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The impact of integrated STEM education on academic achievement, reflective thinking skills towards problem solving and permanence in learning in science education

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Abstract

This research has been conducted to evaluate the effects of integrated science, technology, engineering and mathematics (STEM) education on academic achievement, reflective thinking skills towards problem solving and permanence in learning in science education. This study, which used pre-test–post-test and semi-experimental model with permanence test, control group as a research model, was conducted with 44 students attending to the 6th grade of a public school in 2015–2016 academic year. The study consisted of the control group with constructivist teaching and the experimental group with integrated STEM education. Academic achievement test and reflective thinking scale towards problem solving were applied. In SPSS 24 package program, analysis of quantitative data was performed using *t*-test and Mann–Whitney U test. In conclusion, the integrated STEM education does not significantly increase success, reflective thinking skills towards problem solving and their effects on permanence according to constructivist teaching, but provides positive contributions to academic achievement.

Keywords: Integrated STEM education, science education, academic achievement, problem solving, reflective thinking skills.

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1. Introduction

In the twenty-first century, the skills that students must have been expressed as: creativity, innovation, problem solving, critical thinking, technology literacy, information literacy, career and life skills, initiative, flexibility and social and cultural skills (Akgunduz, 2016; P21, 2017; WEF, 2016). This science, technology, engineering and mathematics (STEM) education that aims to equip the students with these skills is pointed out as one of the significant emerging approaches in the field of education in the twenty-first century. STEM education is an approach that combines the disciplines of science, math, engineering and technology (Akgunduz et al., 2015a; Akgunduz, 2016; Corlu, 2014). All of these disciplines highlight the skills in the twenty-first century, enabling students to obtain the abilities to adapt social skills, communication skills, scientific thinking, self-control and adaptation to innovation and creativeness (Bybee, 2010; National Research Council, 2010). The purpose of the implementation of qualified STEM education is to raise quality engineers, scientists, mathematicians and tech experts. In addition, it aims to prepare the children for the post-school life, facilitating an encounter with real-world problems (Akgunduz et al., 2015a; Akgunduz, 2016; Corlu, Adiguzel, Ayar, Corlu & Ozel, 2012).

The difference of STEM education from other approaches is that it is integrative. That STEM education is integrative means that it blends the content of science and math with engineering and technology (Akgunduz et al., 2015a). In the integrative STEM education, learning quality and students' interest have the potential to increase with project-based activities. With project-based education integrated with math, engineering, technology and science courses, students' desire to learn and their learning levels could be higher. At this stage, methods based on problem solving, exploration and research all have great importance for the integration of STEM education (Sahin, Ayar & Adiguzel, 2014).

Actions taken to initiate STEM education have progressed with the space race starting in the 1950s and the education reforms and policies during this race. Especially in the United States, this reform targeted to raise quality engineers and scientists and aimed to lead the world economy (Akgunduz et al., 2015a; Bybee, 2010). Some of these reforms include National Science Education Standards laid down in 1996 (National Research Council, 1996) and the Next Generation Science Standards laid down in 2012 (Achieve, 2012). With the last reforms, Science Education Standards included engineering design and standards on engineering design from pre-school to the end of high school, strengthening the interdisciplinary relations (Achieve, 2012). The United States Government as part of state policy devotes an average of $3 billion each year to STEM disciplines and STEM education (Akgunduz, 2016).

Turkey has in recent years achieved major advances in STEM education. Under the leadership of Istanbul Aydin University (Akgunduz et al., 2015a; Akgunduz, Ertepinar, Ger, Kaplan Sayi & Turk, 2015b) and TUSIAD (2014, 2017), various reports have been prepared and shared with the public. In addition, although many of them are not at the level of K12, there is an increase in their level each day in the research conducted, but it must be taken into consideration that the actual development of STEM education will be provided with research and application on the K12 level.

2. The importance and purpose of the research

At the national level, education programmes are replenished at time periods of several years. A recent change made in science education was carried out at the beginning of 2018 (TTKB, 2018). With this change, actions regarding STEM education were included in the science education teaching programme with an engineering component. However, there are a variety of issues related to the implementation of these steps. In this context, there is no adequate knowledge and application experience. In order to have this experience, a lot of research and many applications are needed.

What is required is the development of STEM education design with the aims of increasing the cooperation with technology, science and math teachers and supporting the innovative and critical thinking skills of students, adaptation of this education to the conditions of our country, and preparing, testing and evaluating the curriculum of professional development (Corlu, 2014). Especially in science education at middle school level, STEM education must be evaluated from the viewpoint of several variables and examples of implementation must be replicated.

When research about STEM education on databases such as Web of Science, Google Scholar, etc., is examined, it has been established that international research started in the 2000s, whereas at the national level, considerable research was done since 2014. However, it has also been observed that most of the research was conducted on one or two STEM disciplines, that research integrating the four disciplines is very rare, that the research is mostly conducted with prospective teachers, that research on academic success on middle school level is rare and that no research was conducted on reflective thinking towards problem solving.

Unlike problem solving, what is central in the reflective thinking which adapts to the input–output framework of the process of problem solving is not inputs of problem, but one's own actions (Kizilkaya & Askar, 2009). Therefore, it is vital that reflective thinking should be used effectively in problem solving during STEM education.

This study differs from others in that it investigates the application of integrative STEM education with all its disciplines together, the academic success in science course at middle school level and the development of reflective thinking skills geared for problem solving.

The main problem of the study in accordance with this information is determined as 'Does integrated STEM education have an impact on academic success, reflective thinking skills towards problem solving and permanence?' The purpose of studying this problem is: given the constructivist approach, to quantitatively determine the outcomes of the applications of integrated STEM education in science education affecting academic achievement, reflective thinking skills towards problem solving and permanence.

The following research questions were sought in line with the research objective:

In the 6th grade science class in secondary school, for students who apply constructivist approach and integrated STEM education

1. Is there a meaningful difference between the averages of pre-test and post-test scores of academic achievements?
2. Is there a meaningful difference between the academic achievement permanence test (PT) score averages?
3. Is there a meaningful difference between the mean of pre-test and post-test scores of reflective thinking skills towards problem solving?
4. Is there a meaningful difference between the mean scores of retroreflective ability PT for problem solving?

3. Method

3.1. Model of the study

In this study, quasi-experimental design (pattern with pre-test and post-test control group) was used. According to Buyukoztork, Kilic Cakmak, Akgun, Karadeniz and Demirel (2010), semi-experimental designs with paired patterns are assigned to experimental and control groups as unselected. The independent variable of the study is integrated STEM education. Dependent variables of research are academic achievement, reflective thinking skills towards problem solving and permanence in learning.

Quantitative data is used in the study. The level of the relationship between the quantitative data and the variables is determined. Goksu, Padem and Konakli (2012) explained quantitative research as numerical research in general terms, testing a problem with theory, measuring it with numbers and analysing it with statistical methods.

The research design used in the study is given in Table 1.

Table 1. Study pattern

Groups	Learning approach	Pre-test	Post-test	PT
Control group (CG)	Constructivism	AAT, RTSSPS	AAT, RTSSPS	AAT, RTSSPS
Experimental group (EG)	Integrated STEM education	AAT, RTSSPS	AAT, RTSSPS	AAT, RTSSPS

The academic achievement test (AAT) was used on all students to determine the effects of learning approaches on the academic achievement of students, the reflective thinking skills scale towards problem solving (RTSSPS) to determine the effect of reflective thinking skills towards problem solving and the PT to determine the effect of the study on permanence. Tests and scales were applied to students as pre-test, post-test and PT.

3.2. Study group

The study group of the study consists of 44 students studying middle school in the province of Umraniye, İstanbul, in the academic year of 2015–2016. The practice was carried out at the school where the researcher worked as a teacher. In the class selection, random selection was made among the classes taught by the researcher who is a teacher. One of the selected classes was designated as the experimental group and the other as the control group. There are 22 students in both the control group and the experimental group. The control and experimental groups consisted of 22 students, 10 girls and 12 boys.

3.3. Data collection tools

In the study, AAT and RTSSPS were used.

3.3.1. Academic achievement test

AAT was applied to measure students' achievements in the units of 'force and motion', 'light and sound', 'electrical conduction' and 'matter and heat'. AAT consists of 20 multiple-choice questions prepared in accordance with achievements.

In many countries, multiple-choice questions are used to measure students' cognitive levels or cognitive capacities (Pressley, Yokoi, van Meter, van Etten & Freebern, 1997). These tests are also used because it is easy and quick to evaluate and allows many sub-gains to be measured.

In the 6th grade of middle school, a pool of 50 questions was created in accordance with the gains in the units of 'force and motion', 'light and sound', 'electrical conduction' and 'matter and heat'. In order to ensure the validity of the test coverage, the opinions of one faculty member working in the department of science teaching of the state universities and two faculty teachers of science class have been taken into consideration. The scientific suitability of the questions was considered and a pilot study was conducted with 60 students studying in the 7th grade. At the end of the pilot study, the number of questions was reduced to 20.

The AAT used in the study was evaluated according to the number of answers given by the students. Questions that were left blank and answered incorrectly were evaluated as 0 points in the test and the correctly answered questions as 1 point. The scores of the students who will take the test are rated at a maximum of 20 points and a minimum of 0 points.

The difficulty and discriminatory indices of the test questions were determined in accordance with the data obtained as a result of the preliminary evaluations of the prepared success test, and the reliability of the test (KR-20) was found to be 0.87. The average strength of the 20-item success test was 0.64 and the average discrimination was 0.58. In a success test, the substance strength is expected to be around 0.50 (Buyukozturk et al., 2010). The questions in the AAT consist of moderate and easy questions. If the test item discriminantity index value is ≥ 0.40, the item is considered very good

(Buyukozturk et al., 2010). When we look at item discrimination values, the questions in the AAT are highly discriminatory.

Table 2 shows how many questions are included in the subjects of 'force and motion', 'light and sound', 'electrical conduction' and 'matter and heat' in AAT.

Table 2. Distribution of the items constituting the achievement test according to the subject headings

Title of topics	Subtitle of topics	Related question numbers
Force and motion	Velocity	1, 2, 3, 4
Light and sound	Absorption of sound	5, 6, 7, 8
Matter and heat	Interaction of heat with matter	9, 10, 11
Light and sound	Reflection of light	12, 13, 14
Electrical conduction	Electrical conduction and electrical resistance	15, 16, 17, 18, 19, 20

3.3.2. Reflective thinking skills scale for problem solving

'RTSSPS' was applied to reveal the change of reflective thinking skills of students towards problem solving. The scale was developed by Kizilkaya and Askar (2009) and consists of 14 items. The options range from 'Always: 5' to 'Never: 1'. The scale is a 5-point Likert-type measure that determines to what extent the respondents agree with the research-related statements. The highest score that can be obtained from the scale is 70. The lowest score is 14.

Kizilkaya and Askar (2009) calculated the Cronbach alpha value as 0.83 for all of the items on the scale. The reliability analysis of the items in the RTSSPS used in this study was carried out again and the internal consistency coefficient of Cronbach alpha was found to be 0.85.

3.3.3. Permanence test

PT is the instrument used to measure students' memory levels and problem solving levels, which are conducted within the experimental setup of the research, 1 year after the last test. In order to determine the permanence level, the AAT and RTSSPS, which were applied pre-test and post-test were applied as a PT.

3.4. Data collection

The data were collected by two researchers. One of the researchers is an academician conducting high-level research on STEM education, and the other is a science teacher who has attended the STEM teacher certification program organised by a foundation university and obtained an STEM teacher certificate.

Pilot study for 1 week (4 lesson hours) was given to the experimental group students before the study. The aim of the pilot study is to prepare students for the engineering design cycle and for STEM integration. In total, the application lasted 22 hours (5 weeks). The whole study was carried out by researchers. AAT and RTSSPS pre-test were applied to all students before application. Table 3 shows the durations of the implemented applications according to the subjects.

Table 3. Duration of the applications performed in the control and experiment groups according to subjects

Title of topics	Duration (hours)
Electrical conduction and electrical resistance	6
Reflection of light	4
Absorption of sound	4
Interaction of heat with Matter	4
Velocity	4
Total	22

3.5. Control group (constructivist approach) applications

1. In the control group, lesson plans were implemented within the science program in accordance with the gains in 'force and motion', 'light and sound', 'electrical conduction' and 'matter and heat' units.
2. All lessons were administered as 4 hours per week, in accordance with the course book, in accordance with the annual plan.
3. In the course of the lessons, the constructivist approach was used with appropriate techniques.
4. The course book, worksheets, posters and laboratory supplies were used as references.
5. Homework assignments were given to the students at the end of each course to prepare them for the next lesson. Homework has been checked and evaluated.
6. In the evaluation of the students, mostly the textbook was used.

3.5.1. Experimental group (integrated STEM training) applications

1. In the experiment group, integrated STEM Education was implemented within the science program in accordance with the gains in 'force and motion', 'light and sound', 'electrical conduction' and 'matter and heat' units.
2. All lessons were carried out within the annual plan and 4 hours per week with appropriate lesson plans for STEM approach.
3. The course book, worksheets, posters and laboratory supplies were used as references.
4. Homework assignments were given to the students at the end of each course to prepare them for the next lesson. Homework has been checked and evaluated.
5. In the experiment group, some activities appropriate to the STEM approach, which required engineering design process in the control group were applied instead of some activities in the control group.
6. The students were asked to design proposals for solutions of the problem and to design these solutions, and the designs were transformed into products and the engineering processes of the students were evaluated.

3.5.2. Sample lesson schedule flow

The first activity applied to the students of the experiment group belongs to the sub-topic titled 'velocity' of the 'force and movement' unit. According to the lesson plan prepared, firstly, questions were asked to determine the students' prior knowledge about the topic. In the second phase, students were able to discover the concept of velocity. In the third phase, the concept of velocity is explained, velocity units are given and problems related to unit conversions are solved. In the fourth stage, the 'I design a racing car' activity, which is appropriate to the engineering design cycle, was held to transfer learned information onto everyday life. In the activity, students are asked to design a vehicle, determine velocity and figure out how a vehicle will change velocity. In line with the information they learned in the third phase, the students measured the distance taken by the meter while calculating the velocity by the meter and the passing time by the stopwatch. As a result of the measurements made, they calculated an object's velocity by the ratio of the road covered to the passing time. In the fourth stage, students studied the structure of a toy car and designed a car of their own. While doing their designs, they made prototype drawings and made calculations using mathematical information. At the last stage, measurement and evaluation were done with the evaluation questions.

3.6. Analysis of data

One sample Kolmogorov–Smirnov Z test was used to determine whether the data obtained in the study conformed to the normal distribution, as a result of AAT, RTSSPS pre-test, post-test and PT. The Kolmogorov–Smirnov Z test is used to test whether a coincidental sample of data fits a uniform distribution such as uniform, normal or Poisson distribution (Akgul, 2005).

In the study, Mann–Whitney U test was used for non-parametric tests for AAT pre-test and RTSSPS pre-test data with no normal distribution of control and experiment groups ($p < 0.05$). The t-test was applied to the parametric analyses for AAT post-test, AAT PT, RTSSPS post-test and RTSSPS PT data showing normal distribution of control and experiment groups ($p > 0.05$). The t-test is used to test whether the difference between the two related sample averages is significantly different from zero (Buyukozturk, 2006).

4. Findings

4.1. Findings from the first research question

The first research question is to determine whether there is a meaningful difference between the AAT pre-test and AAT post-test score averages of the control and experiment group students who are educated by the constructivist approach and integrated STEM education in the 6th grade science course of middle school.

Table 4 shows the results of the Mann–Whitney U Analyses for the AAT pre-test scores of the control and experimental group students (Kolmogorov–Smirnov Z *p* values: (CG: $p < 0.05$ and EG: $p > 0.05$).

Table 4. The results of the arithmetic mean, standard deviation and Mann–Whitney U analysis of the AAT PT scores of the control and experimental group students

Groups	*N*	*X*	sd	Mean rank	Sum of rank	*U*	*Z*	*p*
CG	22	10.45	1.819	21.77	479.00	226.00	−0.381	0.704
EG	22	11.00	2.944	23.23	471.00			
Total	44	10.73	2.434					

When Table 4 was examined, the control group had a mean AAT pre-test of 10.45 and a standard deviation of 1.819; the experimental group's mean AAT pre-test is 11.00 and the standard deviation is 2.944. According to Table 4, it is seen that control and experiment group students have similar values of AAT pre-test scores. Since the *P* value was 0.704 ($p > 0.05$), there was no significant difference between the two groups' AAT pre-test scores. Given the average values of the AAT pre-test scores, the students in the experimental and control groups may be regarded as equivalent in terms of academic achievement, although the students in the experimental group with integrated STEM training seem to have a higher academic success.

Table 5 shows the results of the arithmetical mean, standard deviation and independent group *t*-test on the AAT post-test scores of the control and experimental group students (Kolmogorov–Smirnov Z p values: (CG: $p > 0.05$ and EG: $p > 0.05$).

Table 5. Arithmetic mean, standard deviation and independent group t-test results of AAT post-test scores of control and experimental group students

Groups	*N*	*X*	sd	t-Test		
				t	sd	*p*
CG	22	12.50	3.851	−1.377	21	0.176
EG	22	14.23	4.450			

When Table 5 is examined, the control group's AAT post-test average is 12.50 and standard deviation is 3.851; The AAT post-test average of the experiment group is 14.23 and the standard deviation is 4.450. According to Table 5, it is seen that PT' group averages of the students in the experimental group are higher than the average post-test' points of the control group students. However, there was no significant difference between the two groups when compared with AAT post-test data ($p > 0.05$). Integrated STEM education increases the academic achievement averages more than the constructivist approach, but this does not make a meaningful difference.

4.2. Findings from the second research question

The second research question is to determine whether there is a meaningful difference between the RTSSPS pre-test and RTSSPS post-test score averages of the control and experiment group students who are educated by constructivist approach and integrated STEM education in the 6th grade science course of middle school.

Table 6 shows the results of the arithmetic mean, standard deviation and Mann–Whitney U Analyses of RTSSPS pre-test scores of the students in the control and experimental groups (Kolmogorov–Smirnov Z *p* values: CG: $p < 0.05$ and EG: $p > 0.05$).

Table 6. The results of the arithmetic mean, standard deviation and Mann–Whitney U analysis of the RTSSPS pre-test scores of the control and experimental group students

Groups	*N*	*X*	sd	Mean rank	Sum of rank	*U*	*Z*	*p*
CG	22	55.59	9.127	23.59	479.00	218.00	−0.564	0.573
EG	22	54.45	8.606	23.23	471.00			
Total	44	55.02	8.786					

When the Table 6 was examined, the control group's average of the RTSSPS pre-test score is 55.59 and standard deviation is 9.127; the average of the experimental group's RTSSPS pre-test is 55.45 and the standard deviation is 8.606. According to Table 6, it is seen that control and experiment group students have similar values of RTSSPS pre-test scores. Since the *P* value was 0.573 ($p > 0.05$), there was no significant difference between the two groups' RTSSPS pre-test scores. Regarding the mean values of the RTSSPS pre-test, although the students in the control group to which the constructivist approach is applied do not seem to have reflective thinking skills to solve a higher problem, the students in the experimental and control groups can be regarded as equivalent in terms of reflective thinking skills towards problem solving.

Table 7 shows the results of the arithmetical mean, standard deviation and independent group t-test on the RTSSPS post-test scores of the control and experimental group students (Kolmogorov–Smirnov Z p values: (CG: $p > 0.05$ and EG: $p > 0.05$).

Table 7. Arithmetic mean, standard deviation and independent group t-test results of RTSSPS post-test scores of control and experimental group students

Groups	*N*	*X*	sd	t-Test		
				t	sd	*p*
CG	22	52.86	8.055	0.627	21	0.534
EG	22	51.09	10.542			

When Table 7 was examined, the control group's RTSSPS post-test average is 52.86 and standard deviation is 8.055; the experimental group's RTSSPS post-test average is 51.09 and the standard deviation is 10.542. According to Table 7, it is seen that the average scores of the students in the control group are higher than the average scores of the students in the experimental group in RTSSPS post-test However, there was no significant difference between the two groups when compared with RTSSPS post-test data ($p > 0.05$). When evaluating the RTSSPS post-test scores, it can be said that the effect of constructivist approach and integrated STEM education did not make a significant difference.

4.3. Findings from the third research question

The third research question is to determine whether there is a meaningful difference between students' AAT PT score points and the constructive method and integrated STEM education in the 6th grade science course of middle school.

Table 8 shows the results of the arithmetical mean, standard deviation and independent group t-test on the AAT PT scores of the control and experimental group students (Kolmogorov–Smirnov Z p values: (CG: $p > 0.05$ and EG: $p > 0.05$).

Table 8. Arithmetic mean, standard deviation and independent group t-test results of AAT PT scores of control and experimental group students

Groups	*N*	*X*	sd	t-Test		
				t	sd	*p*
CG	22	9.50	5.031	−1.569	21	0.124
EG	22	11.86	4.960			

When Table 8 was examined, the control group had a mean AAT PT of 9.50 and a standard deviation of 5.031; the experimental group's average AAT PT is 11.86 and the standard deviation is 4.960. According to Table 8, it is seen that control and experiment group students have similar values of AAT PT scores. Since the *p* value was 0.124 ($p > 0.05$), there was no significant difference between the two groups' AAT PT scores. Given the average values of the AAT PT scores, the students in the experimental and control groups may be regarded as equivalent in terms of academic achievement, although the students in the experimental group with integrated STEM training seem to have a higher academic success.

Table 9 shows the results of the arithmetical mean, standard deviation and independent group *t*-test on the AAT post-test and AAT PT scores of the control and experimental group students (Kolmogorov–Smirnov Z p values: (CG: $p > 0.05$ and EG: $p > 0.05$).

Table 9. Dependent group t-test results for control and test group students' AAT post-test and AAT PT scores

Groups	*N*	*X*	sd	*t*-Test		
				t	sd	*p*
CG AAT post test	22	12.50	3.851	4.095	21	0.124
CG AAT PT	22	10.25	3.436			
EG AAT post test	22	14.23	4.450	2.767	21	0.012
EG AAT PT	22	12.86	4.006			

When Table 9 was examined, it was found that the control group students had an average AAT post-test of 12.50 and a standard deviation of 3.851; 10.25 of the mean AAT PT and 3.436 of the standard deviation; 14.23 of the AAT post-test average of the students of the experimental group and 4.450 of the standard deviation; It is seen that the average AAT PT is 12.86 and the standard deviation is 4.006. There was no significant difference between the AAT post-test and AAT PT scores of the control group students ($p > 0.05$), but there was a statistically significant difference in favour of post-test between the AAT post-test and AAT PT scores of the students of the experimental group ($p < 0.05$).

4.4. Findings from the fourth research question

The fourth research question is to determine whether there is a meaningful difference between students' RTSSPS PT score points and the constructive method and integrated STEM education in the 6th grade science course of middle school.

Table 5 shows the results of the arithmetical mean, standard deviation and independent group t-test on the RTSSPS PT scores of the control and experimental group students (Kolmogorov–Smirnov Z p values: (CG: $p > 0.05$ and EG: $p > 0.05$).

Table 10. Arithmetic mean, standard deviation and independent group t-test results of RTSSPS PT scores of control and experimental group students

Groups	*N*	*X*	sd	*t*-Test		
				t	sd	*p*
CG	22	52.27	11.797	−1.028	21	0.310
EG	22	55.45	8.461			

When Table 10 is examined, the control group has a RTSSPS PT mean of 52.27 and a standard deviation of 11.797; the average of the experimental group' RTSSPS P is 55.45 and the standard deviation is 8.461. According to Table 10, it is seen that the average RTSSPS PT scores of the students in the experimental group are higher than those in the control group students. However, no significant difference was found between the two groups in terms of the RTSSPS PT score ($p > 0.05$). It can be said that the constructivist approach and integrated STEM training do not make a significant difference to the results of RTSSPS PT.

Table 11 shows the results of the arithmetical mean, standard deviation and independent group t-test on the RTSSPS post-test and RTSSPS PT scores of the control and experimental group students (Kolmogorov–Smirnov Z *p* values: (CG: $p > 0.05$ and EG: $p > 0.05$).

Table 11. Dependent group t-test results for control and test group students' RTSSPS post-test and RTSSPS PT scores

Groups	*N*	*X*	sd	t-Test		
				t	sd	*p*
CG RTSSPS post-test	22	52.86	8.055	0.233	21	0.818
CG RTSSPS PT	22	52.25	11.915			
EG RTSSPS post-test	22	51.09	10.542	2.323	21	0.074
EG RTSSPS PT	22	54.75	10.896			

When Table 11 is examined, it is seen that the control group students have an RTSSPS post-test average of 52.86 and the standard deviation is 8.055; RTSSPS PT average is 52.25 and the standard deviation is 11.915; 51.09 and the standard deviations of the RTSSPS post-test average of the students in the experimental group is 10.542; RTSSPS PT average is 54.75 and the standard deviation is 10.896. According to Table 11, when the data of RTSSPS post-test and RTSSPS PT is analysed, there was no significant difference between the average scores of RTSSPS post-test and RTSSPS PT in the control group students ($p > 0.05$). There was no significant difference between the RTSSPS post-test and RTSSPS PT scores of the students in the experimental group ($p > 0.05$).

5. Conclusion and discussion

In the first research question, it was examined whether there was a meaningful difference between AAT PT and AAT post-test score averages of students who were applied structured approach and integrated STEM education in 6th grade science course of middle school. It was determined that there was no significant difference between the academic achievement of the groups administered by the constructivist approach and integrated STEM education before and after the research. It has been observed that integrated STEM education seems to increase academic achievement more according to constructivist approach but has limited effect on academic achievement. It is thought that the reason why academic achievement does not reach a significant level is due to the fact that STEM education is process-oriented and evaluated with a result-oriented achievement test. The relevant literature has in general presented results in the opposite direction of the results of this study. In the studies conducted by Tabaru (2017) on the subject of simple electrical circuits, by Salman Parkalay (2017) on the unit Let's Get Familiar With the Fauna of Living Beings, by Irkicatal (2016) on the simple machines of the unit Force and Movement, by Yildirim (2016) on the subjects of the 7th grade, by Ceylan (2014) on Acids and Alcalis, by Roth (2001) on the 6th and 7th grade Simple Machines subject and by Doppelt, Mehalik, Schunn, Silk and Krysinski (2008), it has been established that the final academic success test scores of experimental group students working STEM-based activities or activities toward STEM are higher than those of the control group students. Fortus, Dershimer, Krajcik, Marx and Mamlok-Naaman (2004) showed that learning levels of 10th and 11th grade students are improving with activities that can be considered as a design-based STEM education. Becker and Park (2011) In the related literature, there were no studies showing that there were no significant differences between groups with STEM-based activities and those with other approaches and models. However, there are studies which show that there is no difference between the schools named as STEM schools and the other schools in terms of academic success (Judson, 2014; Oner & Capraro, 2016; Young et al., 2011). For example, Oner and Capraro (2016) conducted a survey of STEM schools in Texas to determine the extent to which the integration of STEM schools' technology and engineering has succeeded, and found no significant difference between the mathematics and science achievement scores of T-STEM schools and other schools, and found that there was a significant difference between science and mathematics achievement scores over the years among students of both schools.

The second research question is to determine whether there is a meaningful difference between the RTSSPS pre-test-RTSSPS post-test score averages of the control and experiment group students who are educated by the constructivist approach and integrated STEM education in the 6th grade science course of middle school. Analysing the RTSSPS pre-test data obtained in the study shows that there is no meaningful difference between the students in the control and experimental group in terms of the reflective thinking skills towards problem solving. It is seen that the control group who were applied the constructivist approach has higher reflective thinking skills towards problem solving than the integrated STEM education group with higher scores in the final test. It was observed that students in the control and experiment groups had a decrease in their reflective thinking skills scores for problem solving after the application. A significant reduction in the reflective thinking skills scores for problem solving by the students with integrated STEM training and constructivist approach shows that the applied approaches do not change students' reflective thinking skills towards problem solving in the subject matter. This is not considered as a conclusion expected by the researchers. This is because the STEM education practices include the stages expressed in the report prepared by the OECD (2003) as; identification of the problem, identification of the appropriate information, determination of possible solutions, solution of the problem, evaluation of the solution and sharing of the results. These steps are also similar to engineering design process steps. In addition, relevant literature shows that problem solving abilities and reflective thinking skills are among the twenty-first century skills (P21, 2017; WEF, 2016), and are among the objectives of the STEM education (Akgunduz et al., 2015a, 2015b; Akgunduz, 2016; Ozcelik & Akgunduz, 2018). In the related literature of STEM education, there is limited research on the reflective thinking skills of STEM education towards problem solving, and the results are contrary to the results of this research. Gulhan (2016) concluded the research he conducted in the 5th grade science class that STEM applications were more effective in the development of the layer of reflective thinking, which is the highest level of creativity. Pekbay (2017) obtained the conclusion in the researched conducted in the 7th grade science applications that STEM activities developed students' problem solving skills based on everyday life. In another study, Ozcelik and Akgunduz (2018) stated that problem solving skills of students improved as a result of extra-curricular STEM education practices based on science education with gifted middle school students.

In the third research question, it was examined whether there was a meaningful difference between AAT PT score averages of students who are applied structured approach and students who are applied integrated STEM education in 6th grade science course of middle school. When the results of AAT conducted as PT 1 year after the last test, it was found that there was no significant difference between the academic achievement levels of control and experiment group. However, according to the results of the AAT PT, the group with integrated STEM education received higher scores than the constructivist approach group. The STEM education or constructivist approach does not influence the permanence of the academic achievement of students. This conclusion is in parallel with AAT post-test results.

In the fourth research question, it was examined whether there was a meaningful difference between RTSSPS PT score averages of students who are applied structured approach and students who are applied integrated STEM education in the 6th grade science course of middle school. When the results of RTSSPS test conducted as PT 1 year after are analysed, it was seen that there was no significant difference between the control and the experimental group's ability to think reflective with regard to problem solving. Although there is no significant difference, the group with integrated STEM education seems to have a higher score than the constructivist approach group. This situation is in parallel with the results of RTSSPS pre-test, post-test and PT.

5.1. Suggestions

Although in this study integrated STEM education relative to the constructivist approach did not make a meaningful difference in terms of academic achievement, it also increased the scores more. The longer-term use of integrated STEM training in science education can positively contribute to the academic achievement of students. Other studies on various topics and class levels suitable for STEM education can be conducted. It is believed that the evaluation of academic achievement with process-oriented assessment methods will provide a clearer picture of success. Better planning of problem solving steps can make meaningful differences in reflective thinking skills towards problem solving. In this study, the effects of integrative STEM education and constructivist approach on academic achievement and reflective thinking skills towards problem solving are examined. The effects of integrated STEM education can be investigated with different variables, on different school levels and subject matters. This research is limited to the middle school science curriculum and the topics covered.

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