Educational Policy Analysis and Strategic Research, V16, N4, 2021


# The Impact of Science Teaching based on Science-Technology-Society (STS) Approach to Elementary School Students*

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## Abstract

The aim of this study is to find out effects of science teaching through Science-Technology-Society [STT] approach on elementary school students' creative thinking skills, attitudes towards science lesson, and academic success. To this end, a quasi-experimental pretest-posttest design without the control group was used among quantitative research models. The study particiants were composed of 6 classroom teachers who had previously taken in-service training [IST] on STS approach and their students (N=273) selected through random sampling. Study data were collected by using the Creative Thinking Skills Scale (CTSS), Science and Technology Course Attitude Survey [STCAS], and Academic Achievement Test [AAT]. The data were analyzed by conducting one-way ANOVA test with SPSS. The results showed that the students in STT classes could improve their creative thinking skills, attitudes towards science course, and academic achievement compared to their peers in the classes. It can thus be useful to encourage teachers to perform teaching based on approaches addressing science-tehcnology-society relation. As another recommendation, it is suggested to prepare professional development programs.

**Keywords:** STS Approach, Science Education, Elementary School Students, In-Service Training.

**DOI:** 10.29329/epasr.2021.383.11

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* This study includes part of the first author's PhD thesis supervised by the second author.

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## Introduction

STS approach is grounded in associating knowledge with everyday life, assuring interdisciplinary cooperation, making sense of learned information by students, the individual's learning from a critical perspective, and developing creative thinking skills (Amirshokoohi, 2016; Hacıeminoğlu, Alı, Yager, Oztas & Oztas, 2015). The underlying principle of STS is constructivist learning theory, which emphasizes students' prior knowledge and everyday life experiences (Enger & Yager, 2009; Halwany, Zouda, Pouliot & Bencze, 2017). According to Aikenhead (2006), STS is a good example of the application of the constructivist theory in classrooms (Cho, 2002; Kousa, Aksela & Savec, 2018; Tsai, 2002). According to Kotkievicz (2021), STS studies aim to understand how society, culture, scientific research and technological development all affect and relate to each other. In classrooms where STS-based science program is implemented, the learning environment is structured around the science-technology-society theme and social issues originating from science and technology are used as an interdisciplinary pedagogical tool (Kousa, Aksela & Savec, 2018; Primastuti & Atun, 2018; Tsai, 2002). In such an environment, students start their science education with a personal or social matter of curiosity in science and technology, then research the problem, discuss and produce solutions in a group, and then they reach a conclusion on the solution and announce it (Enger & Yager, 2009). During this process, students also employ many mental activities as a part of identifying and resolving problems, such as;

- ✓ Utilizing their own knowledge in defining and solving the problem,
- ✓ More creative thinking
- ✓ Taking action based on information and evidence,
- ✓ Communicating effectively with science,
- ✓ Positive attitude towards science and technology,
- ✓ Knowing how they learn (Firmino et al., 2019; Nuutinen, Kärkkäinen & Keinonen, 2011; Pimvichai, Yuenyong & Buaraphan, 2019; Primastuti & Atun 2018; Wongsila & Yuenyong, 2019).

STS is not a prescriptive approach to science teaching. Rather, it is an interdisciplinary understanding that includes issue-oriented activities that are appropriate for students and begin with a problem or situation appealing to the students. According to the current trends in the field of education, it has taken its place in science curriculum with different names such as "Context-Based Learning Approach", "Socioscientific Subject-Based Teaching Approach", and "Science-Technology-Engineering-Mathematics [STEM] Approach" (York, 2018). To exemplify, STS approach was introduced by the Ministry of National Education [MoNE] in Turkey in 2005 to teach students the knowledge and skills necessary to solve local and national problems through an interdisciplinary perspective, and it was incorporated in the science curriculum with the title of Science-Technology-Society [STS] relationship. However, in 2013, the curriculum of science and technology course was restructured to cover the same learning domain under the name of Science-Technology-Society-Environment [STSE] as a result of the increased interest in environmental problems. Later, in 2017, Science-Engineering-Technology-Society [SETS] was introduced as a learning domain to the science course curriculum after integrating engineering applications with the effect of 4.0 industry-industrial revolution. The purpose of the SETS learning domain is to enhance students' levels and strategies of making innovation and invention by improving their creativity founded on acquired knowledge and skills (MoNE, 2018). For a clearer depiction of the relationship between STS approach and creativity, general characteristics of an STS-based science lesson learning environment (Enger & Yager, 2009) and the principles that should be existent in teaching that supports creativity (Aslan, 2007) are compared in Figure 1.

| Basic principles of creativity-enhancing teaching | General characteristics of STS-based science learning environment |
|---|---|
| To respect unconventional ideas and questions: Asking a good question can open up a good research path. Children should be taught respect and tolerance for different thoughts. | Local/regional issues or problems related to a matter of interest or curiosity are identified. |
| To respect and give support for imagination: Imagination frees thoughts from pressure and gives unlimited thinking power. | The student uses local resources to obtain information and to solve the problem/issue. |
| To show that their ideas are valuable: It should be made them feel that the basic task of the human mind is not only to store information, but also to generate information. Searching for and trying to find information will make it more valuable than accepting easy-to-grasp information. | The student takes an active part in researching the information to be used in solving the problem. |
| Doing exercises that are not grade-oriented: That everything is planned around grading in school poses an obstacle to revealing new and unfamiliar ideas. The process of presenting ideas and thinking without the threat of assessment is necessary for students especially when doing creative activities and acquiring a new skill. | Learning also occurs outside of class time. |
| Being flexible in time: Students need to take time to put forward a creative product, the teacher spreads the activities over time by extending them beyond school time. | The teacher focuses on personal attention and puts the student's creativity to work. |
| | The student does not only see science content as the knowledge that is necessary to be successful in exams. |
| | The student focuses on a variety of careers in science and technology. |
| | Students become aware of their role of citizenship while attempting to solve the problem(s) they identified. |
| | The student sees and understands the importance of science in their lives. |

**Figure 1.** Comparison of STS-based science teaching and creative thinking principles

As can be seen above, the locus of both creativity-enhancing teaching and STS-based science teaching is to identify a problem and to produce solutions to it. In classes planned around STS approach, the students engage in a long-term problem solving process where they take action to solve the problem related to the topic of science in question. The process both improves the students' attitudes towards science course as it is initiated with a personal or local problem they observe, and boosts their creativity since the students explore various aspects of the problem within the process (Chowdhury, 2016; Firmino et al., 2019; Nuutinen, Kärkkäinen & Keinonen, 2011; Pimvichai, Yuenyong & Buaraphan, 2019; Primastuti & Atun 2018; Wongsila & Yuenyong, 2019; Yager, Choi, Yager & Akcay, 2009; Yalaki, 2014). Moreover, the students learn the information in the best way possible as they are really involved in the learning process since they offer solutions to the problem by referring to their knowledge and implement these solutions after analyzing them (Bishop & Denley, 2007; Enger & Yager, 2009; Koch, 2000; Rule, 2005). The study by Mulyanti, Halim, Murniati , Ilyas, Syukri and Mursal (2021) shows that the STS approach can improve students' critical thinking ability and better learning outcomes. Some researchers (Akçay & Akçay, 2015; Ayua & Tartenger, 2020; Kapici, Akçay & Yager, 2017; Lee & Erdoğan, 2007; Tete, 2011; Yager et al., 2009) have argued that the academic achievement of students in STS classes is higher than those in conventional classes.

**Problem Statement**

Science learning environment in the elementary school as the first academic experience of childhood must be designed in a way to present events and phenomena as a whole rather than separately because pupils of this age are not capable of conceiving the information presented in separate pieces integratedly and they get are mentally caught up in the features of the pieces (Sönmez, 2005). In addition, primary school curriculum is founded on the idea of the students' wish for learning and their kicking off the learning by themselves (Lee & Park, 2012). Therefore, science teaching at elementary level should be carried out with an instructional mind set based on an interdisciplinary approach that gives the central role to children's interests and developmental characteristics, attaches particular importance to their effectiveness and researching and problem solving skills, and makes their decisions the centrepiece. STS approach builds a bridge between science course and other fields mainly including social studies, mathematics as well as applied fields like technology and engineering. In order to maintain this interdisciplinary relationship, it uses social issues around students and their lives, which develops students' attitudes towards the lesson and their creative thinking skills (Kapici, Akçay & Yager, 2017; Nuutinen, Kärkkäinen & Keinonen, 2011). It is very important for raising creative, active and social individuals that these social problems or problems include disciplines such as the environment, art, and ethics (Kotkievicz, 2021).

In this regard, there is an abundance of STT studies regarding secondary school and upper level students in the literature (Akçay & Akçay , 2015; Amirshokoohi, 2016; Neguda et al., 2016; Prismistuai & Atun, 2018; Vazquez-Alonso, Garcia-Carmona, Manassero-Mas & Benassar-Roig, 2013; Yager & Akçay 2008; Yager et al., 2009) while an only small number of studies have delved into elementary school students' creative thinking skills, attitudes to science lesson, and academic achievement as a result of teaching with STS (Nuutinen, Kärkkäinen & Keinonen, 2011; Yager, Choi, Yager & Akcay, 2009).

Within the framework of the theoretical explanations above, the main problem of the study was set as follows: ‘‘What impact does teaching of science course based on STS approach bring to elementary school students’ creative thinking skills, attitudes towards science course, and academic achievement?”

## Method

This study was designed as a single group pretest-posttest quasi-experimental research without control group. Experimental design refers to research designs used to discover the cause-effect relationships between variables (Büyüköztürk, 2007). It has the same purpose as experimental design with the only difference that the experimental groups are selected not by chance, but by certain criteria in quasi-experimental design (Ekiz, 2003; Karasar, 2012). The study sample here included six out of 15 classroom teachers who had attended the STS course held by Ministry of National Education and the students in their classrooms. The participant teachers (T2, T5, T8, T9, T12, and T15) took part in the study on a voluntary basis. The sampling of the students was done with no selectiveness. The independent variable of the study is the science lessons taught with STS approach. These lessons were conducted for four weeks by the six classroom teachers who had completed their STS training. Apart from this, the study was carried out with a large experimental group in order to check whether the change in the dependent variables of the research was at a similar level in all of the six groups treated with the same independent variable. The demographic profile of the participating classroom teachers is shown in Table 1.

**Table 1.** Participants’ Demographics

| Code name | Gender | Professional experience | Location of school | No of students |
|---|---|---|---|---|
| T2 | Male | 10 years | Center of district | 26 |
| T5 | Female | 4 years | Rural area | 22 |
| T8 | Female | 12 years | Center of district | 30 |
| T9 | Male | 8 years | Center of district | 31 |
| T12 | Male | 12 years | Center of district | 30 |
| T15 | Female | 13 years | Center of district | 33 |

As seen in Table 1, the sample consists of three males and three females, and only one participant works in the rural side of the city while the others work in the district center. As for the students, they are equivalent in terms of the developmental characteristics as far as it is reported by the classroom teachers.

### STS Course

STS course is an in-service training (IST) program targeted at primary school teachers and devised by the authors with the support of the Ministry of National Education. The course was organized by taking into account the system approach model, which sees the education process as a system and encourages joint and effective functioning of all elements that make up the system to achieve the goals (Yalın, Hedges, & Özdemir, 1996). The training was comprised two stages: a *practical training* to teach knowledge and skills about STS approach to the trainees and a *monitoring and evaluation* to follow up the extent at which the trainees apply the learned knowledge and skills in their classrooms after the practical stage.

*The practical training stage of the course*; at this stage, 15 classroom teachers were given practical training for nine days (36 hours) at Recep Tayyip Erdogan University. It consisted of four parts; (1) "STS Relationship Awareness" for trainees' figuring out the relationship among science, technology, and society; (2) "Teaching of STS" to teach trainees knowledge and skills on methods and techniques that will help them integrate the STS relationship into science course; (3) "STS Assessment and Evaluation" to teach trainees the knowledge and skills necessary for measuring and evaluating the learning outcomes of students in the STS learning environment; and (4) "STS Lesson Planning Workshop" to teach trainees how to prepare a science learning environment according to STS approach.

*Monitoring and evaluation stage of the course;* during this stage, the four-week (16 lesson hours) science lesson applications of six classroom teachers were evaluated. The teachers participated in this stage voluntarily. The evaluation focused on the classroom teachers' levels of practising the knowledge and skills gained from the IST course in their classes. This aspect was measured by using the "Constructivist Learning Environment Observation Survey-BORAN" developed by Keser (2003). BORAN survey findings obtained from the teachers are given in Table 2.

**Table 2.** BORAN Results

| Teacher | Steps of 5E model Observation | Engage | Explore | Explain | Elaborate | Evaluate | General |
|---|---|---|---|---|---|---|---|
| T2 | I. Observation | 2.0 | 2.2 | 2.3 | 2.1 | 1.5 | 2.0 |
| | Observation | 2.0 | 1.5 | 1.0 | 1.0 | 1.5 | 1.4 |
| | Observation | 2.5 | 2.0 | 2.5 | 2.5 | 2.0 | 2.3 |
| | Observation | 2.0 | 1.0 | 3.2 | 2.1 | 1.5 | 2.0 |
| T5 | Observation | 3.3 | 3.1 | 3.5 | 2.5 | 2.5 | 3.0 |
| | Observation | 3.3 | 3.4 | 3.5 | 2.4 | 2.5 | 3.1 |
| | Observation | 3.8 | 3.0 | 3.3 | 3.2 | 2.5 | 3.2 |
| | Observation | 3.6 | 3.5 | 3.8 | 3.5 | 3.0 | 3.5 |
| T8 | Observation | 3.6 | 3.0 | 3.7 | 3.0 | 2.0 | 3.1 |
| | Observation | 3.6 | 3.2 | 3.5 | 3.2 | 2.3 | 3.2 |
| | Observation | 3.8 | 3.5 | 3.6 | 3.4 | 3.0 | 3.6 |
| | Observation | 3.2 | 3.1 | 3.7 | 3.7 | 3.0 | 3.3 |
| T9 | Observation | 3.0 | 3.7 | 3.3 | 3.2 | 3.0 | 3.2 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | II. Observation | 3.7 | 3.3 | 3.3 | 3.2 | 2.5 | 3.1 |
| | III. Observation | 3.7 | 3.5 | 3.6 | 3.2 | 2.5 | 3.3 |
| | IV. Observation | 3.8 | 3.5 | 3.6 | 3.8 | 3.3 | 3.6 |
| T12 | Observation | 1.5 | 2.0 | 1.5 | 1.4 | 1.2 | 1.5 |
| | II. Observation | 2.5 | 3.0 | 1.2 | 2.5 | 2.5 | 2.3 |
| | Observation | 3.0 | 2.2 | 3.2 | 3.3 | 3.0 | 3.0 |
| | Observation | 3.0 | 2.2 | 3.3 | 3.1 | 3.1 | 3.0 |
| T15 | Observation | 3.0 | 1.5 | 2.5 | 1.0 | 2.0 | 2.0 |
| | Observation | 3.2 | 1.2 | 1.5 | 1.0 | 1.0 | 1.6 |
| | Observation | 2.0 | 1.0 | 2.0 | 2.0 | 2.0 | 1.8 |
| | Observation | 1.2 | 2.0 | 2.2 | 3.0 | 2.0 | 2.1 |

According to the scale put forward by Keser (2003), the scores of the 5E steps in the BORAN questionnaire which are equal to and above 3 mean that the course is realized at the desired level. In this context, when Table 2 is examined, it can be said that some of the teachers (T5, T8, T9 and T12) teach science based on the STS approach and the others (T2 and T15) teach science based on the traditional approach.

**Data Collection Process**

Pre- and post-test procedure was applied to see the variance in creative thinking skills, attitudes towards science course, and academic achievement of the students in the classrooms owned by the 6 trainee teachers before and after the training given. During the 4-week monitoring and evaluation process, the teachers called T5, T8, T9, and T12 applied STS teaching strategies such as problem solving, project-based learning, and collaborative learning in science classes. Contrarily, T2 and T15 preferred teacher-centred and traditional methods such as lecturing, question-answer, and demonstration in the same context. The distribution of students by gender, socioeconomic levels, and class sizes was almost the same in the STS and conventional classes. The same textbooks were also used for teaching of the science course in both types of classes. The only difference between them was that various exercises were planned based on the STS approach to motivate students to ask questions and discuss with their classmates in the STS classes. The students in those classes basically used the textbook to search for information and arguments on the problem instead of following the flow of the lesson. The teacher assumed the role of facilitator for learning and tried to create a learning environment where students would actively research and have debates with other students. On the other hand, the teachers in the other classrooms mostly acted like a supervisor and conveyed the information to the students in detail through direct instruction or demonstration method. In order to overcome potential internal validity threats such as practice or practitioner bias, the teachers were reminded to minimize such threats and appropriate guidance was given.

**Data Collection Tools and Data Analysis**

*Creative Thinking Skills Survey [CTSS]:* This tool was obtained by looking at the "Assessment of Student Creativity" questionnaire in the "Iowa Assessment Book" (Enger & Yager, 2009). The CTSS instrument includes three different subscales: Questioning, Reasoning, and Predicting Consequences. Students are instructed to ask questions, guess the answers and causes, and predict consequences relative to the situation statements. Enger and Yager (2009) suggest connecting in the mind the learnt module with the sitution expression that will be used to measure creativity so that they can note the relationship between what they have learnt and what is being measured. During the analysis, the responses given by the student at each stage are divided into three groups as "irrelevant", "relevant" and "creative", where each irrelevant response is rated 0 point, relevant one is rated 1 point, and creative one is rated 2 points (Enger & Yager, 2009). Inter-rater reliability was established as 0.89 on the classification of levels of questions and statements in the current study. The CTSS was filled out by all classrooms as pre- and post-test, and the responses were analyzed with one-way ANOVA using SPSS.

*Science and Technology Course Attitude Survey (STCAS***):** STCAS, developed by Özsevgeç (2007), consists of 13 positive and 4 negative items. A 3-point Likert type rating scale is used in the questionnaire. The responses are rated by giving 3 points to every "yes", 2 points to "medium", and 1 points to "no". The negative statements are scored in the opposite way giving the highest value to a negative response till the lowest value for an affirmative answer. The Cronbach-alpha reliability coefficient of the scale was found to be .70. Since the survey was originally applied to elementary school pupils in the source, it was not deemed necessary to repeat the reliability analysis in the current study. The STCAS was answered in all of the classrooms pre- and post-test, and the collected data were analyzed by one-way ANOVA using SPSS.

*Academic Achievement Test (AAT):* The academic achievement test developed by the researchers consists of 10 open-ended questions. The questions were prepared in line with the acquisitions in the science program. The construct and content validity of the test was ensured by taking opinions of two lecturers specialized in the field of primary school education and assessment and evaluation, and two experienced primary school teachers. In addition, the pilot study of the test was conducted and the wording of the items was improved to eliminate any misunderstanding or extreme difficulty of questions.

Student responses were categorized into 5 levels based on the taxonomy of Abraham, Williamson, and Westbrook (1994). Total scores were calculated by counting up scores from the categories of complete comprehension (4 points), partial comprehension (3 points), partial understanding with a specific misconception (2 points), specific misconceptions (1 point), and noncomprehension (0 point). The data collected from the pre- and post-test were processed by one-way ANOVA using SPSS, and the results are presented in the following section.

## Results

*Findings from the Creative Thinking Skills Survey [CTSS]*

In order to compare the creative thinking skills of the student groups before the training, the pre-test scores of the CTSS were analysed using one-way ANOVA. ANOVA results of pre-test are displayed in Table 3.

**Table 3**.CTSS Pre-test ANOVA Results

| Classroom | N | Mean | Std. deviation | Sum of squares | | sd | F | p |
|---|---|---|---|---|---|---|---|---|
| | | | | Intragroup | Intergroup | | | |
| T2 | 26 | 9.96 | 2.69 | 1891,75 | 36.065 | 5 | .583 | .713 |
| T5 | 22 | 10.00 | 3.410 | | | | | |
| T8 | 30 | 9.96 | 4.27 | | | | | |
| T9 | 31 | 10.38 | 3.63 | | | 158 | | |
| T12 | 22 | 10.31 | 3.53 | | | | | |
| T15 | 28 | 11.25 | 3.21 | | | | | |

When table 3 is examined, it is understood that there is no significant difference ($F_{(5,158)}$= .538, p>0.05) between creative thinking skill levels of the student groups taught by the teachers before the applied training.

As a result of the applications of teachers, the post-test scores of the student groups were compared. Post-test results were analysed by one-way ANOVA. In addition, multiple comparisons between groups were made by Tukey-HSD. ANOVA results of post-test are displayed in Table 4.

**Table 4.** CTSS Post-test ANOVA Results

| Classroom | N | Mean | Std. Deviation | Sum of squares | | sd | F | p |
|---|---|---|---|---|---|---|---|---|
| | | | | Intragroup | Intergroup | | | |
| T2 | 26 | 14.34 | 2.13 | 2159.92 | 1981.03 | 5 | 28.06 | .000 |
| T5 | 22 | 21.13 | 4.90 | | | | | |
| T8 | 30 | 23.36 | 4.93 | | | | | |
| T9 | 31 | 20.77 | 3.63 | | | | | |
| T12 | 22 | 19.04 | 3.86 | | | 158 | | |
| T15 | 28 | 14.17 | 2.16 | | | | | |

Table 4 indicates a significant difference ($F_{(5,158)}$ = 28.06, p<.05) between the creative thinking skill levels of the student groups in the post-test. The results of multiple comparisons between the CTSS post-test scores of the groups are demonstrated in Table 5.

**Table 5.** CTSS Post-Test Tukey-HSD Results

| (I) | (J) | Mean difference (I-J) | p |
|---|---|---|---|
| T2 | T5 | -6.79* | .000 |
| | T8 | -9.02* | .000 |
| | T9 | -6.43* | .000 |
| | T12 | -4.70* | .000 |
| | T15 | .167 | 1.000 |
| T5 | T8 | -2.23 | .285 |
| | T9 | .36 | .999 |
| | T12 | 2.09 | .440 |
| | T15 | 6.96* | .000 |
| T8 | T9 | 2.60 | .082 |
| | T12 | 4.32* | .001 |
| | T15 | 9.19* | .000 |
| T9 | T12 | 1.72 | .567 |
| | T15 | 6.60* | .000 |
| T12 | T15 | 4.87* | .000 |

* The mean differences are significant at the 0,05 level.

When the post-test scores of the groups are compared, it is seen that there is a significant difference between them ($p < .05$) and this difference is in favour of the four student groups (T5, T8, T9, T12) who received STS education. When these four student groups are further compared among themselves, T8 is seen to have the highest creative thinking skills.

*Findings from the Science and Technology Course Attitude Survey (STCAS)* The difference between the student groups' attitudes towards science course before the training was checked by performing one-way ANOVA analysis on STCAS pre-test. ANOVA results of pre-test are displayed in Table 6.

**Table 6.** STCAS Pre-test ANOVA Results

| Classroom | N | Mean | Std. deviation | Sum of squares | | sd | F | p |
|---|---|---|---|---|---|---|---|---|
| | | | | Intragroup | Intergroup | | | |
| T2 | 26 | 34.73 | 5.48 | 28.957 | 24.056 | 5<br>158 | .831 | .530 |
| T5 | 22 | 36.31 | 4.50 | | | | | |
| T8 | 30 | 34.76 | 6.1 | | | | | |
| T9 | 31 | 36.32 | 5.67 | | | | | |
| T12 | 22 | 36.30 | 4.94 | | | | | |
| T15 | 28 | 37.00 | 5.22 | | | | | |

As understood from Table 6, there is no significant difference ($F_{(5,158)} = .831$, $p>0.05$) between the student groups' attitudes in the pre-test.

As a result of the teachers' applications, the *STCAS* post-test scores of the student groups were analysed by one-way ANOVA. In addition, multiple comparisons between groups were made by Tukey-HSD. Post-test scores of the groups are compared and shown in Table 7 in terms of ANOVA results.

**Table 7.** STCAS Post-test ANOVA Results

| Classroom | N | Mean | Std. Deviation | Sum of squares | | sd | F | p |
|---|---|---|---|---|---|---|---|---|
| | | | | Intragrou | Intergrou | | | |
| T2 | 26 | 35.19 | 5.30 | 21.129 | 254.062 | 5<br>158 | 12.062 | .000 |
| T5 | 22 | 42.86 | 3.38 | | | | | |
| T8 | 30 | 43.20 | 4.14 | | | | | |
| T9 | 31 | 40.70 | 4.68 | | | | | |
| T12 | 22 | 40.21 | 5.31 | | | | | |
| T15 | 28 | 37.38 | 4.22 | | | | | |

Table 7 indicates a significant difference ($F_{(5,158)}$= 12.062, p>0.05) between the student groups' attitudes in the post-test. The other set of results, which indicate multiple comparisons between the STCAS post-test scores of the groups, is demonstrated in Table 8.

**Table 8.** STCAS Post-Test Tukey-HSD Results

| (I) | (J) | Mean difference (I-J) | p |
|---|---|---|---|
| T8 | T9 | 2.71 | .197 |
| | T5 | .336 | 1.00 |
| | T12 | 2.98 | .109 |
| | T15 | 5.81* | .000 |
| | T2 | 8.00* | .000 |
| T5 | T9 | 2.37 | .432 |
| | T12 | 2.65 | .295 |
| | T15 | 5.47* | .001 |
| | T2 | 7.67* | .000 |
| T9 | T12 | .271 | 1.00 |
| | T15 | 3.09 | .120 |
| | T2 | 5.29* | .000 |
| T12 | T15 | 2.82 | 1.20 |
| | T2 | 5.01* | .001 |
| T15 | T2 | 2.91 | .521 |

* The mean differences are significant at the 0,05 level.

Comparison of the post-test results revealed a significant difference between the groups, and this difference was found to be in favour of the student groups (T5, T8, T9, and T12) receiving STS training (p <.05).

Findings from the Academic Achievement Test (AAT)

This test was applied to all of the classrooms before the training and the pre-test data were analysed by one-way ANOVA to calculate the variance, if any, between the groups' academic achievement levels. ANOVA results of the pre-test application are shown in Table 9.

**Table 9.** AAT Pre-test ANOVA Results

| Classroom | N | Mean | Std. Deviation | Sum of squares | | sd | F | p |
|---|---|---|---|---|---|---|---|---|
| | | | | Intragroup | Intergroup | | | |
| T2 | 26 | 23,73 | 6,45 | 4720,19 | 1595,71 | 5<br>158 | 10,345 | ,000 |
| T5 | 22 | 23,19 | 4,89 | | | | | |
| T8 | 30 | 24,03 | 6,03 | | | | | |
| T9 | 31 | 24,65 | 6,00 | | | | | |
| T12 | 22 | 28,32 | 5,04 | | | | | |
| T15 | 28 | 31,96 | 4,34 | | | | | |

As can be seen in Table 9, there is a significant difference between the student groups' academic success levels in science classes before the training ($F_{(5,158)} = 10.345$, $p<0.05$). Also, multiple comparisons were examined by applying Tukey-HSD to the pre-test scores in the AAT. The results of this statistical test are given in Table 10.

**Table 10.** AAT Pre-test Tukey-HSD Results

| (I) | (J) | Mean difference (I-J) | p |
|---|---|---|---|
| T8 | T9 | -,61183 | ,998 |
| | T5 | ,85152 | ,994 |
| | T12 | -4,28485 | ,072 |
| | T15 | -7,93095* | ,000 |
| | T2 | ,30256 | 1,000 |
| T5 | T9 | -1,46334 | ,999 |
| | T12 | -5,13636* | ,030 |
| | T15 | -8,78247* | ,000 |
| | T2 | -,54895 | ,999 |
| T9 | T12 | -3,67302 | ,173 |
| | T15 | -7,31912* | ,000 |
| | T2 | ,91439 | ,989 |
| T12 | T15 | -3,64610 | ,199 |
| | T2 | 4,58741 | ,055 |
| T15 | T2 | 8,23352* | ,000 |

When the pre-test results of the groups were compared, a significant difference was found between the groups (p <.05), and this difference was in favour of the student groups (T12 and T15) who received the conventional education.

After the training, AAT was administered as a post-test and the collected data were subjected to one-way ANOVA for the difference between the student groups. ANOVA results regarding the comparison of the groups are demonstrated in Table 11.

**Table 11**. AAT Post-test ANOVA Results

| Classroom | N | Mean/Average | Std. Deviation | Sum of squares | | sd | F | p |
|---|---|---|---|---|---|---|---|---|
| | | | | Intragroup | Intergro | | | |
| Ö2 | 26 | 39,1154 | 4,63 | 3424,409 | 604,081 | 5<br>158 | 5,398 | ,000 |
| Ö5 | 22 | 44,0000 | 6,13 | | | | | |
| Ö8 | 30 | 44,4333 | 4,92 | | | | | |
| Ö9 | 31 | 42,6452 | 5,25 | | | | | |
| Ö12 | 22 | 39,7727 | 2,94 | | | | | |
| Ö15 | 28 | 41,8571 | 3,79 | | | | | |

Looking at Table 11, it is found that there is a significant difference ($F_{(5,158)}$ = 12.062, p> 0.05) in academic success between student groups after the application. Multiple comparisons between the AAT post-test scores of the groups were made by Tukey-HSD, and the data obtained are given in Table 12.

**Table 12.** KKT Post-test Tukey-HSD Results

| (I) | (J) | Mean difference (I-J) | p |
|---|---|---|---|
| T8 | T9 | 1,78817 | ,680 |
| | T5 | ,43333 | 1,000 |
| | T12 | 4,66061* | ,008 |
| | T15 | 2,57619 | ,307 |
| | T2 | 5,31795* | ,001 |
| T5 | T9 | 1,35484 | ,908 |
| | T12 | 4,22727* | ,040 |
| | T15 | 2,14286 | ,607 |
| | T2 | 4,88462* | ,006 |
| T9 | T12 | 2,87243 | ,254 |
| | T15 | ,78802 | ,988 |
| | T2 | 3,52978 | ,062 |
| T12 | T15 | -2,08442 | ,635 |
| | T2 | ,65734 | ,997 |
| T15 | T2 | 2,74176 | ,279 |

* The mean differences are significant at the 0,05 level.

Comparison of the post-test results of the groups reveals that there is a significant difference between the groups, and this difference is in favour of the student groups receiving science education based on the STS approach ($p < .05$).

## Discussion, Conclusion and Recommendations

This section is devoted to the general evaluation of the study results.

Firstly, when examining the science teaching approaches applied by primary school teachers in their classrooms after the FTT course, it was determined that the teachers with the codes of T5, T8, T9 and T12 taught science based on the FTT approach while the teachers with the codes of T2 and T15 taught science based on the traditionalist approach. It can be inferred from the literature that the teachers might avoid using FTT approach as a teaching strategy because of the fear that applying the FTT approach in classrooms will not allow in-depth coverage of the course content or it will decrease student success (Amirshokoohi, 2016; Autieri, Amirshokoohi & Kazempour, 2016; Enger & Yager, 2009).

Secondly, a closer look at the creative thinking skills of the students taught by classroom teachers suggests that the groups were equivalent with quite close scores before the training (Cho, 2002; Enger & Yager, 2009; Lee & Erdogan, 2007; Şen & Baz, 2018). However, a significant difference emerged between creative thinking skills of the groups after the training, and the imbalance was in favour of the classes taught by Ö5, Ö8, Ö9, and Ö12. It can be suggested that the creativity of those students may have increased since they identified the problems related to the subject and did research to solve the problems on their own, and they speculated about the causes and results of the selected problem in the STS-based setting designed by their teachers (Hacıemınoglu et al., 2015; Lee & Erdoğan 2007). Yet this result does not seem surprising because critical thinking by nature means looking critically, being authentic, spotting the problem, and drawing new conclusions via different paths (Mulyanti, et al., 2021). Another possible explanation for this difference may be the fact that Ö5, Ö8, Ö9, and Ö12 applied teaching techniques inspired by 5E model such as projects, problem solving, sample events, and debate whereas the others, i.e. Ö2 and Ö15, predominantly taught science by lecturing and demonstration in their classes (Tsai, 2002). Other researchers also (Chantaranima & Yuenyong, 2014; Cho, s2002; Hacıemınoglu et al., 2015) found that students' creative thinking skills improved, and their subject concept knowledge increased in STS classrooms. Hence, it can be said that creative thinking skills can advance as a result of specific activities in the classroom and that STS approach has a noticeable influence on the development of students' creative skills (Yager, Yager & Lim, 2006).

Thirdly, with respect to the change in the participant students' attitudes towards science course, there was not a significant difference among the groups before the teachers attended the STS training. This implies that there is no considerable difference between the teachers' ways of teaching

(Akçay & Akçay, 2015; Lee & Erdogan; 2007). But a significant difference was noted in the students' attitudes towards science course when the teachers completed their in-service training. The post-test averages in the STCAS prove that the students of Ö5, Ö8, Ö9, and Ö12, who employed STS approach in their classes, experienced notable progress in attitudes to science course. This change can be accounted for by a number of factors in STS classrooms such as the teachers' role of facilitator and mentor besides the students' facing a real problem of interest and curiousity, class discussions, group discussions, and democratic activities like voting (Akçay & Akçay, 2015; Devi & Aznam, 2019; Cho, 2002, Enger & Yager, 2009, Lee & Erdoğan, 2007; Smitha & Aruna, 2014). According to Davasligil (1991), learning environments which allow free discussion of problems and solutions related to the learning topic help pupils develop positive attitudes towards learning and those settings offer an effective motivating ambiance to make learning fun.

When the changes in the academic achievement of students were examined after the classroom teachers' science teaching, it was seen that there was a significant difference between student groups both before and after the training. Before the training, the significant difference was in favour of the student groups T12 and T15. Contrarily, the significance turned in favour of the T5, T8 and T9 after the training.

In STS classrooms, the teachers introduced the students to a social issue from their real life connected with the topic of science teaching. Then, the students read up on the problem before offering solutions, and finally used the information to solve the problem. This series of actions might have enabled students to develop the concepts in their cognitive structures independently (Nuutinen, Kärkkäinen & Keinonen, 2011; Primastuti & Atun, 2018). Kapici, Akçay and Yager (2017) found in their study that students in STS classrooms proved to be more successful with regard to knowledge of concepts than those in classrooms where the traditional approach was applied. Further similar findings are also available in the literature (Ayua & Tartenger, 2020; Lee & Erdoğan, 2007; Negedu et al., 2016; Nuutinen, Kärkkäinen & Keinonen, 2011; Primastuti & Atun, 2018; Tete 2011; Wongsila & Yuenyong, 2019; Yager, Yager & Lim, 2006).

Given that the main goal of any newly-proposed science curriculum is to educate individuals to possess the 21st century skills, formal teaching plans should be based on Science-Technology-Society approach (STS) (Devi & Aznam, 2019; Yalaki, 2014). Several governmental organizations and science education institutions including the National Science Teachers Association [NSTA] (2010) and the National Research Council [NRC] (2013) declared that it is an essential way to build curricula on STS philosophy for promoting and actualizing individuals' 21st century skills. In this context, in Turkey, it is strongly emphasized that teachers should give place to learning strategies that improve students' inquisition and creativity in order to meet the requirement of raising individuals with skills of the 21st century as pointed by the Ministry of National Education (2018). To this end, the use of approaches and methods relating to science-technology-society relation by teachers should be explicitly encouraged and reinforced. In this scope, professional development courses should be planned to help teachers teach in their own classrooms based on approaches relying on the relation of science, technology, and society. It should be also made sure that teachers attend such events. As mentioned earlier, this study explores the impact of STS approach on elementary school students' creative thinking, attitudes towards science course, and their academic achievement. Since the approach grants students a free learning environment in which they become responsible for their own learning, future researchers can examine the effect of STS approach on learner skills such as communication and collaboration, entrepreneurship, and responsibility. Lastly, quantitative research approach was adopted in this study. It is recommended that researchers try mixed research methods to collect a greater amount of qualitative and quantitative data on dependent variables under scrutiny.

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