutluca & Kaya, 2013; Larrain, Moreno, Grau, Freire, Salvat, Lopez & Silva, 2017; Mason & Scirica, 2006), "inquiry skills" (Gobert, Kim, Sao Pedro, Kennedy & Betts, 2015; Wang, Guo & Jou, 2015), "thinking skills" (Thaiposri & Wannapiroon, 2015; Vong & Kaewurai, 2017), "metacognitive skills" (Tanner, 2012; Yabas & Altun, 2009; Yildiz & Ergin, 2007), "problem solving skills" (Bunterm, Wattanathom, Vangpoomyai & Muchimapura, 2012; Tok & Sevinc, 2010) and so on. Scientific reasoning skills, which are the main topic of this research, are closely related to the skills mentioned above.

### Definition of Scientific Reasoning

Although there seems to be no consensus about the definition of scientific reasoning skills (SRS), most researchers have defined them as skills used in the inquiry process (Han, 2013; Kuhn, 2002; Lawson, 2004; Zimmerman, 2000). The reason for this is that while a person is in inquiry process, he/she also uses scientific reasoning skills. For example, when a person wants to solve a problem, he/she determines some probable solutions by using hypothetical-deductive reasoning skills and chooses one of them to test. Then, he/she makes observations related to problem, determines the variables that may affect the problem and related to problem, designs experiments and collects data. In this process, while conducting an experiment kinesthetically correspondences to science process skills, inferring causal relationships mentally about which variable should be dependent or independent correspondences to scientific reasoning skills (Chen & Klahr, 1999). After that, he/she uses causal or correlational reasoning skills to determine the pattern of data or to infer the cause-effect relationships between variables and then draw a tentative conclusion from data patterns by using inductive, deductive or causal reasoning skills. Similar to controlling variables skills, while drawing conclusion correspondences to science process skills, mental activities about drawing conclusion correspondences to scientific reasoning skills. After reaching the conclusion, if he/she still needs to know something new about the problem, again he/she engages with the cycle, which starts with formulating hypotheses and ends with drawing tentative conclusion by using science process skills and scientific reasoning skills. Hence, Benford (2001) stated that teachers having high scientific reasoning skills could design more effective inquiry based learning environments for students. This result has clearly showed the function of scientific reasoning skills in inquiry process. Therefore, researchers have presented common opinions that scientific reasoning skills include control of variables, deductive and inductive reasoning, causal and correlational reasoning, proportional and probabilistic reasoning (Lawson, 1978; Zimmerman, 2000).

According to Klahr and Dunbar (1988), scientific reasoning skills are seen as problem-solving approach. Students propose hypotheses based on prior knowledge or observation data and then conduct experiments to test their hypotheses and finally evaluate evidences and construct scientific knowledge. From this perspective, SRS contribute to both meaningful conceptualization and process skills.

**Researches about Scientific Reasoning Skills**

This study addresses the effect of a professional development program on students' scientific reasoning skills development. Many researchers reported students' status and the difficulties they had about SRS. For example, Sadler et al. (2004) stated that only %10 of high school students gave a correct and complete explanation about how data could be used in an argument. Similarly, there were also other studies reported that students were naive in generating explanations from collected data (Gyllenpalm, Rundgren, Lederman & Lederman, 2021; Penn, Ramnarain, Kazei, Dhurumraj, Mavuru & Ramaila, 2021; Schimek, 2012) and in conducting multiple designs (Kuhn, 2007; Penn et al., 2021; Piraksa, Srisawasdi & Koul, 2014; Rind & Ning, 2020). In another study, Erlina, Susantini and Wasis (2018) explained the reasons for students' difficulties in proportional, probabilistic, correlational and hypo-deductive reasoning and control of variables strategy.

According to them, students could not use mathematical computing in comparative situations in the context of proportional reasoning and they tended to consider same assumptions for different situations in the context of probabilistic reasoning. They could not also define the variables operationally and identify dependent and independent variable in the context of control of variables strategy. Further, they could not generate an argument including a logical relationship when using correlational reasoning and associate solutions with concepts in hypo-deductive reasoning.

Studies about students' SRS point out the need for other studies to improve the skills. Leach (1999) emphasized the importance of learning environments where teachers use and model scientific reasoning skills. However, teachers as designers of learning environments had deficiencies and inadequacies in scientific reasoning skills. Geist (2004) reported that although teachers were successful in performing some inquiry learning characteristics, they could not assess the explanations and coordinate theory with evidence. Findings from other studies showed that teacher did not have the understanding of evidence role (Beyer & Davis, 2008) and the knowledge about SRS and designing learning environment based on these skills (Kocagül Sağlam & Ünal Çoban, 2020; Smit, Gijsel, Hotze & Bakker, 2018), they had difficulties in including data and reasoning for supporting claims (McNeill & Knight, 2013; Sampson & Blanchard, 2012), controlling all variables (Boudreaux, Shaffer, Heron & McDermott, 2008; Hilfert Rüppell, Loob, Klingenberg, Eghtessad, Höner, Müller, Strahl & Pietzner, 2013) and coordinating theory and evidence (Kang, Orgill & Crippen, 2008).

Teachers and students cannot be thought separately from each other in learning process. Students' needs for what and how to learn shape teachers' learning needs. Therefore, the first step should be to provide teachers' development in SRS to improve students' reasoning skills. Hogan, Nastasi and Pressley (1999) specified those whole class discussions guided by the teacher who promotes scientific reasoning skills could contribute to development of students' scientific reasoning skills and quality discussions. Similar to this, Gillies (2011) gave a training focused on scientific reasoning, problem solving and questions that promote thinking to teachers and at the end of this training, it was found that teachers could use questions that promote scientific reasoning and metacognition and their students could use these types of questions when talking each other. In another study, training about bioethics cases was given to teachers and it was found that trained teachers' students gained significantly important achievements about subject knowledge, analyzing socio-scientific issues, awareness for ethic subjects, discussing different views and understandings about science and society (Chowning, Griswold, Kovarik & Collins, 2012).

**Purpose of the Present Study**

In detailed literature analysis, studies that aim to develop students' reasoning skills with the help of teacher training programs were heavily on dialogical-pedagogical approach mostly (Sedova, Sedlacek & Svaricek, 2016; Smit et al., 2018; Tadesse, Kind, Alemu, Atnafu & Michael, 2017), changes in preferred instructional methods (Alonzo & Kim, 2018; Gillies, 2011; Stammen, Malone & Irving, 2018) and teachers' growth in scientific literacy (Koenig, Schen & Bao, 2012; Laius & Rannikmae, 2011). Our current study also aims to evaluate the effectiveness of a professional development program entitled Scientific Reasoning Skills Training Program (SRSTP). Results from SRSTP indicated that it was effective on teachers' knowledge about scientific reasoning skills and their self-efficacy perceptions towards teaching them (Kocagül Sağlam, 2019). Further, depending on other studies' results, it was thought that classroom observation is the best method to assess a training program authentically. Through present study, it was aimed to assess SRSTP, which focused on seven scientific reasoning skills (inductive, deductive, causal, correlational, proportional and analogical reasoning skills and control of variables strategy) used in inquiry process, by observing trained teacher and testing his students' developments in scientific reasoning skills.

In this context, the following research questions were addressed:

1. To what extent did trained teacher reflect his learnings about scientific reasoning skills in the classroom?
2. Did instructional practices implemented by trained teacher develop students' scientific reasoning skills?

## Method

This study is about the second part of a professional development program aimed at promoting students' SRS through their science teacher's training. In this context, this study was on case study design. According to Karagöz (2017), case studies are based on examining in detail for testing a theory or answering how, why and what questions about original or extreme cases. The study was on holistic single case study design because it was aimed to describe how trained teacher teaches SRS in his classroom in detail through teacher observation and quantitative data obtained from students (Yin, 2003).

**Program Description**

Scientific Reasoning Skills Training Program (SRSTP) was developed based on teachers' needs for teaching scientific reasoning skills, which researchers commonly agreed on (Kocagül Sağlam & Ünal Çoban, 2020). We eliminated probabilistic reasoning skill from SRSTP due to the lack of science lesson learning outcomes in Turkish Science Lesson Curriculum (Ministry of National Education [MoNE], 2018) related to this reasoning skill and we included analogical reasoning skill into SRSTP due to its role in scientific inquiry such as justifying a hypothesis or a model (Sullivan Clarke, 2015). We taught these reasoning skills (deductive and inductive reasoning, causal and correlational reasoning, proportional and analogical reasoning and control of variables strategy) clearly, directly and explicitly in the context of SRSTP. Further, rather than using only one instructional technique and focusing on only one subject knowledge for teaching SRS, we used various subjects like electricity, laminar flow, Bernoulli principle, fossils etc. and instructional techniques such as modelling, field trip, game and art-based activities, experimentations, computational practices and cooperative group working based activities.

Whole training lasted for 4 days. In the first day, teachers engaged into "Introduction to scientific reasoning" activities which include activities about what the claim, evidence, reasoning are, how they relate to each other, similarities and differences between evidence and reasoning, roles of competing theories in reasoning and ways for assessing reasoning in classroom. In the second day, teachers engaged into "Identification of scientific reasoning skills" activities, which include activities focused on each reasoning skill (inductive, deductive, causal, correlational, proportional, analogical reasoning skills and control of variables strategy) and how this specific reasoning skill can be developed in classes. In the third day, teachers engaged into "Development of scientific reasoning skills" activities which include activities about asking open-ended, investigable question and three approaches of inquiry-based learning to promote SRS. Finally, in the fourth day, teachers engaged into "Designing learning environment" activities that include activities about designing SRS based learning environment. The first part of SRSTP lasted for nearly 5 hours 15 minutes, the second part for 8 hours, the third part for 5 hours 15 minutes and finally the fourth part for 12 hours 15 minutes respectively.

Nearly 18 discussion sessions (after each activity) focused on "what can we do to implement this in our classes?, what may possible problems be in terms of students and us?, how can we deal with these problems?" were held during SRSTP.

**Participants**

The participants of the research were a science teacher determined via purposive sampling, which is one of non-probabilistic sampling techniques (Fraenkel & Wallen, 2008) and his 5th grade students. Purposive sampling was preferred because the teacher to be observed must have attended to SRSTP and should be volunteer to continue the research.

Participant teacher was a science teacher working at state middle school in one of center districts of Izmir, Turkey and he had professional experience of 6-10 years. Participant students (16 female and 15 male), studying at 5th grade and attending to science and also science practices lessons of the participant teacher, were nearly 10-11 years old.

**Data Collection Tools**

**Teaching Scientific Reasoning Skills Observation Form (TSROF):** Kocagül Sağlam (2019) developed TSROF to guide observation of learning environment based on SRS. The observation form has three dimensions entitled "teacher behaviors", "teaching and learning" and "assessment" and twenty-four behaviors to be observed totally. Observation form is semi-structured due to the inclusion of sign system from quantitative methods (Wragg, 1993) and critical events technique from qualitative methods (Wragg, 1999). Expert opinions from one professor from science education department and two professors from physics education department provided content validity of the form. Reliability of the form was provided through observing teachers' presentations, each of which lasted 15-20 minutes, about designing learning environment based on SRS in the last part of SRSTP by three independent trainers. At the end of each presentation, Cochran Q test provided evidence for the inter-observer agreement. There are agreements for five out of nine groups between observers ($p1=0,273>.05$; $p2=0,407>.05$; $p3=0,071>.05$; $p4=0,174>.05$; $p5=0,735>.05$). For four groups, it was seen that observers except one gave similar points (p6=0,028<.05; p7=0,001<.05; p8=0,012<.05; p9=0,001<.05). When discussing the reason for that, observers agreed on limited time for group presentations and tiredness of observers. However, agreement on five of nine groups (%55,6) created evidence for the reliability of observation form.

**Force and motion scientific reasoning skills test (FMSRT).** Kocagül Sağlam (2019) developed the test in order to determine students' usage of scientific reasoning skills (inductive, deductive, causal, correlational, analogical, proportional reasoning and control of variables strategy) in the context of Force and Motion Unit. While content validity of test was provided by expert opinions and construct validity of test was provided by both tetrachoric correlation based factor analysis, comparing high and low groups' mean scores and item analysis. Results indicated that FMSRT had 17 items with average difficulty (p=0,560) and high discrimination index (rjx= 0,588) under one factor. KR-20 reliability coefficient of test was .812. Final version of the matrix of unit gains and reasoning skills was shaped as Table 1.

Table 1

*The Matrix of Force and Motion Unit Gains and Scientific Reasoning Skills*

| Unit Gains | IR | DR | CR | CoR | PR | AR | CoV |
|---|---|---|---|---|---|---|---|
| Measures the quantity of force by using a dynamometer. | Item 7 | Item 8 | | Item 6 | Item 4 | | |
| Designs a simple dynamometer by using ordinary tools. | Item 12 | | | | | | Item 13 |
| Gives examples for friction force from daily life. | | Item 10 | Item 11 | | | | |
| Explores the effect of friction force on movement in various surfaces by experimenting. | Item 1 | Item 3 | | | Item 14 | Item 17 | Item 9 |
| Produces new ideas to minimize and maximize the friction force in daily life. | | Item 16 | Item 2 | Item 5 | | | Item 15 |

*Note.* IR=inductive reasoning; DR= deductive reasoning; CR= causal reasoning; CoR= correlational reasoning; PR= proportional reasoning; AR=analogical reasoning; CoV= control of variables strategy

## Data Collection Process

The study was in holistic single case study design because we intended to describe how trained teacher teaches SRS in his classroom in detail through teacher observation and students' quantitative data (Yin, 2003).

After the completion of SRSTP, we informed all teachers about following "class practice" and determined one volunteer teacher. Volunteer teacher is still working at middle school in one of central districts of Izmir, Turkey and has 6-10 years' professional experience. He was teaching "Science" and "Science Practices" to fifth graders in the time of class observation.

The aim of class practice was to determine by observing how trained teacher reflected his learning from SRSTP and how much he was successful at teaching SRS to his students and the effectiveness of SRSTP by measuring the developments of students' SRS. Observation process started four months later from the end of SRSTP. First author who was also the trainer of SRSTP and two pre-service science teachers who were given training about SRS conducted observation process. Totally 21 lessons were observed but in one of these lessons, a participant student asked a question about genes that was out of context and so, this lesson was excluded from analysis. In all 20 lessons, ten of them were observed only by the first author, three of them by the first author and Observer 1 and seven of them by the first author, Observer 1 and Observer 2. Each observed behavior was scored as 1 and unobserved as 0. Reliability of observation process was provided by calculating coherence between observers with Cochran Q test. Results showed that there was % 80 agreement between the first author and Observer 1. The reason of inconsistency between observers was discussed and thought that this might be stemmed from making faulty observation due to Observer 1's simple health problems. It was also found that there was %57,14 agreement (4 of 7 lessons) between the first author, Observer 1 and Observer 2; %57,14 agreement between the first author and Observer 2 and %100 agreement between Observer 1 and Observer 2. The reason of inconsistency between observers was also discussed and found that two of observers gave close points and other observer gave lower points from them. It was thought that this might be stemmed from observers' personal error sources such as tiredness etc. However, it can be said that observation process was reliable finally.

**Data Analysis**

In order to answer the first research problem "To what extent did trained teacher reflect his learnings about scientific reasoning skills in the classroom?", teacher were scored as 1 or 0 for each observed item in TSROF. Then, total TSROF scores were calculated for each lesson and quantitative data were analyzed by using descriptive statistics. For this, mean scores of each lesson and teacher's success percentage about each observed lesson were calculated. Although TSRSOF had qualitative part, any qualitative data were not obtained. Because, no critical events occurred in observation process.

In order to answer the second research question "Did instructional practices implemented by trained teacher develop students' scientific reasoning skills?", data obtained from FMSRT were analyzed by using statistical programs. Students got 1 point for each correct answer and 0 for each blank or wrong answer. Then, total scores for each scientific reasoning skill were calculated and tested for normal distribution. Parametric tests were conducted for scores having normal distribution while non-parametric tests for other scores.

## Results

In order to answer the first research problem "To what extent did trained teacher reflect his learnings about scientific reasoning skills in the classroom?, we analyzed teacher's success percentage for teaching SRS. Obtained findings were presented at Figure 1.

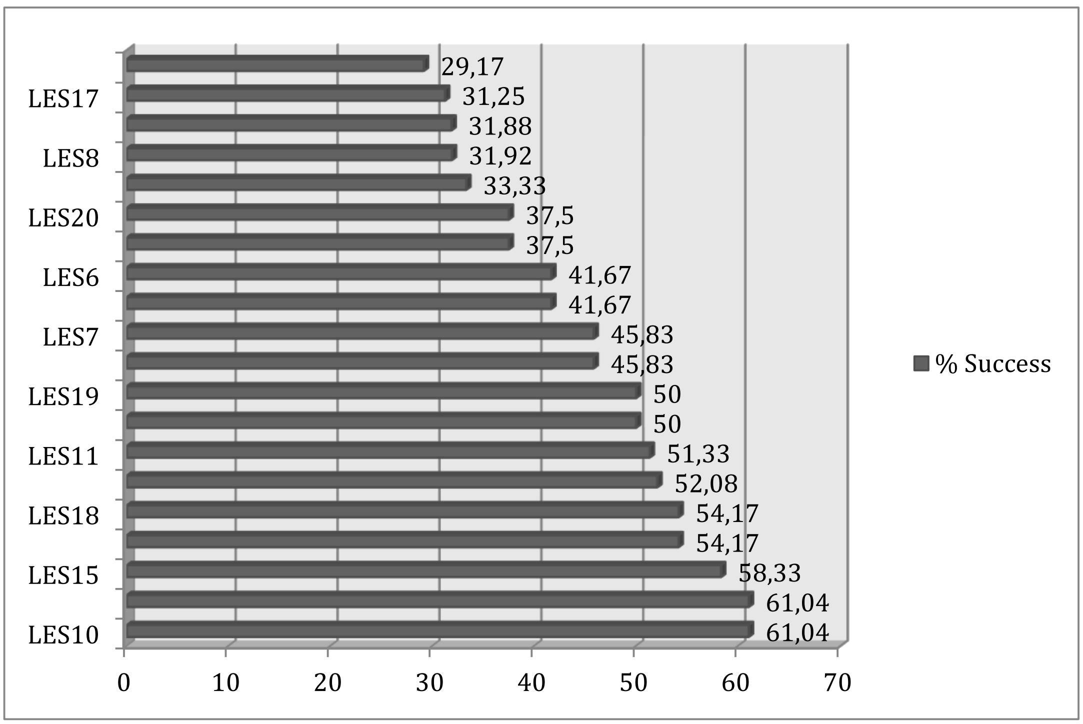


*Figure 1*. Trained teacher's success rate for teaching scientific reasoning skills
*Note.* x-axis shows the success percentage and y-axis shows the observed lessons

As seen in Figure 1, trained science teacher performed minimum %29,17 and maximum %61,04 of behaviors in TSROF. When evaluating total scores of TSROF, it was seen that teacher had minimum success percentages in lesson 2, 9 and 17 and maximum success percentages in lesson 10, 12 and 15.

During the lessons with minimum success percentage (lesson 2, lesson 9 and lesson 17), teacher had conducted some activities instead of teaching content knowledge of unit. For example, in lesson 8, teacher got his students to watch a documentary about Isaac Newton's life and his studies. In lesson 18, teacher answered students' exam questions. In this lesson, researcher noted that some exam questions were at knowledge level but some of them were for assessing inductive, deductive and proportional reasoning skills. Finally, in lesson 2, teacher acted in a way that limits students' scientific reasoning skills such as showing no tolerance to students' explanations and not encouraging students to explain their thinking etc. Further, in maximum success percentage lessons (lesson 10, lesson 12 and lesson 15), teacher conducted activities related to teaching and assessing learning gains of Force and Motion unit. For example, in lesson 15, teacher asked open-ended questions about friction force such as "if no one continues to rock a child on the swing, what is the reason of stopping swing after a while?" or "what is the reason of leaning their head forward for bike racers when riding?" etc. These questions were answered through justification during whole class discussion. In lesson 10, which had the highest success percentage, students solved multiple-choice tests related to factors affecting a dynamometer's extension with justifications. In this lesson, the first author noted that multiple-choice questions were for assessing inductive, deductive and proportional reasoning skills and teacher modelled scientific reasoning skills promotive behaviors like thinking aloud etc.

Besides the success percentages for each lesson, teachers' success percentages for each dimension of TSROF were also analyzed. Findings were presented at Figure 2.

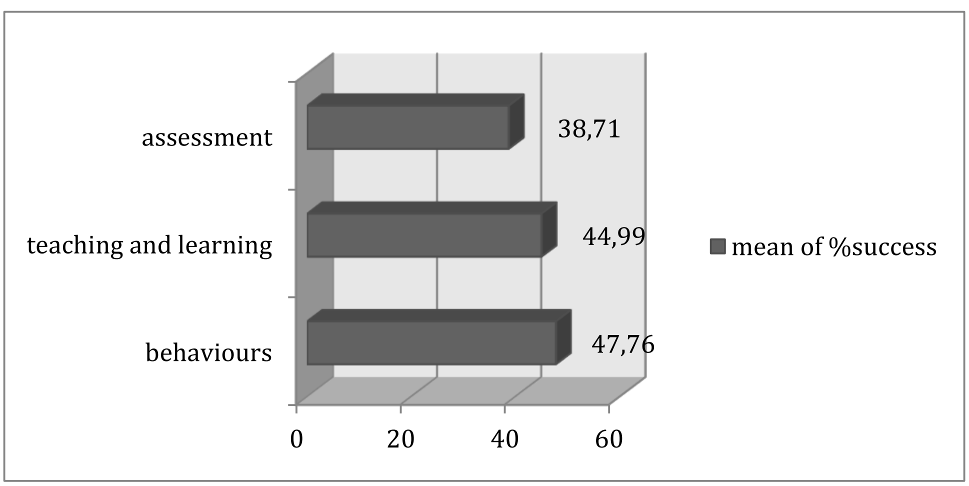


*Figure 2*. Mean of success percentages for each dimension of TSROF

*Note.* x-axis shows the success percentage and y-axis shows the dimensions of TSROF.

According to Figure 2, trained teacher had the highest success performance in behaviors dimension and the least in assessment dimension.

In order to answer second research problem "Did instructional practices implemented by trained teacher develop students' scientific reasoning skills??" both test total score and total scores for each scientific reasoning skill were calculated and then they were tested for normal distribution. Shapiro-Wilks test results showed that while pre and posttest total scores distributed normally ($Z_{pretest}$=.952, p=.173; $Z_{posttest}$=.961, p=.309), total scores for each scientific reasoning skills did not ($Z_{preIR}$=.804, p=.000; $Z_{postIR}$=.840, p=.000; $Z_{preDR}$=.855, p=.001; $Z_{postDR}$=.828, p=.000; $Z_{preCR}$=.760, p=.000; $Z_{postCR}$=.794, p=.000; $Z_{prePR}$=.694, p=.000; $Z_{postPR}$=.719, p=.000; $Z_{preCoR}$=.462, p=.000; $Z_{postCoR}$=.548, p=.000; $Z_{preAR}$=.629, p=.000; $Z_{postAR}$=.519, p=.000; $Z_{preCoV}$=.789, p=.000; $Z_{postCoV}$=.798, p=.000). For this reason, we used parametric tests for test total scores analysis and nonparametric tests for sub-dimensions scores.

In order to determine whether there was a significant difference between pre and post scores of FMSRT, paired-sample t test was conducted and results were presented at Table 2. Effect size value for paired sample t-test was calculated with t/√N formula (Cohen, 1988).

Table 2

*FMSRT Pre and Posttest Mean Scores t-Test Results*

| Measure | N | M | SD | t(30) | p | d |
|---|---|---|---|---|---|---|
| Pre test | 31 | 7.51 | 2.46 | 6.261 | .000*** | 1.124 |
| Post test | 31 | 10.48 | 2.85 | | | |

*Note.* ***p<.001

As shown in Table 2, students' post test scores of FMSRT ($\bar{x}$= 10.48) showed an increase by comparison with their pre test scores ($\bar{x}$= 7.51) and this increase was statistically significant (t(30)= 6.261; p<.001). The Cohen's d statistics (d=1.124) indicated a large effect size (Cohen, 1988; Pallant, 2010). This finding indicates that scientific reasoning skills learning practices and behaviors for supporting them by the trained teacher have large effect on developing students' SRS.

In order to learn which skill/s developed specifically Wilcoxon Signed Rank Test was conducted and results were presented at Table 3. Effect size value for Wilcoxon signed rank test was calculated with IzI/√N formula (Corder & Foreman, 2014).

Table 3

*Results of Wilcoxon Signed Rank Test for FMSRT Pre and Posttest Scores*

| | Posttest-pre test | n | Mean rank | Sum of ranks | Z | p | d |
|---|---|---|---|---|---|---|---|
| IR | Negative rank | 17 | 12.53 | 213.00 | -2.925 | .003* | .525 |
| | Positive rank | 5 | 8.00 | 40.00 | | | |
| | Equal | 9 | | | | | |
| DR | Negative rank | 22 | 14.80 | 325.50 | -3.369 | .001** | .605 |
| | Positive rank | 5 | 10.50 | 52.50 | | | |
| | Equal | 4 | | | | | |
| CR | Negative rank | 15 | 11.00 | 165.00 | -2.419 | .016* | .434 |
| | Positive rank | 5 | 9.00 | 45.00 | | | |
| | Equal | 11 | | | | | |
| CoR | Negative rank | 6 | 6.83 | 41.00 | -.758 | .448 | .136 |
| | Positive rank | 5 | 5.00 | 25.00 | | | |
| | Equal | 20 | | | | | |
| PR | Negative rank | 9 | 8.33 | 75.00 | -.943 | .346 | .169 |
| | Positive rank | 6 | 7.50 | 45.00 | | | |
| | Equal | 16 | | | | | |
| AR | Negative rank | 11 | 6.00 | 66.00 | -3.317 | .001** | .595 |
| | Positive rank | 0 | 0 | 0 | | | |
| | Equal | 20 | | | | | |
| CoV | Negative rank | 14 | 10.54 | 147.50 | -2.276 | .023* | .408 |
| | Positive rank | 5 | 8.50 | 42.50 | | | |
| | Equal | 12 | | | | | |

*Notes.*IR=inductive reasoning; DR=deductive reasoning; CR=causal reasoning; CoR=correlational reasoning; PR=proportional reasoning; AR= analogical reasoning; CoV=control of variables strategy

*p<.05; **p<.01

As shown in Table 3, there were statistically significant differences in inductive, deductive, causal, analogical reasoning skills and control of variables strategy in support of post test scores ($Z_{IR}$=-2.925; p=.003; $Z_{DR}$=-3.369; p=.001; $Z_{CR}$=-2.419; p=.016; $Z_{AR}$=-3.317; p=.001; $Z_{CoV}$=-2.276; p=.023). Scientific reasoning skills learning practices and behaviors for supporting them by trained teacher have large effects on developing students' inductive, deductive and analogical reasoning skills and medium effects on causal reasoning and control of variables strategy.

## Discussion and Conclusion

This study was the second part of a long-term study, which focused mainly on the reflections of science teacher's learning from a teacher training program and development of students' scientific reasoning skills. In this context, firstly researchers developed Scientific Reasoning Skills Training Program (SRSTP) and then implemented to 35 in-service science teachers through 4-day workshop. At the end of SRSTP, participant teachers showed significant developments especially in causal and correlational reasoning skills in the context of scientific reasoning skills knowledge. In addition, their academic proficiency and perceived abilities about designing SRS based learning environment, using SRS in the classroom, preferring instructional methods to promote SRS and assessing SRS improved significantly in the context of self-efficacy perceptions towards teaching SRS. Therefore, SRSTP activities provided support for both gaining knowledge and skills for teaching scientific reasoning skills. Then, one of the participant teachers was determined for the present study and he shared their understanding and gains with their students and tried to support them in using SRS in the context of Force and Motion Unit. Our current research aimed to evaluate the effectiveness of SRSTP authentically by observing trained teacher in the classroom and implementing multiple-choice test to his students for determining SRS development.

Findings of observation process showed that trained teacher performed minimum %29,16 of the behaviors in TSROF. Teacher solved multiple choice questions about force and motion concepts, which is requirement for Turkish exam system and got students to watch some documentaries related to Newton's life etc. in lessons with minimum score. Supporting this, Geist (2004) also reported that teachers had difficulties in practicing SRS in the classroom due to requirement to use multiple-choice tests for evaluating students. Besides, lessons with minimum observation scores make us think that teacher cannot use these teaching materials (watching documentary etc.) for fostering students' SRS or in another words he cannot apply his reasoning skills to these materials. However, trained teacher performed maximum %61,08 of the behaviors in TSROF. The reason may stem from the discipline-specific disposition of teacher's SRS. In the present study, we observed trained teacher's use of scientific reasoning skills in the context of a physical unit, Force and Motion Unit. Therefore, teachers' use and quality of SRS may be affected from his content knowledge as Hogan (2002) said. Another reason may be training time. SRSTP lasted for 4 days and only one day was on designing learning environments. This anticipated time may not be enough for teachers to get their independence for designing and implementing a SRS-based lesson. Similarly, other researchers stated that teachers did not become independent in designing learning environment skills (Davis, Beyer, Forbes & Stevens, 2007; Smit et al., 2018). However, we still say that SRSTP was effective in teachers' use and students' development of SRS depending on the present findings. In lessons with maximum scores, trained teacher used open-ended questions, whole group discussions etc. which could lead students to think. Data also showed that trained teacher had the highest performance in behaviors dimension of TSROF. We interpret this as the reflection of SRSTP. Because, in SRSTP researchers enabled participant teachers to experience the ways for promoting students' SRS such as asking questions activities and three approaches for inquiry implementation in class. Further, teachers experienced many instructional techniques while engaging into reasoning activities. For example, they conducted a data-reasoning activity based on competing theories or causal reasoning activity based on modelling etc. In addition, whole group discussion sessions were held after each activity. This may explain the success percentages in TSROF and the reason for the use of discussion and questioning methods dominantly. This is consistent with other studies reported that direct and explicit teacher training about scientific reasoning skills was effective for developing participant teachers' scientific reasoning skills and their ability for designing learning environment based on these skills (Koenig et al., 2012; Stammen et al., 2018; Tadesse et al., 2017).

Another finding reveals that teacher's behaviors for promoting SRS were effective in developing students' skills. This may stem from teachers' behaviors such as using open-ended questions, allowing students to think when asked a question, solving problems together by think aloud strategy in whole class discussions etc. This finding supports other studies' results reported that scientific reasoning skills could be developed via discussion method (Hogan et al., 1999; Mercer, Dawes, Wegerif & Sams, 2004; Schwartz, Lederman & Crawford, 2004; Smit et al., 2018; Tadesse et al., 2017; Wu, Tseng & Greenan, 2003).

Based on these two findings, it is obvious that trained teacher's behaviors and preferred methods have a vital role in developing students' SRS. This finding supports other studies reported that students' scientific reasoning skills could be developed through teachers' training (Chen & She, 2015; Chowning et al., 2012; Gillies, 2011; Hogan et al., 1999; Jacops, Franke, Carpenter, Levi & Battey, 2007; Mercer et al., 2004; Schwartz et al., 2004; Sedova et al., 2016).

## Limitations and Suggestions

The first limitation of our study is that only one trained teacher was observed about reflecting his learning from SRSTP. In hindsight, it might be better to observe more trained teachers to learn to what extent they can reflect their learning from SRSTP in the classroom. Another limitation is that observation process was restricted only by 5th grade Force and Motion Unit. It might be helpful to observe trained teacher while he teaches different subjects to various graders for evaluating SRSTTP authentically. In another study, more observation data should be collected in detail.

The change in students' SRS are mainly brought by the teacher's behaviors and his preferred methods such as asking open-ended questions and holding whole class discussions etc. Creating a classroom culture based on debate and effective communication between students and teachers and model some behaviors such as listening students' explanations with patience, promoting students to justify their thinking, presenting daily lives problems, encouraging them to explain their thinking, thinking loudly when solving a problem should be better for developing students' SRS. Further, researchers should give training to more teachers about asking investigable questions and creating effective and productive classroom discussions.

Another limitation of the study is that, the effects of trained teacher's instructional practices on students' SRS development were evaluated only by observing depending on quantitative data. Collecting data with triangulation should be used for revealing students' development of SRS in detail.

Further, researchers may investigate the effect of teachers' instructional practices after SRSTP on students' various variables such as cognitive development levels, critical thinking levels and so on.

### Ethics Statement

Scientific, ethical and citation rules were followed during the writing process of the study entitled "A Case Study for Evaluating Scientific Reasoning Skills Training Program", no falsification was made on the collected data and ethical permission (11/10/2018, Meeting No: 09) was obtained from the Dokuz Eylul University Institute of Educational Sciences Ethics Committee. I guarantee that "Mehmet Akif Ersoy University Journal of Education Faculty Editorial Board" has no responsibility for ethical violations, all responsibility belongs to the corresponding author and this study has not been sent to any other academic publication for evaluation simultaneously. In the implementation process, written permissions for students were received from their parents and participant teacher provided the written form of "Voluntery Participant Consent Form".

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## Geniş Özet

### Çalışmanın Gerekçesi

Teknoloji ile birlikte gelişen dünyaya ayak uydurabilmek için günümüz ve gelecek toplumları bilimsel sorular sorabilen, bilimsel modeller kullanabilen ve geliştirebilen, bilimsel araştırmalar yapabilen, bilimsel açıklamalar üretebilen, problemlere çözüm önerebilen bireylere ihtiyaç duymaktadırlar. Akıl yürütme becerileri ise, bilimsel bilginin oluşturulmasında kullanılan beceriler olması sebebiyle bu süreçte önem taşımaktadırlar. Bununla birlikte yapılan çalışmalar öğrencilerin (Gyllenpalm ve diğ., 2021; Kuhn, 2007; Penn ve diğ., 2021; Piraksa, Srisawasdi ve Koul, 2014; Rind & Ning, 2020; Sadler, 2004; Schimek, 2012; hatta öğretmenlerin dahi (Beyer ve Davis, 2008; Boudreaux ve diğ., 2008; Geist, 2004; Hilfert Rüppell ve diğ., 2013; Kang, Orgill ve Crippen, 2008; Yazar 1 ve Yazar 2, 2020; McNeill ve Knight, 2013; Sampson ve Blanchard, 2012; Smit ve diğ., 2018) akıl yürütme becerileri konusunda bazı eksiklikleri olduğunu rapor etmişlerdir.

### Çalışmanın Amacı

Bu çalışma, fen bilimleri öğretmenlerinin katıldığı Akıl Yürütme Becerileri Eğitim Programı (AYBEP)'nın ikinci aşamasını oluşturmaktadır ve eğitim alan öğretmenin sınıf ortamında gözlemi ve öğrencilerinin akıl yürütme becerileri konusundaki gelişimlerinin sınanması yoluyla söz konusu eğitim programının değerlendirilmesini amaçlamaktadır. Çalışma kapsamında aşağıdaki araştırma soruları ele alınmıştır:

- Eğitim alan fen bilimleri öğretmeni, öğrendiklerini ne ölçüde sınıf ortamına yansıtabilmektedir?
- Eğitim alan fen bilimleri öğretmeni tarafından gerçekleştirilen öğretimsel uygulamalar, öğrencilerin akıl yürütme becerilerini geliştirmekte midir?

**Yöntem**

Bu çalışmada, eğitim alan öğretmenin sınıfında nasıl akıl yürütme becerileri öğretimi yaptığı gözlem yoluyla ve öğrencilerden toplanacak nicel veriler yoluyla detaylı bir şekilde incelenmek istendiğinden bütüncül tekli durum çalışması kullanılmıştır (Yin, 2003). Çalışmanın katılımcılarını AYBEP'na katılan ve sonrasında çalışmaya devam etmeye gönüllü bir fen bilimleri öğretmeni ve onun 32 beşinci sınıf öğrencisi oluşturmaktadır. Çalışma kapsamında veriler her ikisi de birinci yazar (2019) tarafından geliştirilen "Akıl Yürütme Becerileri Öğretimi Gözlem Formu (AYBÖGF)" ve "Kuvvet ve Hareket Akıl Yürütme Becerileri Testi (KUHAYBET)" aracılığıyla toplanmıştır. AYBÖGF, öğretmen davranışları, öğrenme ve öğretim ve değerlendirme olarak üç boyut altında toplam 24 gözlenecek davranış içermektedir. KUHAYBET ise, orta güçlükte (p=0,560) ve yüksek ayırıcılıkta (rjx= 0,588) toplam 17 sorudan oluşmaktadır ve KR-20 güvenirlik katsayısı .812 olarak bulunmuştur.

Çalışma kapsamında toplam 21 ders gözlemlenmiştir ancak bu derslerin birisinde öğrencilerden biri tarafından sorulan ve konuyla ilgili olmayan bir soru tartışıldığı için bu ders gözlem verileri arasından çıkarılmıştır. Gözlem süreci, AYBEP'nın tamamlanmasından yaklaşık dört ay sonra başlamıştır ve birinci yazar ile akıl yürütme becerileri eğitimi verilen iki fen bilimleri öğretmen adayı tarafından gözlem süreci yürütülmüştür.

AYBÖGF'ndan elde edilen verilerin analizinde betimsel istatistik kullanılmıştır. Bu amaçla, gözlemlenen her ders için ortalamalar ve öğretmenin başarı yüzdeliği hesaplanmıştır. KUHAYBET'nden elde edilen verilerin analizinde ise istatistik programlarından yararlanılmıştır. Bu kapsamda önce genel test puanlarının ve her biri beceriden alınan puanların normal dağılım durumu sınanmış ve uygun olan testler ile analiz gerçekleştirilmiştir.

**Sonuç ve Tartışma**

AYBÖGF'ndan elde edilen bulgular, öğretmenlerin gözlemlenecek davranışların minimum %29,16'sını yapabildiklerini göstermiştir. Öğretmen gözlem formunda en az puan aldığı derslerde ülkemiz sınav sisteminin bir gereği olarak söz konusu üniteyle ilgili çoktan seçmeli testler çözdürmüş ya da ünite kapsamında bahsedilen bilim insanlarına yönelik belgeseller izletmiştir. Elde edilen bu bulgu, Geist (2004) tarafından ifade edilen değerlendirme için çoktan seçmeli testler kullanımının akıl yürütme becerilerini sınıfta uygulamada zorluklar oluşturduğu görüşüyle uyum göstermektedir. Bunun yanı sıra, belgesel izlettirme vb. yöntemlerin seçildiği derslerde öğretmenin akıl yürütme becerileri puanının düşük olması, öğretmenin bu öğretim materyallerini öğrencilerin akıl yürütme becerilerini teşvik edebilecek şekilde kullanamadığını düşündürmektedir. Bununla birlikte, öğretmen gözlem formundaki davranışların en fazla %61,08'ini yerine getirebilmiştir. Eğitim alan öğretmen, çalışmanın da bir sınırlılığı olarak ifade edilebilecek yalnızca tek bir ünite kapsamında gözlemlenmiştir. Bu sebeple, Hogan (2002)'nın da ifade ettiği gibi öğretmenin akıl yürütme becerileri kullanım durumu gözlemlendiği dersin konu alan bilgisinden kaynaklı olabilir. Bir diğer sebep, AYBEP'nın süresi olabilir. AYBEP kapsamında öğretim ortamı tasarlamaya yalnızca 1 gün ayrılmıştır. Bu süre, öğretmenin bağımsız bir şekilde akıl yürütme becerilerini teşvik edici öğrenme ortamı tasarlama yeterliği kazanmasına yetmemiş olabilir. Bununla birlikte, öğretmen tarafından davranışların yaklaşık %60'ının gerçekleştirilmesi de önemlidir. Öğretmen yüksek puan aldığı derslerde açık uçlu sorular kullanmış ve tüm sınıf tartışmaları yürütmüştür. AYBEP kapsamında gerçekleştirilen her etkinlikten sonra da tartışma oturumlarının düzenlenmesi, öğretmenin derslerinde baskın şekilde sınıf tartışmaları kullanmasını teşvik etmiş olabilir. Gözlem formundan elde edilen bir diğer bulgu ise öğretmenin gözlem formunda en fazla "öğretmen davranışları" boyutuyla ilgili davranışları gerçekleştirebilmiş olmasıdır. Bu durum AYBEP ile öğretmenin sınıf içi akıl yürütme becerileri teşvikinin sağlanmasında farkındalık kazandığı şeklinde yorumlanmaktadır.

KUHAYBET'nden elde edilen bulgular ise öğretmenin akıl yürütme becerilerini geliştirmek üzere sınıf içi davranışlarının öğrencilerin akıl yürütme becerileri gelişimini etkilediğini göstermiştir. Gözlemlenen derslerde öğretmen açık uçlu sorular sorarak öğrencileri düşünmeye yönlendirmiştir, soru sorduğunda düşünmeleri için onlara zaman tanımıştır, sesli düşünme tekniği ile problemlerin çözümünde onlara model olmuştur ve etkili tüm sınıf tartışmaları yürütmüştür. Bu bulgu, öğretmen eğitimi yoluyla öğrencilerin akıl yürütme becerilerinin gelişebileceğini ortaya koyan diğer çalışma sonuçlarıyla uyum göstermektedir (Chen ve She, 2015; Chowning ve diğ., 2012; Gillies, 2011; Hogan ve diğ., 1999; Jacops ve diğ., 2007; Mercer ve diğ., 2004; Schwartz ve diğ., 2004; Sedova ve diğ., 2016).

**Sınırlılıklar ve Öneriler**

Çalışmanın iki temel sınırlılığı olduğu düşünülmektedir. Bunlardan birisi AYBEP'nın sınıf içi etkiliğini değerlendirmek üzere yalnızca bir öğretmenin gözlemlenmiş olmasıdır. Görev yaptıkları okul açısından farklı olan daha fazla öğretmen gözlemlenebilseydi, AYBEP'nın daha gerçekçi bir değerlendirilmesi yapılabilirdi. İkinci sınırlılık ise gözlem yapılan konu ile ilgilidir. Bu çalışma kapsamında eğitim alan öğretmen yalnızca tek bir sınıf seviyesinde tek bir konunun öğretimi bağlamında gözlemlenmiştir. Öğretmenin farklı sınıf seviyelerinde ve farklı konu alanlarında gözlemlenmesi AYBEP'nın daha gerçekçi değerlendirilmesini sağlayabilirdi.

Çalışmada öğrencilerin akıl yürütme becerileri gelişimlerinin, öğretmenlerin sınıf içi davranışları ve tercih ettikleri yöntemler sonucu gerçekleştiği ön plana çıkmaktadır. Buradan hareketle sınıf ortamında öğretmen-öğrenci arasındaki etkili bir iletişimin kurulması ve öğretmenlerin öğrencileri sabırla dinleme, düşüncelerini gerekçelendirmelerini isteme vb. davranışları modellemeleri önerilebilir.

**Etik Beyan:** "*Akıl Yürütme Becerileri Eğitim Programının Değerlendirilmesine Yönelik Bir Durum Çalışması*" başlıklı çalışmanın yazım sürecinde bilimsel etik ve alıntı kurallarına uyulmuş; toplanan veriler üzerinde herhangi bir tahrifat yapılmamış ve veriler toplanmadan önce Dokuz Eylül Üniversitesi Eğitim Bilimleri Enstitüsü Etik Kurulu'ndan etik izin alınmıştır (11/10/2018, Toplantı No: 09). Karşılaşılacak tüm ihlallerde "Mehmet Akif Ersoy Üniversitesi Eğitim Fakültesi Dergisi Yayın Kurulunun" hiçbir sorumluluğunun olmadığını, tüm sorumluluğun Sorumlu Yazara ait olduğunu ve bu çalışmanın herhangi başka bir akademik yayın ortamına eş zamanlı değerlendirme için gönderilmemiş olduğunu taahhüt ederim. Uygulama sürecinde, öğrencilerin ailelerinden yazılı izinler alınmış ve ayrıca katılımcı öğretmen "Gönüllü Katılımcı Onam Formu"nu doldurmuştur.