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The Relationship between Turkish Middle School Students' 21st Century Skills and STEM Career Interest: Gender Effect

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Abstract

Several conceptual and theoretical studies on the importance of science-technology-engineering-mathematics (STEM) careers and the 21st century skills required for these careers have been carried out; because they have been accepted as important for the improvement of society and maintenance of economic growth. However, there has not been research within the current educational literature examining the relationship between 21st century skills and STEM career interests of middle school students. Therefore, the main aim of this study is to examine the presence and level of the relationship between middle school students' 21st century skills and their interest in pursuing a STEM career. In addition, the presence of significant differences between male and female students' STEM career interest and 21st century skills was also investigated. The participants of the study were 282 middle school students. The research was completed via a quantitative study based on the relational survey model; data collection tools were STEM career interest survey and 21st century skills scale. A Pearson product-moment correlation method was used to explore the presence and level of the relationship between students' 21st century skills and STEM career interest. In addition, an independent samples t-test was used to answer whether there are significant differences between students' STEM career interest and/or 21st century skills in terms of gender. The findings showed that there is a statistically significant relationship between students' 21st century skills and STEM career interest. In addition, there is not a significant difference between female and male students' STEM career interest, while there is a significant difference between their 21st century skills.

Introduction

Science, Technology, Engineering, Mathematics (STEM) education is described as combining at least two STEM subjects or applying each of the STEM subjects together to solve problems of real life (Harwell et al., 2015). STEM education is necessary because it supports economic development, competitiveness in international fields, and job opportunities (Ismail, 2018). In fact, many researchers have argued STEM education's importance in economic growth (Asunda, 2011; Croak, 2018; Kaing, 2016), noting that STEM will continue to be a force for sustainable development (Ndinechi & Okafor, 2016) as it contributes to the fields of health, economy, and welfare (Cohen et al., 2013).

Despite the bright future that STEM fields promise, there has been a decrease in the number of students who are interested in STEM careers in different countries, including the United States and Turkey. For example, the rate of students graduating from undergraduate education from STEM fields in United States was 32% in 1995; it dropped to 27% in 2004 (Hall et al., 2011). Similarly, in Turkey, while undergraduate enrollment in STEM fields was 85.63% in 2000, it dropped to 27.88% in 2010, and increased only to 38.23% in 2014 (Akgündüz et al., 2015). Although an increase was observed in 2014 compared to 2010, the rate is still quite low compared to the previous enrollment 14 years earlier. To ensure economic growth, it is necessary to increase enrollment in STEM fields by increasing student interest in these careers (ArcherKer et al., 2013). The first step in this process is identifying students' current STEM career interest to ensure an increase in interest in those fields. Determining the students' STEM career interest and effects of different factors on this interest is important to lead more students to STEM careers (Koyunlu-Ünlü, & Dökme, 2018).

In Turkey as elsewhere, economic development requires people who are capable of working in STEM fields (Turkish Industry and Business Association [TÜSİAD], 2017). Individuals working in STEM should have certain skills, such as problem solving, questioning, and producing original ideas (TÜSİAD, 2017)—these skills are referred to as "21^{st} century skills" (Binkley et al., 2010; Partnership for 21^{st} Century Skills, 2013). These 21^{st} century skills are grouped under three themes: Learning and innovation skills; information, media, and technology skills; and life and career skills (Partnership for 21^{st} Century Skills, 2013). Learning and innovation skills refer to one's ability to be prepared for today's life and work conditions and include communication, collaboration, problem solving, and critical thinking skills. Information, media and technology skills refer to the ability to collaborate and make individual contributions to technology and media-driven environments and include information literacy, media literacy, and ICT (Information, Communications, and Technology) literacy. Life and career skills refer to the skills that are necessary to navigate complex life and work environments. Flexibility and adaptability, initiative and self-direction, social and cross-cultural skills, productivity and accountability, and leadership and responsibility are considered life and career skills. Therefore, 21^{st} century skills are ways of thinking, ways of working, and skills for living in today's world (Binkley et al., 2012).

Researchers have argued that students looking to work in STEM careers must graduate with 21^{st} century skills (Aydeniz, 2017; TUSİAD, 2014) because there is a natural match between 21^{st} century skills and the basic principles of STEM (Beers, 2013). In addition, the most important driver of success and happiness in a career is to have the skills and interests required by the career (Vurucu, 2010). Skills and interests are also important factors in individuals' career decisions (Ahmed et al, 2017; Kaneez & Medha, 2018). People prefer working in jobs appropriate for their skills (Savickas, 1991) and are more likely to succeed in those careers (Baran et al., 2015). Because one of the factors affecting choice of career is skills (Dinç, 2008), students with 21^{st} century skills can be expected to have more interest in and to prefer STEM careers, which require 21^{st} century skills. Thus, having and improving 21^{st} century skills has been defined as a way to increase students' interest in and tendency toward STEM careers (Baran et al., 2015).

In his study, Jang (2016) identified the following important STEM skills: critical thinking, reading comprehension, active listening, speaking, complex problem solving, judgment and decision making, writing, monitoring, active learning, time management, coordination, system analysis, mathematics, social perceptiveness, systems evaluation, instructing, science, and learning strategies. Considering that critical thinking, problem solving, active listening and speaking (as requirements of communication), and coordination and social perceptiveness (as requirements of collaboration) are accepted as 21st century skills within different frameworks (The Assessment and Teaching of 21st Century Skills, Partnership for 21st century skills), Jang showed that 21st century skills are important for STEM careers. Reeve (2016) also evaluated STEM skills as key 21st century skills; in fact, 21st century skills have been consistently identified and emphasized within the context of STEM learning (Jamaludin & Hung, 2017). Therefore exploring and explaining the relationship between students' 21st century skills and their STEM career interest would contribute to the literature. Previous studies have not determined whether emphasizing and improving students' 21st century skills is one way to support their STEM career interest. The related literature review indicates that there is a gap in the literature: there has been no research exploring the relationship between students' 21st century skills and their STEM career interest. Therefore, the current study aims to investigate the presence and level of the relationship between 21st century skill and STEM career interest of students, in particular, middle school students.

The age of 13 is considered a turning point in the formation of interests and in 8th grade, students begin to think about their future education life and career choices (Babarović et al., 2018). Because students develop their own interests and recognize their academic strengths at the middle school level, efforts for students to increase their interest in STEM careers should begin at that time (Kier et al., 2013). During middle school, students begin to decide their career plans and determine the ways to achieve these goals (Sanders et al., 2017). The interests and skills gained in the STEM fields during the middle school time period may form the basis of a successful career in STEM fields (Woolley et al., 2010). Therefore, grades 7 through 9 (ages 12 through 15) are seen as the key time period for influencing STEM career interest (Blotnicky et al., 2018). Exploring middle school students' STEM career interest at this age is important to lead more students to STEM subjects during the high school period. In addition, career interests at high school age seem to be stable (Wiebe et al., 2018). The results of the study conducted by Sadler et al. (2012)—which demonstrated that students' STEM career interest at the beginning of the high school is a key factor predicting their STEM career interest at the end of high school—confirm this stability. Considering the importance of the middle school time frame for career choices, and the feeling that students' 21st century skills should be improved in middle school education (Kay, 2009), this study focused on middle school students' STEM career interest and 21st century skills.

The more individuals who have STEM field knowledge, who can think critically, cooperate, produce original solutions—that is, the more individuals with 21^{st} century skills—the easier it will be to develop and improve a society (Aydeniz, 2017). Therefore, students of both genders should be supported on the path toward STEM careers and 21^{st} century skills. However, in Turkey, a developing country with a need for economic growth through STEM leaders of all types, the number of studies investigating 21st century skills and STEM career interest of students of both genders is very limited (Aydın et al., 2017; Karakaş, 2015; Karakaya et al., 2018; Korkut-Owen & Mutlu, 2016). Therefore, the present study also aims to investigate whether gender plays a role in students' 21st century skills and their STEM career interest.

Gender Differences and STEM Career Interest

For years, women have been conspicuously absent and under-represented in STEM studies and careers worldwide (Kesar, 2018; Sarseke, 2018). Data from the Measuring, Selection, and Placement Center (ÖSYM) in Turkey shows that among the first 1000 students enrolled in university science and mathematics departments, the rate of male student enrollment is 81.39%, while the rate of female student enrollment is 18.61% (Akgündüz et al., 2015). One of the reasons women are underrepresented in STEM fields might be that they have chosen to avoid those fields. Studies show that men have more interest in STEM careers than women, especially in the fields of technology and engineering (Babarović et al., 2018). A study conducted by Su and Rounds (2015) shows that gender makes a remarkable impact on STEM career choices. The biggest difference is seen in engineering disciplines, in favor of the male students; female students are more likely to study social services and health services. A similar study conducted by Gülhan and Şahin (2018) also showed that female students do not want to work in technology-based careers, though male students do. In addition, Korkut-Owen and Mutlu (2016) found that women prefer natural sciences, mathematics, and statistics; men prefer computer science and engineering.

However there are studies revealing that girls' STEM career interest is in fact higher than boys' interest (Karakaya et al., 2018), or in which there was no significant gender difference in STEM career interest (Aydın et al., 2017; Wyss et al., 2012). Data obtained from the ASPIRE project, which was conducted in order to determine the factors that affect the career choices of students between the ages of 10 and 14 and shaped their expectations, indicated that 18% of the boys and 12% of the girls wanted to be a scientist. Considering different results of the studies in the literature and insufficient study investigating gender's effect on Turkish students' interest in STEM careers, it is worth researching how STEM career interests differ according to gender in that cultural and geographic context.

Turkey is a developing country with a need for economic growth through STEM leaders of all genders. The Region of Eastern Anatolia, where the study was conducted, is a region that gives great importance to traditional values. Responsibilities and duties imposed on girls and boys are determined by these traditional values. The gender-based division of labor formed by these values has a significant effect on shaping what jobs women can do and in which jobs they can work (Parlaktuna, 2010). For example traditional gender roles indicate that women are typically mothers and wives and men are breadwinners (Sarseke, 2018). These cultural expectations and conservative social norms may decrease the number of girls who choose STEM courses—and affect the performance of those who do pursue STEM classes and careers (Jiang et al., 2018). Therefore, the traditional gender roles that cause cultural pressure on girls, is one of the reasons that women are underrepresented in STEM careers (Blickenstaff, 2005).

Langen and Deckers (2005) also categorized four factors that affect choosing STEM courses: education system characteristics, job market and economy, social views and traditions, and government policy. Confirming Langen and Deckers' (2005) study, in developed countries the percentage of STEM graduates in the total labor force is 53% for the United Kingdom, 42% for Germany, 40% for Australia, 39% for Denmark, 35% for Israel, and 29% for the United States. Turkey, as a developing country with both traditional and modern approaches, falls under these ratios with 27% STEM graduates (TÜSİAD, 2017). At the same time, serious efforts made toward gender equality in education in Turkey, including the extension of compulsory education to 12 years and the application of legal penalty to parents who do not sent their children to school, moved the number of female students closer to the number of male students. Considering that traditional perspectives are resistant to change, in this region, it is worth investigating the interest of female and male students in STEM careers. It is still unclear whether female Turkish students would prefer to move into the careers that are considered suitable for girls in traditional societies (such as being a teacher) or to pursue STEM careers. Because they now benefit from equal educational rights, female Turkish students may either take on the traditional values and careers of the society where they grew up, or they may become bored with what traditional society sees fit for them and ask for more opportunities. Thus, the research results will provide important information about the career interests of middle school girls in today's Turkey, where traditional values are more dominant but, in addition, modern approaches have begun to be applied.

Gender Differences and 21st Century Skills

Employers, politicians, and educators agree on the importance of 21st century skills in today's successful students (Rotherham & Willingham 2010). However, studies in the literature rarely measure these skills, instead focusing on building definitions, arguing for the skills' importance, and promoting their development in school settings (Ananiadou & Claro, 2009; Beers, 2013; Rotherham & Willingham, 2010; Saavedra & Opfer, 2012). Of those studies that do measure 21st century skills, there are few researching gender differences. One of these studies, carried out by Arevalo and Ignacio (2018), found that the level of 21st century skills for both male and female students is mid-level. Another study, conducted by Bozkurt and Çakır (2016), indicated that female students' active learning skills, "learning to learn" skills, and problem-solving skills are significantly different from male students, while their communication and collaboration skills do not significantly differ from the male students' skills. Köksal and Çöğmen (2018) indicated, however, that female students' communication and critical thinking skills (in the dimensions of evaluation, deduction, commenting, explanation, and self-regulation) are significantly different—and higher—than male students' communication and critical thinking skills.

A review of the literature demonstrated that 21st century skills are typically evaluated within the scope of specific attributes—active learning, learning to learn, problem solving, communication, and critical thinking skills—instead of as a whole. In addition, problem solving and critical thinking scales are generally used to measure 21st century skills. Therefore, this study would contribute to the literature by using a 21st century skills scale in examining middle school students' skills and the gender differences in those skills. Study findings can then, ideally, be utilized in the process of arranging educational environments and taking gender-specific measures to develop 21st century skills in all students.

Theoretical Framework

Working from Bandura's (1986) general social cognitive theory, Lent et al. (1994) developed the social cognitive career theory (SCCT). This theory emphasizes the personal, contextual, and experiential factors that affect our career choices, including self-efficacy, outcome expectancy, and personal goals. According to this theory, outcome expectancy refers to physical or social rewards; self-efficacy is the belief that one can succeed. Both are critical indicators of interest in a career path. Personal traits such as predisposition, gender, ethnicity, and health status contribute to individuals' perceived self-efficacy.

According to this theory, people's environment exposes them to various activities that may affect their career interests during childhood and adolescence. Through repeated activity participation and feedback from people in the environment, children and adolescents develop their abilities, achieve personal performances, feel that they can accomplish certain tasks, and gain expectations about the results of their performance. Result expectations, such as physical or social rewards, reinforce the interests of children and adolescents. In addition to environmental effects, gender and race affect our interests and choices. Lent et al. (2000) gave the following example of how these factors influence career choice: A female student may believe that she has strong mathematics and science skills, but lack confidence because of the pressure of gender bias that women in mathematics or science face. In relation to the present study, differences in self-efficacy and interest between genders can affect the number of women and men who choose STEM fields (Wang & Debol, 2013). In the present study, taking the critical impacts of interest and gender on career choice/acquisition into account (Lent et al., 1994; Su & Rounds, 2015), we investigated students' STEM career interest and the presence of gender differences. The researchers were particularly interested in whether outcome expectancy—including physical or social rewards from society, like the region of Eastern Anatolia of Turkey where the study was conducted and where personal traits like gender are highly valued—make a significant difference in STEM career interest and 21st century skills of male and female students.

Social cognitive career theory also explains the influences of abilities on succeeding and persisting in a task (Lent et al., 2002). According to this theory, people are likely to be interested in an activity/task when they think they have the ability to do it. So, they set goals in line with their thoughts about their abilities. Thus ability directly influences student performance and persistence in a task. In addition, abilities affect self-efficacy and outcome expectations, which work in harmony with abilities directly. Figure1 shows how ability influences self-efficacy and outcome expectations, and so performance goals and performance attainment level.

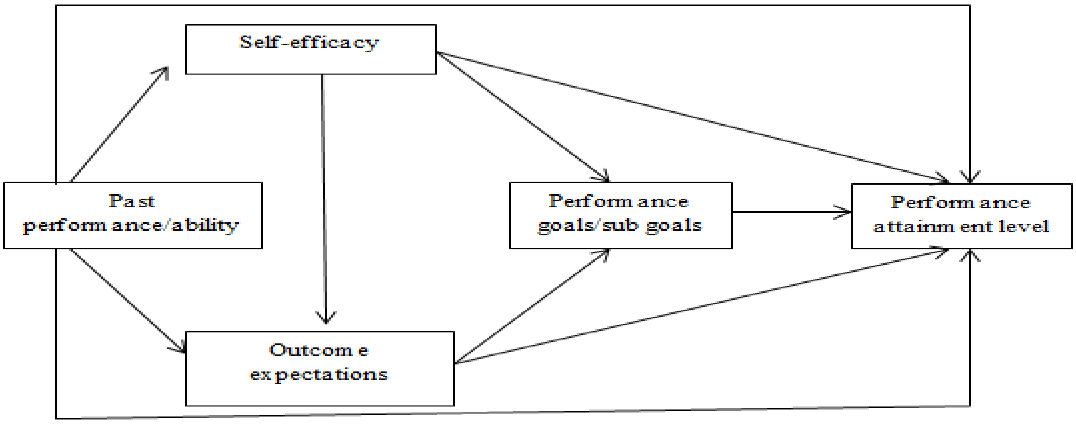

Figure 1. Predicting task performance in social cognitive career theory (Lent et al., 1994)

According to Figure 1, abilities are one of the factors influencing performance goals in terms of affecting self-efficacy and outcome expectations. In this model, "goals" refers to career plans, decisions, and choices (Lent et al. 1994). In fact, according to this model self-efficacy and outcome expectations cause an increase in interest. Then interest supports cognitive career choice goals, including intentions, plans, or turning to a specific career. Choice actions then lead to specific performance areas and success experiences. To summarize these relationships between abilities, self-efficacy, outcome expectations, interest, and career choice, Perkmen (2009) created a model. This model is presented in Figure 2.

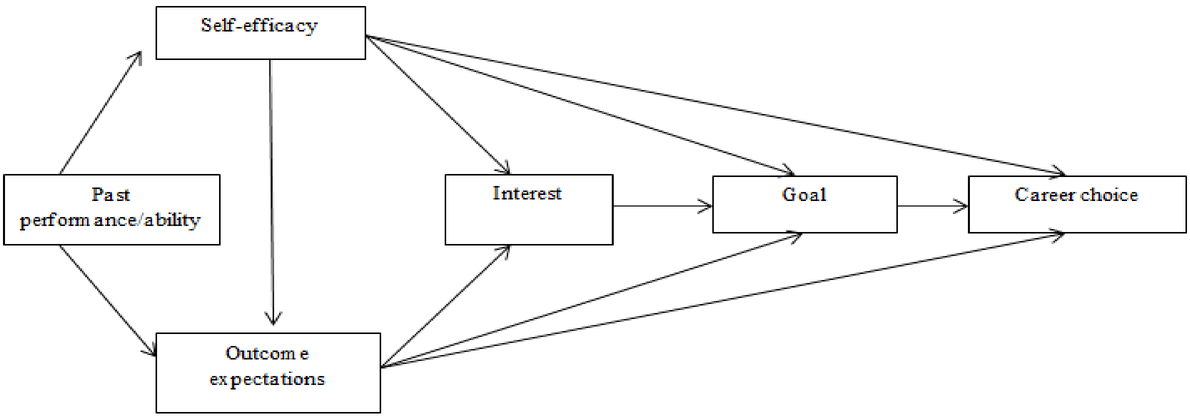

Figure 2. Partial career choice model of social career theory (Perkmen, 2009)

As it is seen in Figure 2, abilities, self-efficacy, outcome expectations, interests, and goals are factors affecting career choice. Perkmen (2009) explains the relationship between these factors with an example. When we consider a woman who chooses to be a lawyer, we can say that this person has the ability to defend herself very well based on the available data. Her ability can make her feel confident about her career and give her positive expectations about her career. As a result of this high self-efficacy and positive outcome expectations, this person may become interested in being a lawyer and ultimately choose to be a lawyer.

Based on the social cognitive career theory, which explains individuals' career paths by addressing personal input such as abilities (Lent & Brown, 2017), we aim to explore the relationship between 21st century skills, which are accepted as necessary skills for STEM careers, and STEM career interest of middle school students, taking gender into account.

The Purpose and Research Questions of the Study

The main aim of the study is to examine the presence and level of the relationship between 21st century skills and STEM career interest. The questions guiding our study are as follows:

(1) Is there a relationship between middle school students' 21st century skills and their STEM career interest?

(2) Are there any significant differences between male and female students' STEM career interest and/or their 21st century skills?

Method

The relational survey model was used in this study. This model investigates the relationship between two or more variables (Cohen et al., 2002). The main aim of the present study was to investigate the presence and level of the relationship between students' 21st century skills and STEM career interest.

Participants

The participants of the study were 282 middle school students. These students attended two different public schools, both located in the Eastern Anatolia region of Turkey. Both schools are in the center of the city and similar in terms of socioeconomic conditions and academic performance. One school provided 138 of the students and the remaining 144 were at the other school. The students were in the 6th , 7th, and 8th grades; 174 were female (61.7%) and 108 were male (38.3%). In Turkey, 1st through 4th grade students attend elementary school, children between grades 5 and 8 attend middle school, and children between grades 9 and 12 attend high school. Detailed information on the grade levels and gender of the students in the study is given in Table1.

Table 1. Gender and grade levels of the participants

Gender	Grade levels	N	%
Girl	6	65	23.04
	7	65	23.04
	8	44	15.60
Total		174	61.7
Boy	6	52	18.43
	7	31	10.99
	8	25	8.86
Total		108	38.3

Data Collection Tools

The data used in this study was collected via the STEM Career Interest Survey and 21st Century Skills Scale. Information on these data collection tools is given below.

Science, Technology, Engineering and Mathematics Career Interest Survey

The STEM Career Interest Survey was developed by Kier et al. (2013) to determine students' STEM career interest. The survey, which is based on Bandura's social cognitive learning theory, was adapted to Turkish by Koyunlu-Ünlü and Dökme (2018). The original form includes 44 items and the adapted version includes 40 items; both use a five-point Likert-type scale. The options are strongly agree (5), agree (4), neutral (3), disagree (2), and strongly disagree (1). The survey consists of four sub-dimensions: science, technology, engineering, and mathematics. The total reliability coefficient was calculated as 0.93 for Koyunlu-Ünlü and Dökme's adaptation. In addition, the reliability coefficients for the science, technology, engineering, and mathematics subscales were 0.86, 0.88, 0.94, and 0.90, respectively.

21st Century Skills Scale

This scale was developed by Kang et al. (2012) to determine 21st century skills. The scale was adapted to Turkish by Karakaş (2015). It includes 32 items and uses a five-point Likert-type scale. Options are strongly agree (5), agree (4), neutral (3), disagree (2), and strongly disagree (1). The scale has three sub-dimensions: cognitive skills, affective skills, and sociocultural skills. The cognitive skills sub-dimension includes 12 items; the affective skills and sociocultural skills sub-dimensions include 10 items each. The cognitive sub-dimension comprises cognitive domains such as questioning, critical thinking, problem solving, metacognition, and creative thinking. The sociocultural sub-dimension includes areas such as community sentiment, social values, and global citizenship. The affective sub-dimension includes skills such as self-efficacy, self-esteem, and self-responsibility. The three sub-dimensions—cognitive skills, affective skills, and sociocultural skills—have 0.77, 0.70 and 0.67 Cronbach's alpha reliability coefficients, respectively. The total Cronbach's alpha reliability coefficient was calculated as 0.90 by the researchers; Karakaş (2015), who adapted the scale, did not present the total alpha value.

Data Collection Process

The two schools that researchers could easily access were investigated and the directors of these schools were contacted. The researchers asked to give the STEM career interest survey and 21st century skills scale to students. After getting permission for data collection, the data were collected from 282 middle school student participants. First, the purpose and importance of the study were shared with the 6th, 7th, and 8th grade students. Then, the student participants voluntarily answered the questions from the data collection tools at times chosen by school administration. Students spent an average of 40 minutes answering the questions.

Data Analysis

The first research question aimed to determine the presence and level of the relationship between 21st century skills and students' STEM career interest. For this purpose, Pearson Product-Moment Correlation analysis was used. In this process, series mean was used for missing values. The second research question was "Are there any significant differences between male and female students' STEM career interest and/or their 21st century skills?" In order to find an answer to this research question, the assumption of normality was checked, then an independent samples t-test was used (the assumption of normality was met for both STEM career interest and 21st century skills variables). In cases when the variances were not homogeneous, p-values in the related column were taken into consideration.

Results

In this section, the findings of the analysis are given in accordance with the research questions.

Relationship between 21st Century Skills and Interest in STEM Careers

Before answering the first research question, tests for the assumption of normality were carried out. The findings are presented in Table 2.

Table 2. Descriptive statistics for students' 21st century skills and STEM career interest

Variables	N	$\bar{X}$	sd	Skewness	Kurtosis
Cognitive	282	48.52	6.59	-.67	.85
Affective	282	42.71	6.02	-1.2	2.4
Sociocultural	282	40.53	6.06	-.79	.61
21st century skills	282	131.76	16.75	-.89	1.46
STEM careers	282	155.11	20.53	-.51	.03

As seen in Table 2, the skewness and kurtosis values of all variables are between +3 and-3, the range required to meet the criteria for normal distribution (Bentler, 2006). Pearson Correlation Analysis was carried out after it was seen that the criteria for normal distribution was met. The findings of this analysis are presented in Table 3.

Table 3. The relationship between students' 21st century skills and their STEM career interest

Variables	N	Interest in STEM careers	*p*
Cogntive	282	.59**	.00
Affective	282	.52**	.00
Sociocultural	282	.57**	.00
21st century skills (total)	282	.63**	.00

Table 3 shows a significant and positive relationship between students' cognitive skills (r = .59, p <.01), affective skills (r = .52, p < .01), and sociocultural skills (r = .57, p < .01) and their STEM career interest. Furthermore, the level of the relationship between the total score of 21st century skills and the students' STEM career interest was found to be 0.63. A correlation coefficient between 0.00 and 0.30 shows a low-level relationship, between 0.30 and 0.70 a mid-level, and between 0.70 and 1.00 a high-level relationship between two variables (Büyüköztürk, 2003). Therefore, a mid-level relationship was found between cognitive, affective, and sociocultural skills — and the total 21st century skills—and the students' STEM career interest. Moreover, these findings might be interpreted to indicate that students' STEM career interest may increase as their 21st century skills increase.

Gender Differences in Middle School Students' STEM Career Interest

First, the assumption of normal distribution was checked. These results were used to choose an analysis method to determine whether there is a significant difference between female and male students' STEM career interest. The findings are given in Table 4.

Table 4. Descriptive statistics for girls' and boys' STEM career interest

Variables	N	$\bar{X}$	sd	Skewness	Kurtosis
Girl	174	155.06	20.44	-.39	-.42
Boy	108	155.20	20.76	-.69	.80

As seen in Table 4, the data for female and male students' STEM career interest show normal distribution. In addition, since the p-value of Levene's test was greater than .05 (p =.63), the hypothesis that there was no significant difference between the variances of the groups was accepted. Therefore, the significant difference between the female and male students' STEM career interest was analyzed by an independent-samples t-test. The findings of this t-test are given in Table 5.

Table 5. t-test results of the difference between girls' and boys' STEM career interest

Group	N	$\bar{X}$	sd	*df*	*t*	*p*
Girl	174	155.06	20.44	280	-.06	.95
Boy	108	155.20	20.76			

As seen in Table 5, there was not a statistically significant difference between the female students' mean scores and the male students' mean scores (t = -.06, p > 0.05). Thus, it can be said that gender made no significant impact on the participants' STEM career interest.

Gender Differences in Middle School Students' 21st Century Skills

First, we checked the assumption of normal distribution in order to choose an analytical method to determine the differences between the 21st century skills of male and female students. The findings are given in Table 6.

Table 6. Descriptive statistics for girls' and boys' 21st skills

	Variables	N	$\bar{X}$	sd	Skewness	Kurtosis
Girl	Cognitive	174	49.1	6.09	-.36	-.45
	Affective	174	43.67	5.42	-1.29	2.24
	Sociocultural	174	40.74	5.91	-.71	.35
	21st century skills	174	133.50	15.30	-.63	-.03
Boy	Cognitive	108	47.59	7.26	-.86	1.46
	Affective	108	41.18	6.63	-1.02	2.06
	Sociocultural	108	40.18	6.32	-.90	.91
	21st century skills	108	128.96	18.57	-1.02	2.06

As can be seen in Table 6, the data on female and male students' 21st century skills show normal distribution. After the assumption of normality was met, the significant difference between the female and male students' 21st century skills was analyzed by an independent-samples t-test. The findings of this t-test are presented in Table 7.

Table 7. t-test results of the difference between girls' and boys' 21st century skills

		N	X̄	sd	*df*	*t*	*p*
Cognitive	Girl	174	49.1	6.09	280	1.87	.062
	Boy	108	47.59	7.26			
Affective	Girl	174	43.66	5.42	193.73	3.28	.001
	Boy	108	41.17	6.62			
Sociocultural	Girl	174	40.73	5.90	280	.74	.46
	Boy	108	40.18	6.31			
21st century skills	Girl	174	133.5	15.3	194.73	2.13	.03
	Boy	108	128.9	18.5			

As seen in Table 7, there was not a statistically significant difference between the female and male participants' mean scores in the cognitive and sociocultural dimensions (t = 1.87, p > 0.05; t = .74, p > 0.05). However, a significant difference was found between the female and male participants' mean scores in terms of affective skills and 21st century skills (t = 3.28, p < 0.05; t = 2.13, p < 0.05). This finding shows that gender made no significant difference on cognitive and sociocultural skills, while it made a significant difference on affective and 21st century skills, with female students scoring higher than their male counterparts on average in those areas.

Discussion and Implications

This section presents the discussions and implications for each sub-problem.

The Relationship between 21st Century Skills and STEM Career Interest

The first aim of this study was to investigate the presence and level of the relationship between the 21st century skills of middle school students and their STEM career interest. The findings showed that there was a statistically significant relationship between total 21st century skills—as well as the cognitive, affective, and sociocultural sub-dimensions—and STEM career interest. This finding indicated that as students' 21st century skills increase, their STEM career interest will increase. Or, as students' 21st century skills decrease, their STEM career interest will decrease. There are no studies in the literature investigating the relationship between students' 21st century skills and their STEM career interest. Similar to the present study, findings from Zorlu and Zorlu (2017), Cooper and Haeverlo (2013), and Arevalo and Ignaco (2018) showed a significant and positive relationship between middle school students' problem solving skills, digital age literacy, and creative thinking and their STEM career interest. Our finding is thus supported by the literature, which is not surprising considering that individuals working in STEM careers should have 21st century skills, and that individuals tend to choose careers suitable to their skills (Savickas, 1991).

The skills needed for STEM-related tasks are defined as STEM skills and they include cognitive skills (e.g., critical, analytical thinking, and problem solving skills), manipulative technological skills (e.g., using technical equipment), and collaboration and communication skills (e.g., teamwork and cooperation) (United Nations Educational, Scientific and Cultural Organization, 2019). As described above, these are also 21st century skills. Therefore it is possible for individuals with 21st century skills to choose STEM careers and to be successful in these fields (Baran et al., 2015), as it is likely that people show interest in subjects they believe they have a suitable aptitude for performing (Lent et al., 2002). As a result, improving students' 21st century skills might be accepted pedagogically as a way of developing student's STEM career interest in educational settings.

Another finding is a significant relationship between STEM career interest and affective dimension skills, including self-efficacy, self-esteem, and self-responsibility. Similarly, Halim et al. (2018) found a positive and significant relationship between students' STEM self-efficacy and their STEM career interest. In addition, McCormick (2019) found a relationship between middle school students' self-efficacy and STEM career interest; this result is also consistent with the present study results. In fact, there are many studies with results supporting the present study's result. For example, Milner et al. (2014) found that college students with a high level of interest in STEM professions also showed a high level of self-efficacy. Blotnicky et al. (2018) found that students with mathematics self-efficacy were more likely to choose a STEM career. Roue (2007) researched the math and science interest of 2,800 young girls and found that self-esteem was the greatest predictor of interest (36.4%) and self-efficacy was the second highest predictor, with 26.5% of the variability. Barth et al. (2018) found that self-efficacy is the best predictor of STEM career interest across gender and grade level. Each of these studies supports the present study's results.

In addition, the theoretical framework that this study is based on explains that self-efficacy causes an increase in interest, and interest supports career choices and goals (Lent et al., 1994). This framework also states that if self-efficacy is weak in a field, it is difficult to develop an interest in that field. Therefore, it is likely that people will be interested in areas where they have strong self-efficacy beliefs and will perform better (Lent et al., 2002). Self-esteem is also among the known factors that affect interests, including career interests. An increase in self-efficacy in a subject supports the increase in value and interest given to a subject (Eccles & Wigfield, 1995); meanwhile, individuals with advanced self-esteem can set realistic goals in terms of career choices. They are likely to pursue these goals and see this effort as valuable (Gök & Tekin, 2015). Therefore, in the present study, the students' self-esteem and self-efficacy might be a cause of the meaningful relationship between STEM career interest and affective skills. With this knowledge, learning environments can be designed to support students' affective skills, like self-efficacy and self-esteem, in order to lead them to STEM careers.

The study results also revealed that there was a significant relationship between sociocultural skills (e.g., social values and global citizenship) and a STEM career interest. Similar to the present study, Agarwala (2008) and Wang and Degol (2013) expressed that career choices are influenced by values. Therefore, values are part of the career decision-making process (Foskett & Hemsley-Brown, 1999). This study result is not surprising; people's perceptions about careers may be determined by their cultural values (Majid et al., 2014) and cultural values are widely considered important in career choice and development (Brown, 2002). Perhaps one reason that values affect the choice of career is that individuals want to live their values as well as their hopes and dreams in their professions (Theresa, 2015). In addition, global citizenship requires students and individuals to be aware of current developments worldwide and to follow these developments. Even at a young age, today's students can follow developments in every field via mobile phones and social media tools; this gives them a chance to realize the importance of STEM education and its value around the world. Increasing students' awareness of STEM studies may have supported their interest in these careers, and thus might have caused a significant relationship between sociocultural skills and STEM career interest.

In conclusion, a significant relationship was found between the cognitive, affective, and sociocultural dimensions of 21st century skills and STEM career interest. In addition, a significant and positive relationship was found between the total scores obtained from the scale on 21st century skills and the scores from the scale on interest in STEM careers. In line with our result, Kan and Murat (2018) found a moderate relationship between students' self-efficacy and perception of their 21st century skills and their attitudes towards STEM careers. The researchers explained their study results by claiming that individuals who think that they have 21st century skills developed positive attitudes toward STEM careers. Other studies found a relationship between problem solving and creative thinking—both 21st century skills—and STEM career interest, which also supports our results (Arevalo & Ignacio, 2018; Cooper & Haeverlo, 2013; Zorlu & Zorlu, 2017). Having 21st century skills arguably improves students' interest in and tendency to pursue STEM careers (Baran et al., 2015), which is logical because individuals' skills guide their career choices (Savickas, 1991) and skills are career path indicators (Al-Abri & Kooli, 2018). Agarwala's (2008) study result, showing that skills, competencies, and abilities are the most important factors influencing career choice, supports the present study result.

Gender Differences in STEM Career Interest

One of this study's findings was that male and female students were not significantly different from one another in terms of STEM career interest. This finding differs from study results in which female participants have a higher STEM career interest than male participants (Karakaya et al., 2018), or vice versa (Christensen & Knezek, 2017; Sadler et al., 2012; Su et al., 2009). Most studies in the literature have found that male participants' STEM career interest is relatively higher than female participants' (Sadler et al., 2012). One potential explanation is that a profession's stereotypes may influence whether girls and women choose those careers (Hill et al., 2010). According to the social role theory (Eagly & Wood, 2012), there are certain roles assigned to women and men in a community, and both genders are expected to fulfill their roles. In this study, the absence of a significant difference between male and female students' STEM career interest might be attributed to changes in social roles over time. The post-industrial period emphasizes equality between men and women: making decisions together and benefiting from political, professional, and/or educational opportunities equally (Rapoport & Rapoport, 1969). With these changes in social roles and modernization, women have started to benefit more from educational opportunities and are gaining gender equality in professional fields (Inglehart et al., 2003). These social changes shift roles by expecting women to take part in new education and employment fields (Eagly & Wood, 2012). The number of women pursuing an education has also increased

(Keskin & Ulusan, 2016). For example, in Turkey, the percentage of schooled female and male children of middle school age was 94.69% and 94.26%, respectively, as of the 2017-2018 teaching year (Ministry of National Education [MoNE], 2018). Similarly, the number of female students enrolled in mathematics and science courses has been increasing remarkably (Burrelli, 2008). Considering these values, we can argue that the schooling ratio is balanced in terms of gender in Turkey as women have increased access to education.

In parallel to the increasing number of female students in education settings, the number of working women has also increased. It has been proven that women capable of performing many jobs (Myrdal, & Klein, 1956). Furthermore, the roles of women and men have begun to change in Turkey and globally; women are working toward a career and men are participating more in home-care activities (Sekścińska et al., 2016). Women have begun to be more active participants in business and social settings (Güldü & Kart, 2009). For example, the Turkish Statistical Institute declared that women who have a university degree participated in the labor force at a rate of 71.3% in 2016. The increasing number of female students in educational settings—especially in science and mathematics—and in the labor force might have supported gender equality in many STEM fields. The change of gender roles over time is likely to impact the career choices of women (Callahan, 2015); educational and societal changes affect ability levels and this may support and increase the number of women succeeding in STEM fields (Wang & Degol, 2013). Supporting women who choose to work and further their education, especially those studying mathematics, science, or technology, would help increase their ability to begin and thrive in STEM careers.

Another reason male and female participants' STEM career interest did not significantly differ might be the increasing number of female role models in STEM fields. For example, Donna Strickland was awarded the Nobel Prize in Physics in 2018, Frances Arnold the Nobel Chemistry Prize, and Nabia Murad the Nobel Peace Prize. In other words, the fact that three female scientists received Nobel Prizes in 2018 alone is an example of women's success in scientific activities. Considering that role models have a positive effect on girls' perspectives (Astin & Sax, 1996), one explanation for the elimination of gender inequality in STEM fields might be the increase in the number of female role models. Quimby and Desantis (2006) confirm role models' influence on career choices; their study results show a significant variance for role models in career choice (Quimby & De Santis, 2006). BarNir et al. (2011) study results also showed that role models positively affect a person's belief that he or she has the skills necessary to succeed in entrepreneurial careers by increasing the knowledge, mastery, or general abilities required for the tasks associated with this career. Mishkin et al. (2016) found that women are more affected by other people with a rate of 43.2 to 22.7. Based on their study result, they recommend to educating young girls about role models in STEM fields to encourage girls to become interested in STEM careers. Introducing students to the stories of women who are successful in STEM fields may encourage girls to consider those careers.

Another factor affecting the elimination of gender differences in terms of STEM career interest might be the increase in research on STEM fields in recent years. For instance, in Turkey, there were 4 studies in 2014, 7 in 2015, and 18 in 2016 focused on STEM (Elmalı & Kıyıcı, 2017). The Ministry of National Education in Turkey supports in-service trainings and projects for STEM education, which might promote STEM awareness in educational settings and in general. In addition, changes have been made in science curriculums to include STEM activities in classrooms in Turkey. To achieve this goal, a STEM activity related to unit content has been added at the end of the every unit in secondary science books. These changes present opportunities for students to be aware of STEM fields, activities, and careers. In fact, this opportunity meets the recommendation to raise awareness about STEM fields in order to prevent failures and decreases in the number of graduates from these fields of study (Buyruk & Korkmaz, 2016). An increase in studies that explore the necessity, benefits, or importance of STEM—or projects that aim to increase women's interest in STEM fields—would support gender equality among the students who choose these professions. In addition, the increased amount of STEM activities in Turkish science books may have caused the disappearance of gender differences in terms of STEM career interest in this sample of participants.

Gender Differences in 21st Skills

In this study, the significance difference of 21st century skills of female and male students was also investigated. There was no significant difference between the female and male students' mean scores in the cognitive and sociocultural dimensions. When the affective dimension and 21stcentury skills were examined, a significant difference was found between the female and male students' mean scores, in favor of the female students. Based on these findings, it can be said that gender made a significant difference on affective dimension and 21st century skills, and it does not lead a significant difference in favor of female students in terms of the cognitive and sociocultural skills.

The cognitive dimension consists of skills such as problem solving, questioning, critical thinking, and metacognition. Many studies have found that girls are not significantly different from boys in problem-solving skills (Fadli, 2019; Jena, 2014; Warren, 2000), scientific process skills (Böyük et al., 2011; Ekon & Eni, 2015), questioning skills (Duran, 2015), critical thinking skills (Salahshoor & Rafiee, 2016), metacognitive skills (Siswati & Corabima, 2017), or creative thinking skills (Vani, 2016); these studies support our results. The absence of a significant difference between the male and female students in terms of cognitive skills could be attributed to the MoNE in Turkey, which has adopted a research– and inquiry-based learning approach. In line with this approach, teachers and educators are instructed to carry out their lessons through problems, projects, discussions, and cooperative learning, in which students are active and teachers are facilitators (MoNE, 2013).These strategies and approaches are educational implementations that improve students' skills in inquiry, problem solving, critical thinking, structuring, and using their knowledge. This program might have supported male and female students' cognitive development equally since its implementation in 2013.

Another finding of this study was that female students' affective skills (e.g., self-regulation, self-esteem, self-efficacy, and responsibility) were significantly higher than the male students'. Similar to our results, other studies demonstrate that female participants' sense of responsibility (Beutel & Marini, 1995), self-regulation skills (Mahmoodi et al., 2014), self-esteem (Bhamani, Jami et al., 2014; Özkan, 1994), and self-efficacy (Willemse, 2008) are more advanced than that of their male counterparts, a difference which can be explained by the social roles that are traditionally attributed to the male and female genders. Self-regulation is the ability to control one's behavior, according to social cognitive theory. Features such as being strong-minded, postponing demands, and controlling feelings are included in self-regulation (Vohs & Baumeister, 2011). In addition, "sense of responsibility" refers to feelings of being in control of and accountable for our achievements or failures (Hinton, 2019). These values are expected from women in traditional societies. Women's behavior is given more attention, and women more frequently express their concerns about undesirable behaviors to their family members, teachers, or other individuals in their social environment (Kesici, 2018) in traditional societies. The Eastern Anatolia region, where the study was carried out, is a region where these social rules are highly dominant, which may increase the girls' sense of responsibility and self-regulation skills. Therefore, the fact that female participants had higher affective skills than male participants can be explained by the fact that the local social structure has higher expectations for girls and women in the affective context (Ersoy, 2009). Self-esteem can be defined as individuals' self-understanding and it is also affected by gender roles (Agam et al., 2015).

Though our results showed that female students have stronger affective skills than male students, many past studies have found that male students have higher self-esteem and self-efficacy (Kling et al., 1999, Nupur & Mahapatro, 2016; Rentzsch et al., 2016;). These studies justify their findings based on the roles assigned to women in society. For example, lower status, education, and income levels have been accepted as reasons for decreased self-esteem and self-efficacy in women and girls (Mcmullin & Cairney, 2004). However, nowadays, women can benefit from all kinds of educational opportunities; they can work in higher status jobs with higher incomes than men; and there are increasingly more female role models achieving success. These social changes might have increased female students' self-esteem and self-efficacy. In the province where the study was conducted, 96.25% of middle school–aged girls attended school during the 2015-2016 school years (Arslan, 2016) and many girls also have opportunities to visit different countries within European Union Projects. Each of these developments could improve female students' self-esteem and self-efficacy, which in turn might have resulted in higher affective skills.

Another finding of this study was that no significant difference was found between the male and female students' sociocultural skills, including sub-dimensions such as sense of community, respect for differences, social value system, and global citizenship. The literature supports our results, indicating that gender made no significant difference on an individual's level of global citizenship (Chui & Leung, 2014), sense of community (Wiseman et al., 2004), or respect for differences (Eren & Erkan, 2016). Global citizenship includes awareness of actual developments in global issues. In Turkey, almost every student studying middle school has a mobile phone; this helps them to be aware of the developments in the world and to follow current developments in education. Thus, mobile access may have supported both male and female students' global citizenship. In addition, living in the same society may have caused the development of similar social values, another sub-dimension of sociocultural skills. Therefore, cultural similarities in students' global citizenship and social values might have prevented a statistical difference between the male and female students.

The final finding from the present study was that the female students' total 21stcentury skills scores were significantly higher than the male students' scores. The study result is consistent with the study which found that female students were better in acquiring 21st century skills than male students (Kanan, 2018). The scale used consists of three dimensions: cognitive, affective and sociocultural; we found that gender made no significant difference on the cognitive and sociocultural dimensions. However, there was a significant difference in the affective dimension in favor of female students, which was likely the cause of the discrepancy in scores. The reasons for the significant difference in affective dimension are discussed above. In addition, Zimmerman and Martinez-Pons' (1990) and Chyung' (2007) studies supports this conclusion. In their study, Zimmerman and Martinez-Pons'(1990) found that girls were better than boys in terms of self-regulated learning including self-monitoring, goal-setting, planning. In another study, Chyung (2007) also found that younger and female students improved their self-efficacy than boys at the end of different learning approaches. In this sense, an increase in girls' self-esteem as a consequence of provided equal opportunities, especially in education; the increase in female role models in business and social life; and the possibility of better-developed responsibility and self-regulation skills due to social expectations might be included among the reasons for the gender difference in 21st century skills evidenced in this study.

Suggestions

In this study, the relationship between 21st century skills and STEM career interest and between the cognitive, affective, and sociocultural dimensions of 21st century skills and STEM career interest was investigated. Only quantitative data were used in this study; similar research questions could be approached using mixed research supported by qualitative data. The results of the study showed that there is no significant difference between male and female students' STEM career interest, this result is different from most of the study results in the literature. Further studies might be carried out to explore why the gender gap in STEM fields appears to be disappearing in this context.

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Scientific Ethics Declaration

We, the authors, declare that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the authors.

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Pre-Service Teachers' Cognitive and Metacognitive Processes in Integrated STEM Modeling Activity

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Abstract

This study was conducted during two educational technology courses in spring term of 2016-2017 academic years. The participants of the study were pre-service teachers who were in mathematics teaching program in a university located at the west part of Turkey. Pre-service teachers were asked to solve a complex problem that requires mathematical model eliciting activities and report their solution. While pre-service teachers were solving the problem and writing their report, they were audio recorded. Additionally, their solutions and reports for problem were collected as data sources. All three various data sources used for triangulation to make the data collection process more reliable. The problem-solving behavior from the study conducted by Kim et al. (2013) was used as the theoretical framework. First, the behavior is classified as cognitive or metacognitive. Then the behavior (either cognitive or metacognitive) is also classified as at individual, social, or environmental levels. Additionally, Lesh Translation Model was used to decide the representations of mathematical content knowledge codes for metacognitive activities. The implications of this study are the developed metacognitive activities for pre-service teachers. Additionally, there is potential usage of technology for the role of metacognition in mathematics education.

Introduction

Mathematical modeling has been increasingly viewed as an educational approach in K-16 classroom (Erbaş et al., 2014; Kaiser et al., 2011). The National Council of Teachers of Mathematics (NCTM) has identified mathematical modeling as one of major abilities in algebra standards (NCTM, 2000). All students from elementary levels to higher education are expected to elicit and use mathematical models (Butler Wolf, 2015). However, studies on a cohesive conceptualization that how mathematical modeling should be incorporated into K-16 mathematics instructions are very limited (Ang, 2015; Blum & Ferri, 2009; Lesh & Fennewald, 2010; Kaiser & Sriraman, 2006).

Teachers have an important role in developing mathematical modeling abilities and competencies of students. According to Gould and Wasserman (2014), teachers need to find meaningful and effective ways to integrate mathematical modeling tasks into instruction. However, implementation of mathematical modeling in the classroom can be challenging (Niss et al., 2007). Difficulties in integrating mathematical modeling into instruction may STEM from the teachers' lack of experience with mathematical modeling (Doerr, 2007; Tam, 2011). Very few pre-service teachers in teacher education programs and in-service teachers learned how to engage students in mathematical modeling activities and prepare and implement such activities (Doerr, 2007; Tam, 2011). Successful learning of mathematical modeling depends on teachers' skills. Therefore, in-service and pre-service teachers must be equipped with knowledge and educational experiences in mathematical modeling activities (Niss et al., 2007). Niss et al. (2007, p. 20) stated that "the inclusion of modeling in teacher pre-service and in-service education courses must be effectively promoted." According to Teague, Levy and Fowler (2016), educational experiences regarding mathematical modeling (open-ended projects, collaboration, use of real data, technology, technical writing, and common mathematical content) should be included in the mathematics teaching methods courses for pre-service teachers.

There is limited evidence that methods courses can address how engaging mathematical modeling tasks lead to teaching and learning mathematics and skills; however, more research on how pre-service teachers learn mathematical modeling is needed (Blum, 2011; Cai et. al., 2014). Pre-service teachers should comprehend what mathematical modeling is, what are the aims and benefits of mathematical modeling and mathematical modeling processes. Their mathematical modeling skills and competencies should be developed with mathematical modeling activities integrated into methods courses (Bal & Doganay, 2014; Lingefjärd, 2007a, 2007b; Lowery, 2002; Tan & And, 2013).

In-service and pre-service teachers' modelling skills and competencies should be developed and improved. According to Blum (2011), metacognition is playing crucial role for developing mathematical modelling competencies. "However, despite the presumed importance of metacognition for modelling, only a few studies have been conducted for answering how metacognition influences the development of modelling competencies and the modelling process, and how to foster' metacognitive modelling competencies best" (Vorhölter, 2018, p. 343). There is a gap in the literature how pre-service mathematics teachers use cognitive and metacognitive skills in a mathematical modelling task.

This paper focuses on cognitive and metacognitive skills and levels and mathematical content knowledge of pre-service mathematics teachers in a model eliciting task. For these purposes, we used two frameworks (Johnson & Lesh, 2003; Kim et al., 2013) related to cognitive and metacognitive levels in complex problem-solving task and mathematical content knowledge in mathematical modelling. These two frameworks are Models and Modeling Perspectives (MMP; Kim et al., 2013) and Lesh Translation Model (Johnson & Lesh, 2003) that are explained with details in the method section used for coding.

Theoretical Framework

Modeling

It is aimed to raise individuals who are able to create solutions for real world problems, to apply the learned mathematics in their life, and to be aware of the connection between mathematics and real world with mathematics education. It is suggested to bring more real-world problems in mathematics classes to get learners more interested in the mathematics (Kaiser & Schwarz, 2006). Mathematical modelling is the process of expression, solution, and evaluation of real-world problems (Haines & Crouch, 2007). Therefore, mathematical modelling has an important role on the solution of the real-world problems.

Modelling activities is very appropriate to apply in group settings (Doruk, 2010). Particularly, modelling can be more useful and practical in small group settings (English et al., 2005; Eric, 2010; Fox, 2006). Group members can help each other in the modelling. Therefore, group work creates a possibility for peer learning. For instance, Deniz and Akgun (2014) concluded that secondary school students found the modelling activities very interesting and more comprehensible. In addition, these students indicated that the group study was very useful, and they have positive thoughts about these kinds of activities applied in their mathematics classes (Deniz & Akgun, 2014).

Model Eliciting Activities (MEAs)

Model eliciting activities (MEAs) are problem-solving activities that elicit a model. "These solutions require to express students' current ways of thinking in forms that are tested and refined multiple times" (Lesh & Yoon, 2007, p. 163). The goal of MEAs is to "engage students' 'real heads' in their school activities and close the gap with their 'school heads" (Lesh & Doerr, 2003, p. 24). MEAs are designed explicitly to reveal and examine students' perceptions and prior knowledge while providing extension, revision, and integration of their ideas to develop a foundation for more abstract or formal ways of understanding (Lesh et al., 2000).

Real-world, open ended, and creative problems requiring the solvers to develop a meaningful, real life situation and create a symbolic model or tool to find a solution are used in MEAs. Problems in MEAs require students to work in collaborative teams (groups) to build and refine a mathematical model for the given a real-world context with the criteria that enables assessment leading to improved models (Diefes-Dux et al., 2008; Lesh & Doerr, 2003; Lesh et al., 2000). There is no only one right answer for the problems in MEAs. MEAs allow divergent thinking to produce different possible models for solutions (Diefes-Dux et al., 2008; Lesh et al., 2000).

MEAs include an iterative process to improve better solutions (Rodgers et al., 2015). MEAs focus on the process rather than the product. The important artifact is the model rather than the results in MEAs (Diefes-Dux et al., 2008; Lesh & Doerr, 2003). The process of solving MEAs reveals how students interpret a given mathematical situation. They develop understanding through mathematizing (e.g. quantifying, dimensionalizing, organizing, computing, explaning) the problem (Diefes-Dux et al., 2008; Lesh & Doerr, 2003; Lesh et al., 2000). Then students communicate about a model and process to address the problem (Diefes-Dux et al., 2008; Lesh & Doerr, 2003; Lesh et al., 2000).

MEAs are characterized by the following six principles:

1. The Reality Principle: MEAs should be realistic and relevant to the students' life. This principle enables students to make sense of situation by ensuring the scenario could happen in real world, which brings the personal meaningfulness to the learning. "One way for curricula developers to test whether the reality principle is to ask, 'could this really happen in a real-life situation?'" (Lesh et al., 2000, p.597).
2. The Model Construction Principle: This principle is interconnected to guide students to create a model and incorporate the development of an explicit construction, description, explanation, or justification of a mathematical situation. The model must demonstrate students' thinking processes. According to Lesh and Doerr (2003), "MEAs are intended to be thought revealing activities" (p.452).
3. The Self-Assessment Principle: This principle requires students to share, assess and modify their models in multiple ways. Students should be assessing their models by given criteria based on improvement on their models. The activity promotes self-assessment on part of students (Carlson et al., 2003, p.472; Lesh et al., 2000).
4. The Construct Documentation Principle: This principle encourages self-reflection on the part of student and emphasizes researchers' investigation into their understanding. Students are also required to document their solutions and thoughts in written or oral form. "One way to make it natural for students to externalize their ways of thinking is to have them work in groups where such processes as planning, monitoring, and assessing must be carried out explicitly" (Lesh et al., 2000, p.623).
5. The Simple (Effective) Prototype Principle: This principle ensures that the context is memorable and requires the development of a significant construct. The principle asks the question "is the situation as simple as possible, while still creating the need for a significant model?" (Lesh et al. 1997, p.3).
6. The Model (Construct) Generalization Principle: This principle expresses that students' models should work with other data sets and have the potential for modification of similar situations. The models that students create must be able to be shared, modified and used beyond immediate problem situation (Lesh et al., 2000). The principle asks the question "does the model provide a general model for analyzing this type of dynamic situation?" (Carlson et al., 2003, p. 472).

Problems in MEAs are intrinsically designed to explore social experiences in small group work (English et al., 2005). Therefore, social interactions are highly important for MEAs. Constructivist learning theory argues that students build knowledge upon their previous knowledge via their experiences and social interactions (Duffy & Cunningham, 1996; Ferguson, 2007). MEAs enable an open-ended learning environment. Therefore, they support development of mathematical skills and divergent thinking (Diefes-Dux & Imbrie, 2008). MEAs can be seen as a part of cooperative learning pedagogy because they provide students to gain personal experiences with model development. MEAs also enable students to identify aspects of high-quality models and gain modeling abilities (Lesh & Doerr, 2003; Zawojewski et al., 2008).

Lesh Translation Model with Technology based Representational Media Layer

Bruner identified cognitive representation had three modes: Enactive, iconic and symbolic (Bruner, 1964). *Enactive Representation* is defined as the representation that an individual understands through motor responses. *Iconic Representation* is defined as the representation that an individual uses images to represent understanding. *Symbolic Representation* is defined as the representation that an individual uses symbol systems such as language, musical notation, and mathematical notation to represent understanding (Driscoll 2000, p. 225). The learner moves from physically modeling the problem with materials (enactive) to diagramming or graphing (iconic), and to put the problem into an abstract mathematical form (symbolic; Lapp & Cyrus, 2000, p.507). At the end of 1970s, Lesh adapted Bruner's framework by separeting the iconic mode into manipulatives and pictures and the symbolic mode into spoken verbal symbols and written symbols. Thus, Lesh has constructed his translation model. Mathematical ideas can be expressed in five different modes based on the Lesh Translation Model (Figure 1). These modes are manipulatives, pictures, real life situations, spoken language, and written symbols. These modes work interactively rather than in a linear relationship (Clement, 2004; Cramer,2003; Lesh, 1979; Lesh et al., 1987; Post et al., 1986; Post & Cramer, 1989).

The Lesh Translation Model is a measure of how strong the content knowledge of students is through five main representations and translations between and within these representations: (1) Representation through realistic, real-world, or experienced contexts (based on metaphors), (2) symbolic representation, (3) language (verbal symbols) representation that includes mathematics vocabulary, (4) pictorial (diagram) representation that are static figurative models, and (5) representation with manipulatives (concrete, hands-on models) such as Lego blocks, number lines, fraction bars, and tangram in which the relationships and operations built into the system that fits many everyday situations (Lesh & Doerr, 2003).

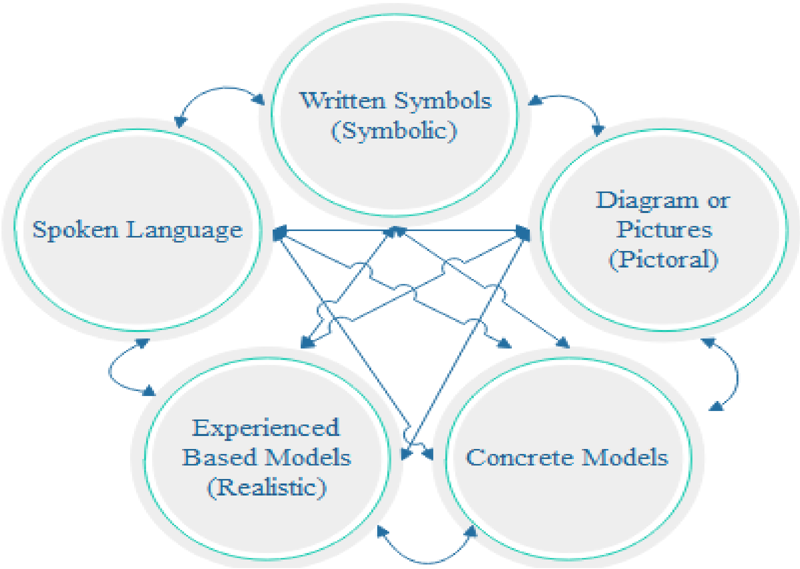

Figure 1. The Lesh translation model

The Lesh translation model asserts that the understanding of concepts lies in the skills of learners to represent mathematical concepts through five different sets of representation and to translate within and between multiple modes of representation (Cramer, 2003; Lesh & Doerr, 2003). A translation in this model is the reinterpretation of a mathematical concept within the same representation or between different representations (Cramer et al., 2009). It is important that students learn mathematics through representations. Conceptual understanding can be developed when students translate between representations (NCTM, 2000). Mathematical representations and communication for the deep understanding of mathematical concepts are centered in the Lesh Translation Model (Moore et al., 2013). Therefore, the model encouraged students to work together as a team and focus on communication and metacognition skills (Glancy & Moore, 2013).

Tables, equations, and graphs were added to Lesh's translation model by some researchers. Lesh and Doerr (2003) described a translation model with eight modes. The model with eight modes serves a variety of representational media. Representational media, such as graphs, tables, and equations represent innovative curriculum materials in the high school and college (Lesh & Doerr, 2003).

Jonhson and Lesh (2003) improved the previous model with eight modes of representational media by including an additional layer (figure 2) that is technology-based electronic media, called *eMedia*, such as computer-based animations, graphics or simulations. eMedia is dynamic, interactive, and linked. Graphing calculators and computer software can be used for eMedia layer (Johnson & Lesh, 2003). In this study we have used GeoGebra as a computer software for eMedia layer. The Lesh Translation Model with technology-based representational media layer is used to measure pre-service teachers' mathematical content knowledge.

Lesh Translation Model was also used as a theoretical framework in this study. This model has five categories for representation (see Figure 1 and 2). These are realistic, pictorial, language, symbolic, and concrete. Representations related to real world are in realistic group. All representations with pictures are in pictorial group. Language group includes the words used by participants to describe the representations. When the participants use an equation, calculation or table, these are in the symbolic group. Using body part, meter, ruler or any measurement or solid materials are in the concrete group (Lesh et al., 2003; Stohlmann et al., 2013).

The Lesh Translation Model includes the representations of mathematical content knowledge. Hence, MEAs are typically organized including and/or asking to develop multiple representations. The Lesh Translation Model has an important adaptation to the idea of MEAs. Therefore, the Lesh Translation Model was also used to analyze pre-service teachers' explanations for the solution of footprint problem in this study.

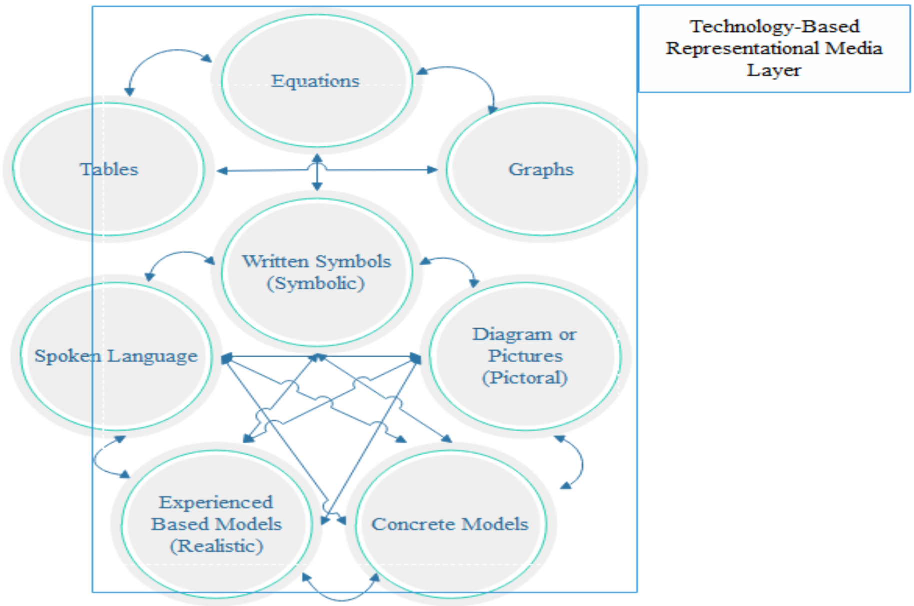

Figure 2. Lesh translation model with technology-based representational media layer

Cognition and Metacognition in MEAs and Problem Solving

Cognitive and metacognitive thinking processes are involved in problem solving and MEAs (Chan, 2008; Lamon, 2003; Lesh & Zawojewski, 2007; Lester et al., 1989; Magiera & Zawojewski, 2011). Cognition is a mental process of receiving knowledge, understanding, problem solving, learning, thinking, knowing, memorizing, judging, and reasoning (Dunlosky & Metcalfe, 2009; Revlin, 2013).

Problem solving process needs cognition and metacognition thoughts (Artzt & Armour-Thomas, 1992; Lester et al., 1989). During problem solving process, cognition and metacognition are parallel and interactive rather than sequential (Mayer, 1998; Schoenfeld, 1992). Problem solving competencies and mathematical cognition can be observed through MEAs (Lester & Kehle, 2002; Lesh & Lehrer, 2003). MEAs are intertwined with problem solving and cognition (Goldin, 2007; Roth, 2007). Problem solving involves iterative modeling cycle. For the reason of MEAs are challenging, authentic and realistic, learners may not have an immediate solution for the given problem (Chan, 2008). MEAs can be so difficult for students because MEAs have cognitive and metacognitive demands (Blum & Leiss, 2007).

Metacognition has been explained as the development of students' outcomes (Biggs, 1987; Brown & De Loache, 1983). Some researchers have explained metacognition in mathematics education as successful mathematical performance (Goos, 1994; Stacey, 1991). Problem solving is a significant skill for mathematical success. Problem solving has been seen by some educators as a higher cognitive activity and it involves cognitive processes (Gagne & Medsker, 1996; Mayer, 2003; Polya, 1957). Problem solving also includes monitoring and reflecting processes that are components of metacognition (NCTM, 2000). As a result, problem solving has been seen as a complex process with interplay cognition and metacognition by some educators (Artzt & Armour- Thomas, 1992; Lester et al., 1989; Schoenfeld, 1992).

Metacognition has an effect on both problem solving and mathematics success (De Corte et al., 1996; Lester, 1994; Lucangeli & Cornoldi, 1997; Kramarski et al.2002; Pintrich et al., 1994; Trainin & Swanson, 2005). Cardelle-Elewar (1992) demonstrated that students who have faced difficulties in mathematics did not use metacognition strategies. Metacognition helps students to overcome obstacles and difficulties in the process of mathematical problem-solving (Goos, 2002; Pugalee, 2001; Rysz 2004; Schoenfeld 1992; Stillman & Galbraith, 1998; Yimer & Ellerton 2006).

An aim of mathematics education is to develop modeling competencies. Metacognition has an important role in mathematical modeling activities and competencies (Blum, 2011; Maaß, 2007). Although knowledge and skills are very important for problem solving and metacognitive strategies, they are not sufficient. Stillman (2004) identified cognitive and metacognitive strategies in applications tasks by using cognitive-metacognitive framework when students work on these tasks. There have been few studies that aimed to analyze students' metacognitive knowledge and strategies related to modeling problems when students work on these modeling problems (Hıdıroğlu & Bukova-Güzel, 2015, 2016; Kim et al., 2013; Maaß, 2007; Stillman, 2011; Stillman & Galbraith, 1998). Most studies focus on metacognitive behaviors of middle and high school students to analyze qualitative metacognitive aspects that were used in problem solving process (Artzt & Armour-Thomas, 1992; Goos, 2002; Goos & Galbraith, 1996; Goos et al., 2002; Jacobse & Harskamp, 2009, 2012; Montague & Bos, 1990; Özsoy & Ataman, 2009; Pugalee, 2001; Teong, 2003).

Even though metacognition is thinking about one's own thinking (Stillman & Mevarach, 2010), it should be evaluated not only at the individual level, but also at the social and environmental level (Kim et al., 2013). In general, modeling tasks are done in the group settings. Group work also requires joint planning process (Vorhölter, 2018). Student-student interaction in a small group promote metacognition to get the better solution for the problem. The correct solution for the problem can be found, if students share metacognitive roles that needed in the problem solving process (Artzt & Armour-Thomas, 1992; Goos & Galbraith, 1996). At the level of verbalization in modeling activity,

> most acts can clearly be distinguished as metacognitive or cognitive strategies. Those used for planning together, monitoring and explaining to each other, are of a metacognitive nature, as they aim at monitoring progress; whereas making progress would be an indicator of cognitive strategy use (Vorhölter, 2018, p.346).

Therefore, we should consider social metacognition in the problem-solving process and modeling activities.

Cognition at Individual Level: At this level, the participants might think with cognitive component. There is no evaluation. Participants also do the thinking processes themselves (Kim et al., 2013).

Cognition at Social Level: At this level, the participants might think with cognitive component. There is no evaluation. And the participants do the thinking processes with others or affected by others (Kim et al., 2013).

Cognition at Environmental Level: At this level, the participants might think with cognitive component. There is no evaluation. And the participants do the thinking processes due to a learning environment (Kim et al., 2013).

Metacognition at Individual Level: At this level, the participants might think about a cognitive or metacognitive component with evaluation. And the participants do the thinking processes themselves (Kim et al., 2013).

Metacognition at Social Level: At this level, the participants might think about a cognitive or metacognitive component with evaluation. And the participants do the thinking processes with others or affected by others (Kim et al., 2013).

Metacognition at Environmental Level: At this level, the participants might think about a cognitive or metacognitive component with evaluation. And the participants do the thinking processes due to a learning environment (Kim et al., 2013).

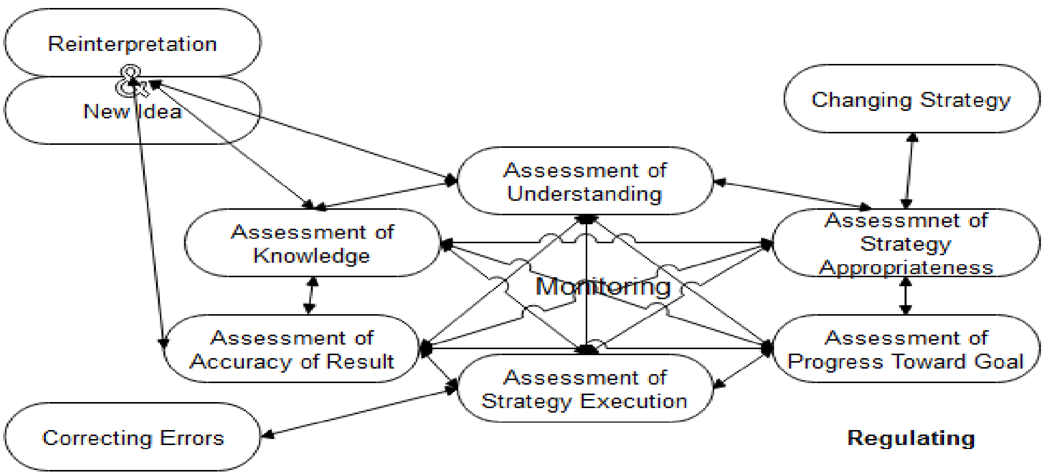

Figure 3. Models and Modeling Perspectives (MMP) view of metacognitive activities during problem solving (Kim et al., 2013).

In this study, the framework developed by Kim et al. (2013) as nonlinear model in Figure 3 was used. The metacognitive strategy that is under monitoring or regulating activity was not investigated in this study. Therefore, changing strategies and correcting errors were removed, which are directly related to the codes assessment of strategy appropriateness and assessment of strategy execution respectively. In addition, only the code of new idea was used even there is a reinterpretation; hence, these two codes are together in the framework.

For this study, pre-service teachers' discussions for solutions of the footprint problem were analyzed based on their strategies related to cognition and metacognition levels (Kim et al., 2013) and the Lesh Translation Model (Lesh et al., 2003; Stohlmann et al., 2013). The problem solving behavior is used as a theoretical framework from the study first developed by Goos (2002) as a linear model and then improved by Kim et al. (2013) as a nonlinear model. This framework has six categories. First, the behavior is classified as cognitive or metacognitive. Then the behavior (either cognitive or metacognitive) is also classified as at individual, social, or environmental level.

Integrated STEM Modeling Activity

Today, most schools' goal is to improve students' knowledge and skills in science, technology, engineering and mathematics (STEM) fields. For students using high-technological products in present and future, they must have knowledge and skills of STEM fields. Highly qualified scientists, technologists, engineers and mathematicians have a crucial role for securing economic prosperity (Bell, 2016). Students can be better problem solvers, innovators, and logical thinkers by taking STEM courses during their educational experiences (Morrison, 2006). STEM courses also help students improve their learning skills (Dewaters & Powers, 2006). STEM education can eliminate abstractness of mathematics and science. It also provides real-world applications related to the concepts of technology and engineering (Nugent et al., 2010).

Mathematical modeling activities and practices can be a bridge between the STEM fields (Lehrer & Schauble, 2000). They are also more appropriate and easier to apply within existing curricula (Moore & Smith, 2014). Model eliciting activities (MEAs) is one application of the mathematical modeling activities. MEAs can be a good example of curriculum materials for integrated STEM education (Kertil & Gurel, 2016; Roehrig et al., 2012). Integrated STEM modeling activity can be defined as involved MEAs in all STEM related situations.

There are few studies related to integrated STEM modeling activity (Moore & Smith, 2014; Stohlmann et al., 2013). Additionally, STEM integration often less included in undergraduate STEM education than K-12 (Moore & Smith, 2014). In terms of the contribution of this study to the literature, it is a good opportunity to investigate pre-service teachers' applications of STEM modeling activity in group settings.

GeoGebra as a cognitive-metacognitive tool in integrated STEM modeling activity

Today technology has an important role in teaching and learning mathematics. It is also getting widely influential in mathematics education (Kaput et al., 2007). Most mathematics educators explained the mathematics classroom as an environment where students are actively constructing their own understanding of mathematical ideas by using the emerging technological tools (Furner & Marines, 2012). NCTM defined the use of technology as one of the principles of learning and teaching in mathematics education (NCTM, 2000). NCTM asserted that learners can work at higher levels of generalizations, model and solve complex and non-routine problems, focus on decision-making and mathematical reasoning through using technological tools in mathematics classrooms (NCTM, 2000).

Computer Algebra Systems (CAS) such as Derive, Mathematica and Dynamic Geometry Software (DGS) such as Cabri Geometry and GeoGebra are powerful technological tools for teaching and learning mathematics (Hohenwarter et al., 2008). This digital software can be used as learning tools to answer problems, to communicate, or to prepare teaching materials (Borba & Villarreal, 2005).

Technology has a significant role on mathematical modeling because of the opportunities it brings. For example, students can be more creative, and they can bring different strategies for solution by using technology (Hıdıroğlu & Bukova-Güzel, 2014; Lingefjärd, 2000). GeoGebra is one of the most commonly used software in mathematics education nowadays. GeoGebra is multi-platform, open-source dynamic mathematics software for all levels of education that joins algebra, geometry, statistics, calculus, graphing, and tables with an easy-to-use package (Hohenwarter et al., 2008). Multiple representation (numeric, graphic and table) is one of the most important features of the GeoGebra. GeoGebra allows learners to construct interactive representations of points, lines, and shapes. Therefore, students are able to see the relationships between different representations easily through GeoGebra. Learners can see that a concept play different roles in mathematical situations with understanding of different representations (Herceg & Herceg, 2007 as cited in Milanović et al., 2012; Yu & Tawfeeq, 2011).

In model eliciting activities related to STEM education, GeoGebra enables multiple representations about a problem situation. Learners can understand the task better, associate between multiple representations, explore new knowledge and relationships, and model mathematical equations for solving a task by using GeoGebra. Learners may explain their thoughts with the help of GeoGebra. From metacognitive point of view, GeoGebra may have a stimulating role. As explained in the previous chapters of this study, the metacognition has three levels which are individual, social and environmental. Geogebra can be a useful tool in terms of environmental level of metacognition with the opportunities it brings.

Integrated STEM Modelling Activity: Footprint Problem

Footprint or Bigfoot problem (Koellner-Clark & Lesh, 2003) (See Appendix A) was used in previous studies to investigate students reasoning skills in the concepts related to proportionality (Lesh & Doerr, 2003; Lesh & Harel, 2003; Stohlmann et al., 2013). This footprint problem has connections with Science, Technology, Engineering and Mathematics (STEM). For instance, the problem includes observation and measurement that are related to Science. Pre-service teachers' access and use GeoGebra covers the technology part. There are many mathematical concepts (ratios, proportions, line of best fit, scatter plots, etc.) and engineering design process that pre-service teachers work within the problem (Stohlmann et al., 2013). This problem is also motivating for pre-service teachers to solve it (Brophy et al., 2008). In addition, student-centered approach might be used via footprint problem. Therefore, students can build on their prior knowledge by bringing their own strategies for the solution of the problem (Stohlmann et al., 2013).

Method

Sample

This study was conducted in a university located in the west part of Turkey. The participants of the study were pre-service teachers who were seniors in mathematics teaching program. There were 32 pre-service teachers who were in mathematics teaching program for middle schools and 20 pre-service teachers who were in mathematics teaching program for high schools.

Participated pre-service teachers had already taken mathematics content courses (e.g., Calculus I, II) and mathematics method courses (e.g., Instructional Technology and Material Design). In the educational technology courses, pre-service teachers have learned about mathematics software such as GeoGebra and Turtle. Therefore, they already had experience with GeoGebra software. They also had experience of mathematical modeling in groups and writing report of the modelling process.

Data Collection

The data is collected in a mathematics method course named *Special Teaching Methods* in the 2016-2017 school years. For this study, the instructor asked pre-service teachers to solve a complex problem that requires mathematical modelling and report their solution. The instructor mentioned the mathematical modelling to warm up the pre-service teachers for the complex problem. He explained the details of this problem. The problem is called footprint problem that requires a modelling to figure out how tall a person whose footprint is given might be (See Appendix A).

Pre-service teachers were in the groups of four or six to study for the solution of the footprint problem. While pre-service teachers were solving the problem and writing their report in 4-hour course time period, they were audio recorded. Pre-service teachers were allowed to use GeoGebra software to solve the problem and they had access to GeoGebra in the Computer Lab during the course. Their solutions in GeoGebra were also collected for this study. Additionally, their reports for the footprint problem were collected for the study. All three data sources made the data collection process more reliable.

Data Analysis

There were two groups selected to analyze the discussion and solutions for the mathematical modeling process. Both group members were four female pre-service teachers. One group was from mathematics teaching program for middle schools and other group was from mathematics teaching program for high schools. These two groups were selected because the Grade Point Average (GPA) of these pre-service teachers' was higher than the average of their classmates in these groups. They also had adequate Pedagogical Content Knowledge (PCK) and Technological Pedagogical Content Knowledge (TPACK).

Pre-service teachers' explanations were coded based on the cognitive or metacognitive thinking. If the explanation is in the category of metacognitive thinking, then this explanation was coded such as *Assessment of progress toward goal*. Later, the level of this explanation (*Individual, Social or Environmental*) was coded (Kim et al., 2013). In the last phase, the type of representation was coded such as *Language* or *Pictural* (Johnson & Lesh, 2003). A pre-service teacher's explanation might have more than one code based on its context. However, a pre-service teacher's explanation might not have any code because of its context. Two researchers coded the data separately at first and later the common coding was decided in agreement.

Results

In this part, findings for both groups in terms of their cognitive and metacognitive thinking and representation of mathematical content knowledge were demonstrated via graphics. In the following figures, G1 represents the four pre-service teachers (P1, P2, P3, P4) for middle school and G2 represents the four pre-service teachers (P5, P6, P7, P8) for high school. Figure 4 demonstrates how frequently the groups used cognitive and metacognitive thinking.

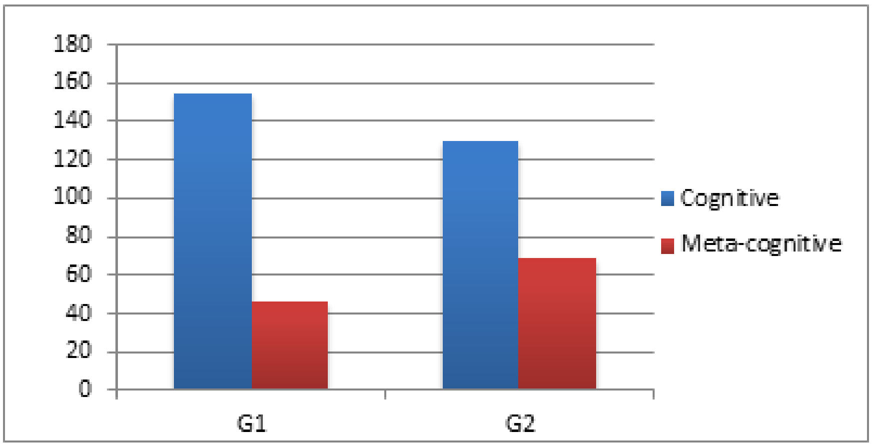

Figure 4. Pre-service mathematics teachers' statements during MEA in terms of cognitive and metacognitive expression.

The results in Figure 4 demonstrates that pre-service teachers (P5, P6, P7, P8) for high school used metacognitive thinking more than pre-service teachers (P1, P2, P3, P4) for middle school. Content and diversity of the courses they take can be the reason of the difference between high school and middle school pre-service teachers' cognitive and metacognitive expressions. High school pre-service teachers' university entry scores are generally higher in order to get into this program and the major area courses they take are more abstract and have high-level mathematics content than the courses pre-service teachers for middle school take. These can be the reasons for high school pre-service teachers' metacognitive thinking usage frequency.

Figure 5 demonstrates high school pre-service teacher group members' cognitive and metacognitive thinking individually. P7 and P8 have more cognitive and metacognitive statements than the other two pre-service teachers. In this group P5 and P7's GPAs are close to each other's GPA and higher than P6 and P8's GPAs. Therefore, it can be said that pre-service mathematics teachers' GPAs cannot be related to their metacognitive thinking skills. There might be other reasons for the frequency of metacognitive statements such as social interaction and technology skills.

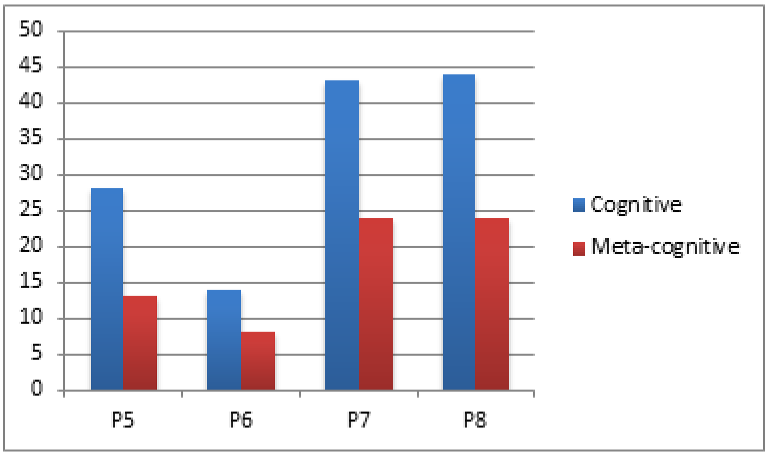

Figure 5. High school pre-service mathematics teachers' cognitive and metacognitive thinking.

Figure 6 also demonstrates middle school pre-service teacher group members' cognitive and metacognitive thinking individually.

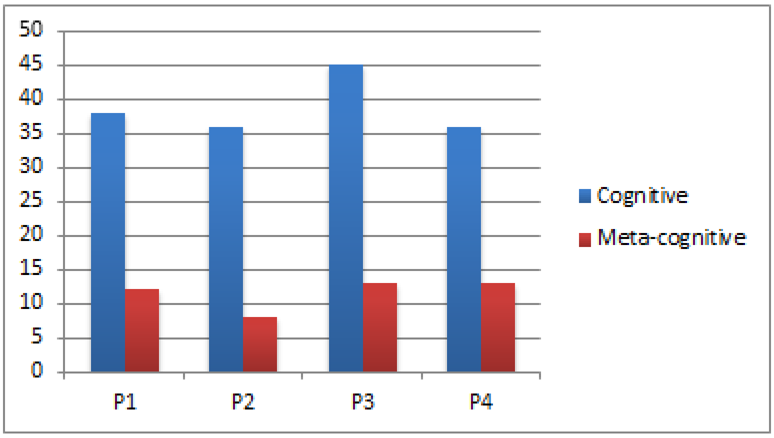

Figure 6. Middle school pre-service mathematics teachers' cognitive and metacognitive thinking.

Middle school pre-service teachers used more cognitive statements than high school pre-service teachers. P1, P2, P3 and P4's frequencies of metacognitive thinking were close to each other. All these pre-service teachers' GPAs were higher than their classmates.

The following statements were made by pre-service teachers who were participants of this study when they were solving footprint problem and writing a report for their solutions. First, the statements were translated to English. Then, they were coded by researchers. In the following sample statements, we used letter S for statement and letter P for pre-service teachers. The codes assigned by researchers are showed bold in brackets.

> S1. P8: First of all, we should measure one of our feet length to figure out footprint. We should figure out the foot size based on the length. There should probably be height interval based on the foot size. Based on this, we can figure out height interval. It is not possible to decide on an absolute value (Metacognitive, New idea & Assessment of knowledge, Individual & Environmental level, Realistic).
>
> S2. P5: I agree with P8. If we do that, we can find the proximate exponential function from the bivariate regression analysis in GeoGebra. We can try to figure out footprint with this function (Metacognitive, New idea & Assessment of strategy appropriateness, Individual & Social level, Realistic & Language).
>
> S3. P7: We can find the ratio with that and check if there is a ratio in our body. I mean relationship with golden ratio (Metacognitive, New idea, Individual & Social level, Realistic & Language).

> S4. P8: Let's say the foot size 38 is not an absolute length. It is a foot length interval (Metacognitive, New idea & Assessment of knowledge, Individual level, Realistic).
>
> S8. P5: First, let's measure our feet length and write down our heights (Metacognitive, Assessment of progress toward goal, Individual & Social level, Realistic & Language).
>
> S18. P7: They use half integers for foot size in United Kingdom. Are they exactly for the foot length? I have measured from toe to the heel (Metacognitive, Assessment of knowledge, Individual level, Realistic & Language).
>
> S26 P6: Shoe template can be changed then (Metacognitive, Assessment of knowledge, Individual level, Realistic & Language).

Pre-service teachers read the problem and then discussed the possible solutions of the problem before they spent enough time to analyze the problem. Pre-service teachers used their mathematical content knowledge to convert the real model to mathematical model. The content knowledge they used were related to the concepts of regression analysis and golden ratio of two numbers. Hence, pre-service teachers already knew how to do regression analysis in GeoGebra, they focused on the relationship between the shoe length and their heights. They also thought that this relationship happens in a standardized interval. First, they measured their feet length and heights by using their knowledge about measurement. They used metacognitive strategies effectively during this measurement step. Pre-service teachers re-considered the knowledge and produced new solutions as parts of metacognitive strategies. Therefore, they used their previous mathematical knowledge here and realistic components existed frequently.

> S44. P7: One of you collect the others' data (P7 is doing herself) (Metacognitive, Assessment of progress toward goal, Individual level, Language)
>
> S46. P7: Let's measure someone who is tall (Metacognitive, New idea, Individual level, Language).
>
> S50. P8: But I think, there is much change… (Metacognitive, Assessment of strategy appropriateness, Individual level, Language).
>
> S59. P5: Because there is space here (pointing the front of the shoe) (Metacognitive, Assessment of knowledge, Environmental level, Realistic & Language)
>
> S60. P8: Uhmm…
>
> S61. P5: My foot length should be shorter than P6's foot length because P6 is taller (Metacognitive, Assessment of knowledge, Individual level, Realistic & Language).
>
> S65. P8: Then, the foot size 38 is 25 cm. Then, how many cm is the foot size 36 (Metacognitive, New idea & Assessment of strategy appropriateness, Environmental level, Realistic & Language)?

Pre-service teachers both measure the foot length and height for themselves and other female pre-service teachers. They thought that the shoe length is not the same as foot length. They tried to check the mathematical model they have conducted via GeoGebra for people who have different height. They expressed that taller people's shoe length is bigger. They used their previous mathematical content knowledge.

> S71. P8: Actually, measuring one male person's foot length makes more sense. In fact, we do not know if it (the footprint in the question) belongs to a male or not. It can belong to a female (Metacognitive, New idea & Assessment of strategy appropriateness, Individual level, Language).
>
> S72.P5: It can be very good to measure Amias's height. Can we reach a function with regression (Metacognitive, New idea & Assessment of progress toward goal, Individual & Social level, Realistic & Pictorial)?
>
> S76. P8: Are we going to generalize it? Can you look at the paper if there is a generalization (Metacognitive, Assessment of strategy appropriateness, Individual & Social level, Realistic & Symbolic)?

S79. P8: First we should get foot length from foot size. Then, we should do the generalization. We should check the difference between foot size and foot length. Then, we should get the height (Metacognitive, New idea & Assessment of understanding, Individual & Social level, Language).

S80. P7: We should get the golden ratio form these data. How do we figure golden ratio in our body (Metacognitive, Assessment of strategy appropriateness, Individual level, Realistic & Language)?

S83. P8: But someone's height and foot length can be disproportionate (Metacognitive, New idea & Assessment of strategy appropriateness, Individual level, Language).

S85. P8: I wonder if there is golden ratio between height and foot length (Metacognitive, New idea & Assessment of knowledge, Individual & Social level, Realistic & Language).

S93. P7: We should check if we can reach a function (Metacognitive, Assessment of progress toward goal, Individual & Environmental level, Realistic & Language).

S105. P7: First, let's divide foot size by foot length. It is one point something. We may reach golden ratio (Metacognitive, New idea & Assessment of strategy appropriateness, Language & Symbolic).

S108. P8: I do not think there is golden ratio between foot length and foot size (Data entry is completed.) (Metacognitive, Assessment of strategy appropriateness, Individual & Social & Environmental level, Language).

Pre-service teachers thought that the footprint could belong to either a male or a female. They tried to measure males' height and foot length as they did for females. They also tried to figure out to make a generalization or create a mathematical model showing a relationship of foot size, foot length and height. They tried to use the golden ratio whether it may help to reach a generalization. During this step, they questioned if the mathematical model they developed was working or not. This is a natural step of the modeling process.

S109. P8: Should this be a line graph (Metacognitive, Assessment of strategy execution, Individual & Environmental level, Language & Pictorial)?

S111. P8: Yes, let's make a line graph. If we did this in Excel, it would be better (Metacognitive, Assessment of strategy execution, Individual & Environmental level, Language & Pictorial).

S112. P6: But there are no such tools in Excel (Cognitive, Environmental level, Language & Realistic).

S113. P8: Could you open Excel? The graph in Excel is better. The graph here is deviant (Cognitive, Environmental level, Realistic & Language & Pictorial).

S114. P7: But here the graph is on the function. (They are looking for the appropriate function in GeoGebra) (Cognitive, Individual & Environmental level, Language & Realistic).

S115. P7: It should be an increasing graph. It should be an exponential function because it is from the daily life (Metacognitive, Assessment of progress toward goal, Social & Environmental level, Realistic & Language).

S117. P5: This function is ok. But of course, there is some deviation (Metacognitive, Assessment of accuracy of result, Social & Environmental level, Realistic & Language).

S118. P6: But there might be measurement errors (Metacognitive, Assessment of accuracy of result, Social & Environmental level, Language).
(Pre-service teachers decided that the mathematical modeling or function should be exponential.)

S119. P8: Let's save these solutions in GeoGebra then. Now, we will correlate foot length and height (Cognitive, Individual & Environmental level, Language & Pictorial).

S120. P7: Yes (Cognitive, Individual level, Language).

S121. P8: Then, we should reach height from foot size (Cognitive, Individual level, Language).

S122. P7: But we have measured foot length (Metacognitive, Assessment of knowledge, Individual & Social level, Language).

S123. P8: There is no point of finding foot size then (Metacognitive, Assessment of strategy appropriateness, Individual & Social level, Language**)**.

S124. P7: Then we can reach the foot size from the measurement we got. Binary (Cognitive, Individual & Social level, Language).

S126. P7: Because we do not know the foot size. We can measure the footprint on the floor (Metacognitive, Assessment of progress toward goal, Individual & Environmental level, Realistic & Language).

S128. P7: First, it becomes exponential in GeoGebra. It means this one is an exponential as well (Metacognitive, Assessment of accuracy of result, Individual & Environmental level, Language & Pictorial).
(Pre-service teachers are trying to find the function).

S130. P7: Hold on. What did we do first (Cognitive, Individual level, Language)?

S131. P8: Correlate the foot size and foot length (Cognitive, Individual level, Language).

S132. P7: Which type of function did we use? Was it an exponential function (Cognitive, Individual level, Language)?

S133. P8: Yes, we used exponential function (Cognitive, Individual level, Language).

S134. P7: Then, what did we do (Cognitive, Individual level, Language)?

S135. P8: We correlated the foot length and height. This one is logarithmic (Metacognitive, Assessment of understanding, Individual & Environmental level, Language & Symbolic).

S136. P7: No, it is not exponential function (Metacognitive, Assessment of understanding, Individual & Social level, Language & Symbolic).

S137. P8: Ooh, yes. First, it was logarithmic, was not it? It turned to exponential function when we changed x and y (Metacognitive, Assessment of understanding, Individual & Environmental level, Language & Symbolic).

S138. P7: Was x for foot size here (Cognitive, Individual & Environmental level, Language & Symbolic)?

S139. P8: No, x is for foot length (Cognitive, Individual & Environmental level, Language & Symbolic).

S140. P6: Was not it the other way around (Cognitive, Individual & Environmental level, Language & Symbolic)?

S141. P8: No, we know that how many cm that is. We do not know the foot size. We should reach the foot size from cm (foot length) (Metacognitive, Assessment of strategy appropriateness, Individual level, Language & Symbolic).

S142. P5: Now, we should correlate these two (She means the first and second steps in the report) (Metacognitive, Assessment of knowledge, Individual & Environmental level, Language & Symbolic).

S143. P7: Will we do multiple regression here? Are we doing triple regression (Cognitive, Environmental level, Language & Symbolic)?

Pre-service teachers have entered all the data set they collected into the GeoGebra software. They tried to find the best mathematical modeling among the created graphs in GeoGebra. They thought that as the created graph in GeoGebra is more representative of the data, as the model is more possible to be correct. Pre-service teachers tried to correlate foot size, foot length, and height. They thought that the function that showed the correlation among these variables should be exponential because the variables were from the real-life. It can be said that this idea is not only form the graph drawing in GeoGebra but also from their previous mathematical knowledge. The used the relationship between logarithmic and exponential functions. This reveals that they used their mathematical content knowledge effectively. During these steps, pre-service teachers used metacognitive strategies mostly at the social and environmental levels. Although the nature of the problem causes environmental level, effective technology usage plays an important role for this level in metacognitive strategies. When the technology is used for the solution, there are more social and environmental levels having an interaction in between. Mathematical models created by using technology affected pre-service mathematics teachers' mathematical content knowledge to develop higher-order thinking, abstract knowledge and various mathematical representations such as symbolic and pictorial.

S144. P8: Do we really need to find the relationship between those two? For example, cannot students get in this way? They can get from foot length to foot size, from foot size to height (Metacognitive, Assessment of strategy appropriateness, Individual & Environmental level, Language & Symbolic).

S145. P7: Okay, but there is also that we need to develop a tool (Metacognitive, Assessment of progress toward goal, Individual level, Language).

S146. P5: Should we do that? We get from foot length to foot size, from foot size to height (Metacognitive, Assessment of strategy appropriateness, Individual level, Language).

S147. P8: Okay, we already did this (Cognitive, Individual level, Language).

S148. P5: We do not do this (Cognitive, Environmental level, Language).

S149. P8: Okay. I just said that (Cognitive, Individual level, Language).

S150. P6: Actually, we can directly get height because we already know the foot size. It makes sense (Metacognitive, Assessment of strategy appropriateness, Individual level, Language).

S151. P8: I just said that already (Cognitive, Individual level, Language).

S152. P6: Yes, I think that is true. We will get from foot size to foot length, from foot length to height (Cognitive, Social level, Language).

S153. P8: No, we will not be able to get from foot size to height, because we do not know the foot size. We should get from foot length to foot size, from foot size to height. In general, there is a relationship between foot size and height except for some people. There is always an exception (Metacognitive, Assessment of strategy appropriateness, Environmental level, Language).

S154. P7: But is it necessary (Cognitive, Social level, Language)

S155. P8: But it does not make sense to use it (foot length & foot size) (Cognitive, Social level, Language).

S156. P7: Do you mean we should get foot size from this (Cognitive, Social level, Language)

S157. P8: I am saying that we should get height from foot size (Cognitive, Individual & Social level, Language).

S158. P6: If foot length is known, we get foot size. We should find a relationship between foot size and height (Metacognitive, Assessment of progress toward goal, Individual & Social level, Language).

S159. P8: I have already been saying that. We already get foot size from foot length. Then, we should get height from foot size **(**Cognitive, Individual & Social level, Language).

S160. P6: Yes (Cognitive, Individual level, Language).

S161. P5: What if we get height directly from foot length (Metacognitive, New idea & Assessment of strategy appropriateness, Individual & Social level, Language)?

S162. P8: That is possible (Cognitive, Individual level, Language).

S163. P7: We can use other ways to find proximity. We can compare (Metacognitive, New idea & Assessment of progress toward goal, Individual & Social level, Language).

S164. P8: Actually, it is like verification (Cognitive, Individual & Social level, Language).

S165. P7: Let's look at the foot size and height then (Cognitive, Individual & Social level, Language).

S166. P5: Okay. Let's save this too (Cognitive, Individual & Environmental level, Language).

S167. P8: Do you know what? We will be looking at the three data set. We will be using the one which is the closest (Metacognitive, Assessment of strategy execution, Individual & Environmental level, Language & Symbolic& Pictorial).

S168. P7: We will say that they are close to each other, and show that the result is correct and develop a tool (Metacognitive, Assessment of strategy execution, Social & Environmental, Language).

S169. Lecturer: GeoGebra is also a tool.

S170. P7: Shall we collect new data (Metacognitive, Assessment of strategy execution, Individual & Social level, Language)?

S171. P8: We do not need them. We can use the data we already have (Cognitive, Social level, Language).

S172. P7: We should look at the logarithm. This is the best one (Metacognitive, Assessment of accuracy of result, Individual & Environmental level, Language & Symbolic & Pictorial).

S173. P8: We are trying to get a ratio by dividing height by foot length (Metacognitive, Assessment of strategy execution, Individual level, Language & Symbolic).

S174. P7: Which number is close to these (Metacognitive, New idea & Assessment of strategy execution, Individual & Environmental level, Language & Symbolic**)**?

S175. P5: We should add them together and divide by the number of people (Metacognitive, New idea & Assessment of strategy execution, Individual & Environmental level, Language & Symbolic**)**.

S176. P8: P7, I want to say something. When the ratios diverge from 6.5, how heights deviate (Metacognitive, Assessment of accuracy of result, Individual & Environmental level, Language & Symbolic**)**?

S177. P7: What? I did not get that (Cognitive, Social level, Language).

S178. P8: For example, 6.50 incline or decline, how many cm changes in height? We will not reach an absolute result; we will find an interval (Metacognitive, Assessment of accuracy of result, Individual & Environmental level, Language & Symbolic & Pictorial).

S179. P5: Let's do what I said (Add the averages and divide by the number of people) (Metacognitive, Assessment of accuracy of result, Individual & Environmental level, Language & Symbolic).

S180. P7: The average is 6.57 (Cognitive, Individual & Social level, Language & Symbolic).

S181. P5: I think, logarithm is good. We found many results. Which one will we choose (Metacognitive, Assessment of strategy execution &Assessment of accuracy of result, Individual & Social level, Language & Symbolic & Pictorial)?

S182. P6: We should decide what we will be using (Cognitive, Individual & Environmental level, Language).

S183. P8: We will not reach an absolute result. We can use a height interval (Metacognitive, New idea & Assessment of progress toward goal, Individual & Social level, Language).

S184. P7: Girls, that much research is enough. Everyone is completing (Cognitive, Individual & Environmental level, Language).

S186. P6: Do we really need to do this? (Metacognitive, Assessment of strategy appropriateness, Individual & Social & Environmental level, Language & Symbolic).

S187. P5: We should write what we did. We should write down all the ways (Cognitive, Individual & Environmental level, Language).

S188. P6: We should, we should write (Cognitive, Individual & Environmental level, Language).

S189. P7: This is a simple solution. Do you know what this is? You saw on the road, then measure to say that the result is around this, I mean to analyze. I mean we should do this first. This should be the first step. This should be the first calculation like around that (Metacognitive, Assessment of strategy execution, Individual & Social & Environmental level, Language & Symbolic).

S190. P6: Well, this gives roughly result (Metacognitive, Assessment of accuracy of result, Individual & Environmental level, Language & Symbolic).

S191. P5: Should we get from length to size (Cognitive, Individual level, Language)?

S192. P7: We get from foot length to foot size. But there is no need for this. We get from foot size to height (Metacognitive, Assessment of strategy execution, Individual & Social level, Language & Symbolic).

S193. P6: If we do the first and third step, we do not need this (foot length & height). I mean, should we do two or more (Metacognitive, Assessment of strategy execution, Individual & Social & Environmental level, Language & Symbolic)?

S194. P7: Did we get height from size (Cognitive, Individual & Social level, Language).

S195. P6: I think, we should find the foot size (Metacognitive, New idea & Assessment of strategy execution, Individual & Social level, Language).

S196. P8: Okay, we get from foot length to foot size (Cognitive, Individual & Social level, Language).

S197. P7: Yes, is not it from foot length to height (Metacognitive, Assessment of progress toward goal, Individual & Social level, Language)?

S198. P5: Then, there is no need for OFMA number. Just one thing would be enough (Metacognitive, Assessment of strategy execution, Individual & Social level, Language).

S199. P7: Let's look at the relation between foot length and foot size (third step) (Metacognitive, New idea, Individual & Environmental level, Language & Symbolic).

S200. P8: Yes, get foot size from foot length and height from foot size (Metacognitive, Assessment of strategy execution, Individual & Social level, Language).

S201. P6: We should write all three on the report. We should write that we used third step as well (Cognitive, Individual & Social level, Language & Symbolic).

S202. P5: How should we write on the report why we found three ways (Cognitive, Individual & Social level & Environmental, Language & Symbolic)?

> S203. P7: Because this is a real-world problem. We need several approximate results (Metacognitive, Assessment of accuracy of result & Assessment of strategy appropriateness, Individual & Environmental level, Language & Symbolic).

In this part of discussion, pre-service teachers more frequently used metacognitive strategies. They have understood completely that they need to develop a mathematical model for model eliciting activity. Instead of trial and error, they developed strategies for the solution of the problem. Then, they investigated and queried whether these strategies were appropriate. They have more efficient interaction. There is less metacognitive thinking at the individual level (Statements 145, 146, 150, and 173). They have worked on the mathematical models in mostly agreed cases. They have evaluated the strategy or the solution individually. Therefore, there are not much new ideas in this part of the discussion.

Pre-service teachers also used metacognitive strategies in both individual and social levels (Statements 158, 170, 192, 195, 197, 198 and 200). Thus, pre-service used more than one metacognitive strategy at the same time (Statements 161, 163, 181, 183). They also used more than one representation for their explanations of the content knowledge (Statements 181 and 193). Social interaction and the feedback from others made the pre-service teachers to create more new ideas. MEAs promote pre-service teachers to develop their ideas and models.

Pre-service teachers also showed metacognitive thinking at both individual and environmental levels (Statements 144, 167, 172, 174, 175, 176, 178, 179, 190, 199, and 203). At first, metacognitive strategies at the environmental level were used because of the nature of the problem. Then, pre-service teachers developed metacognitive strategies at the environmental level by using technology to control and evaluate the ways for the solution. Using technology made pre-service teachers' mathematical modelling process better and faster in terms of evaluation and analysis of their strategies. They also had opportunities to represent their mathematical content knowledge in various ways such as pictorial and symbolic forms for higher order thinking. All metacognition levels (individual, social, and environmental) existed rarely in pre-service teachers statements. However, the statements at all these levels showed higher order thinking, better questioning, and qualified consideration for metacognitive skills.

Discussion

As Joseph (2010) revealed that technology has a positive impact on students' learning and their process of problem solving. In this study, we have showed that technology can be a catalyzer for metacognitive thinking. In the groups, pre-service teachers used technology to solve the footprint problem. They had the opportunity to use their metacognition skills in the technology supported environment. As Gurbin (2015) also mentioned, there might be a reason that students can be motivated in a technology supported environment. The results we reached out in this study also similar to Gurbin (2015) and Azevedo's (2005) explanations regarding that technology adaptation is related to metacognition. Additionally, metacognition is also essential for technology usage taking a significant part of education today (Gurbin, 2015).

Through experiencing the footprint problem, pre-service mathematics teachers had opportunity to understand better how to prepare, work and engage similar integrated STEM modeling activity for middle and secondary school students. Stolmann et al. (2015) showed that there has been a similar development for pre-service mathematics teachers. In this study, pre-service mathematics teachers used their technological mathematical content knowledge (TPACK; Mishra & Koehler, 2006) to solve the problem. They used their mathematical content knowledge to understand the information given in the MEA and to create multiple mathematical representations. They should know what mathematical representations mean and make transitions between these. They used their pedagogical knowledge to evaluate each other's knowledge for making a decision in groups' discussion to write a report. They knew how to use GeoGebra software program. They used GeoGebra to solve the problem and create multiple mathematical representations needed.

Anything that activates students thinking about their learning, review, reflection, discussion, questioning, thinking aloud, monitoring, and social interaction can develop their metacognitive thinking (Bryce & Whitebread, 2012; Goos 2002; Gurbin, 2015; Kim et al., 2013). Therefore, the learning environments should include these kinds of opportunities to facilitate students' metacognitive development process. In this study, writing a report about their solution for the footprint problem caused pre-service teachers to apply these metacognitive components, such as review, thinking aloud, and monitoring. The environment is not sufficient itself to develop metacognition. As metacognition has an important role on effective learning (Gurbin, 2015), teachers should also have a facilitator role on students' leaning in order to develop their metacognitions skills as the instructor did in this study.

Social constructivism emphasizes that knowledge cannot be transferred from one specialist to learner, but rather actively constructed by the learner while solving meaningful problems. Integrated STEM education provides meaningful learning. The meaningful learning can be enhanced through social constructivism. For this reason, STEM integration should be coherent with the theory of social constructivism (Jonassen & Rohrer-Murphy 1999; Moore & Smith, 2014). Therefore, footprint problem was asked pre-service teachers in groups of four or five to discuss and develop their ideas for a solution. Pre-service teachers were engaged in social constructivist and metacognitive learning environment through integrated STEM modeling activity. This learning environment supported pre-service mathematics teachers and led them develop individually, socially and environmentally their cognitive and metacognitive skills integrated mathematical content knowledge. So, this study showed how to put together cognitive and metacognitive skills and mathematical representation knowledge with multiple levels. In this process technology played important role. With the help of technology, pre-service teachers showed all representational modes.

Conclusion

Pre-service teachers were able to find solutions for the footprint problem. Therefore, we can say that they were able to use their content knowledge of proportionality and linear function modeling. Pre-service teachers used different representations to find a solution for the given footprint problem as a modeling activity. They tended to use different representations other than the symbolic representations for their solution. The footprint problem itself and GeoGebra access might be a reason for the usage of different representations such as pictorial and concrete.

In this study, pre-service teachers' cognition and metacognition thinking for the footprint problem and their representations were analyzed based on using related two frameworks (Johnson & Lesh, 2003; Kim et al.,2013). Therefore, this study reveals an important perspective how pre-service teachers use representations and cognitive-metacognitive level of thinking.

Modeling activities play a significant role to develop pre-service teachers higher order thinking and metacognitive thinking in a technology-based environment. Therefore, modelling activities should be given to a group in a technology-based environment to make the modelling process more efficient.

Recommendations

A similar study with a different environment such as using different software or another modelling activity can be conducted. Therefore, it can be possible to compare pre-service teachers' thinking and the representations they use with this study.

Additionally, it can be more useful to conduct a study investigating middle or high school teachers' modeling activities usage in their mathematics classes to get a better understating of how in-service teachers instruct these modeling activities and how students react and think for modeling process. Therefore, we can develop modeling process efficiently in teacher preparation programs to serve the purpose of metacognitive thinking.

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Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the authors.

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Appendix A

The Footprint Problem

Early this morning, Shirley Jones, the local police detective, discovered that sometime late last night some nice people rebuilt the old brick drinking fountain in the park. The mayor, Maria Lopez, would like to thank the people who did it, but nobody saw who it was. All the police could find were lots of footprints. One of the footprints is shown here. But to find this person and his or her friends, it would help it we could figure out how tall he or she really is. Your job is to make a "how to" tool kit that the police can use to figure out how tallpeople are just by looking at their footprints. Your tool kit should work for the footprint shown here, but it should also work for other footprints.

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Computer Game Addiction in Gifted Students and Non-Gifted Children: A Caution for Technology-Oriented STEM Activities

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Abstract

The aim of this research was to examine computer game addiction levels in gifted students, in comparison with addiction levels in non-gifted students. Data were obtained from 614 (169 gifted, 445 non-gifted) primary school students in Turkey, by using The Computer Game Addiction Scale for Children. This research was a correlational study using ANCOVA to compare gifted and non-gifted samples, and the multiple regression was conducted to determine predictors of game addiction in the gifted sample. Research findings showed that there was no statistical difference between gifted and non-gifted students' computer game addiction levels, after controlling for the gender, school type, and game type. However, there was a significant difference in addiction scores between males and females in the sample whilst controlling for the giftedness, school type, and game type. Finally, gender and daily playtime have been found to be significant predictors of game addiction in gifted students.

Introduction

The importance of science, technology, engineering, and mathematics (STEM) continues to increase in modern economies (Ball et al., 2020). Therefore, to compete with other economies, countries have tried to develop STEM-related activities in educational settings. Computers have been one of the main educational tools in teaching STEM. Computers and games have strong implications for education and daily life (Li, 2010). Computer games have been found to be effective for increasing technology-related skills (Admiraal, 2015), and have been considered a pathway to broaden participation in STEM (Sheridan et al. 2013). Playing more video games increases students' willingness to work with technology (Ball et al., 2020). Game-playing can be used to teach mathematics problem-solving (Chang et al., 2012), and as a practice to support social-emotional skills (Li, 2010). Professionals and students consider gaming a valuable tool for STEM instruction (Clark & Ernst, 2009). Gaming in education has been a hot topic in the field of education (Preston & Morrison, 2009). Digital games are found to enhance and motivate learning (Steiner et al., 2006). On the other hand, the negative aspects of playing increasingly more computer games may include computer game addiction. Advance in technology moved games from the streets, where friends were face to face, to the virtual environment where the computer screen is the primary correspondent. These computer games increasingly appeal to many young people (Festl et al., 2013) and have turned into one of the most popular recreational activities for children all over the world (Jadidian et al., 2012). There has been a widespread increase in the use of computers in all the contexts that young people are involved in, including school, family, and leisure (Sureda Garcia et al., 2020). Computer game addiction is one of the concerns we need to consider while teaching or doing technology-related activities.

Computer Game Addiction

Although computer games are recreational tools for most people, they may turn into a computer game addiction for someone who plays excessively (Johansson & Götestam, 2004; Chumbley & Griffiths, 2006). Computer game addiction may have some similar characteristics to other addictive conditions (King et al., 2013). However, there is a debate about how to define and measure computer game addiction (Ferguson et al., 2011; Shaffer et al., 2000). The Diagnostic and Statistical Manual of Mental Disorders (DSM–5; American Psychiatric Association, 2013) defines the addiction to internet gaming as internet gaming disorder (IGD). Tolerance, withdrawal, continued play despite negative outcomes, failure to decrease internet use, constant use of the internet more than intended and impairments in psycho-social functions are some criteria for IGD. Griffiths (2005) defined the six behavioral components of game addiction as salience, mood modification, tolerance, withdrawal symptoms, conflict, and relapse. Moreover, an increase in the amount of computer playtime, enduring desire for playing a game, spending more time gaming than planned, trying to shorten the time playing but not able to succeed, and complaints from people around regarding playtime are some common symptoms observed in-game addicts (Ahn & Randall, 2007; Gentile, 2009). Computer game addiction can be defined as excessive and compulsive gaming that may cause some social and/or emotional problems in daily life with schooling, employment, and social relationships, and failing to control this problematic use (Lemmens et al., 2009; Vollmer et al., 2014). In this study, relative measures of symptoms of computer game addiction on a continuous scale were used, as there were no clinical diagnoses or cut-off scores.

Computer game addiction is considered a worldwide problem, despite the lack of agreement in diagnostic assessments (Starcevic, 2016). Ferguson et al. (2011) reported the prevalence of game addiction as 3.1% when cases of highly engaged players were excluded in their meta-analysis of game addiction. Given that computer game addiction has been seen as an increasing public health issue, some countries, notably in Asia, have set up governmental regulations for problematic computer gaming (Király et al., 2018). Some studies have shown that computer game addiction has been related to a lack of coping skills or as avoidance coping strategies (e.g. escaping, denial) (Beranuy et al., 2013; Şenormancı, et al., 2014; Tejeiro et al., 2012). Similarly, negative associations have been found between game addiction and mental health, particularly anxiety, stress, and depression (Loton et al., 2016; Stockdale & Coyne, 2018). A recent study showed a positive correlation between mobile game addiction and social anxiety, depression, and loneliness (Wang et al., 2019). Peters and Malesky (2008) examined the relationships between personality traits and game addiction. They indicated that video game addiction was positively correlated with neuroticism, and negatively with extraversion, agreeableness, and conscientiousness (Peters & Malesky, 2008). Wittek and his colleagues (2016) identified some factors linked with video game addiction including being male, being young, living alone, scoring low on conscientiousness, scoring high on neuroticism, and having poor psychosomatic health.

The flow experience and enjoyment were found as predictors of game addiction (Chou & Ting, 2003). Social relationships and the specific time and flexibility characteristics in multiplayer games were found as the main causes for enjoyment (Klimmt et al., 2009). Olson (2010) examined children's motivations in playing video games and identified some motivating factors or needs including socializing with peers and making friends, opportunities to lead or teach others, and a sense of accomplishment in winning. These factors could lead children to play multiplayer games. In addition to multi-playing, feelings of pride or success in games would help individuals feel accomplished and higher self-esteem (Olson, 2010), which in turn increases playing time (Hamlen, 2010). Some studies concluded that computer ownership, socioeconomic status, and education level of parents were other important variables in computer game addiction. For example, Yılmaz (2008) found that children who possessed a computer played games more often than their peers who didn't own a computer. Children in families with high socioeconomic status were also higher in computer game addiction levels (Horzum, 2011; Lee & McKenzie, 2015). In addition, adolescent students who preferred evening hours to play games had a higher computer addiction score than students who preferred daytime playing (Vollmer et al., 2014). However, some research results have shown that computer game addiction was negatively associated with age among adolescents (Festl et al., 2013; Vollmer et al., 2014). Research on computer game addiction has shown considerable results in terms of gender differences. Boys were found to play significantly more often and more regularly than girls, preferring more action and fighting games with a high level of violence, and were also more likely to become addicted (Hartmann & Klimmt, 2006; Horzum, 2011).

Gifted Students and Computer Games

Education of the gifted is another area where the use of technology and computers is discussed. Using technology and computers is recommended in gifted education since these students have special needs that require the integration of different kinds of technology into their curriculum (Shaunessy, 2007). Although definition and identification of giftedness vary across cultures, the field of gifted education is based on the belief that gifted individuals are those who have superior abilities or potentials in one or more domains, including intelligence, creativity, art, sports, leadership capacity, or in specific academic fields. These children require differentiated educational services beyond the regular school curriculum (Davis et al., 2011). Lee (2001) proposed that the involvement of technology in gifted education would encourage gifted learners to develop their skills such as critical thinking, creativity, and abstract thinking. In addition, technological applications address many features of gifted learners, including quick information processing, capacity for complexity and depth, and inductive learning (Siegle, 2005). In a study examining the attitudes of gifted high school students toward technology, many of them have used technology throughout their learning process (Kahveci, 2010). Gifted students are able to use computers more efficiently and effectively (Siegle, 2005), and have a positive attitude towards computers (Üstünel & Meral, 2015). Gifted students start to use computers with programming in the fourth grade (Sesko, 1998). Grimes and Warschauer (2008) found that almost all gifted students reported a positive learning experience using laptops at home and in school. Although many gifted students have computer skills that are significant for their education (Periathiruvadi & Rinn, 2012), playing games excessively might have deleterious effects on their social, emotional, and academic development. As they rely on computers much more and play games excessively, the risk of addiction will be higher for gifted children as well (Roberts, 2010).

Gifted children may differ from their non-gifted peers in playing computer games compared to their non-gifted peers. When engaged in these computer games, gifted children showed more goal-oriented behavior, and were able to excel in the game by focusing more on game strategies and cues (Blumberg et al., 2001). A study about the preferences of computer game types of gifted and non-gifted secondary school students concluded that gifted students preferred to play adventure, action, and strategy games to other types. Non-gifted students preferred to play adventure, action, and sports games (Üstünel & Meral, 2015).

Ağaoğlu and Metin (2016) found that gifted students played more computer games than their non-gifted peers did, and the preferences of gifted students were more adventure and mental-logic themed games, whereas non-gifted students reported more violence themed games. Gifted students might make use of computer games to avoid challenges that they confront in real life, by experiencing achievements, discovering new information, and making new connections in games.

The Current Study

Several curricular activities and projects have been launched recently among STEM education to develop computer skills at the K-12 level, but stakeholders in the K-12 systems may not be yet fully aware of the risks of excessive computer game-playing. Computer game addiction among students is one of the potential concerns that people should pay attention to while teaching technology-related activities. Excessively playing computer games, and improper use of computers can lead to computer game addiction (Gentile, 2009). Previous research on computer game addiction has mostly focused on adolescents (Colwell et al., 1995; Lemmens & Bushman, 2006; Wan & Chiou, 2006). Adolescents seem at risk for game internet addiction (Leung, 2007). Griffith and Hunt (1998) stated that the earlier the children start playing computer games; the more likely they become addicted in the future. Low levels of self-control in childhood and the increasing number of child-age players might magnify the importance of this study. It is important to focus on the preadolescence period to prevent the risks related to the use of computer games. Therefore, results from the current study might add to the body of literature providing evidence about game addiction levels in gifted and non-gifted children and related factors. Research about game addiction in the gifted population would help to understand and prevent these addictive behaviors in the gifted population. The study may shed light on game addiction prevention programs in STEM education. This study was conducted as a preliminary study to understand computer addiction levels in gifted students by comparison with addiction levels of non-gifted students within primary school settings. The study attempted to test the following questions:

1. What is the status of computer game preference in gifted and non-gifted students?
2. Will gifted and non-gifted students report differing levels of computer game addiction in primary school settings?
3. Will gifted students report different game addiction levels based on gender, having a computer game friend group, computer game type, and playtime?

Method

Population and Sample

The participants were selected based on the convenience sampling method, which involves gathering responses from readily accessible individuals (Kothari, 2004). The participants of the study were composed of 169 gifted students who were attending the Science and Art Centers (SAC), and 445 non-gifted students who were either from public or private schools in Turkey. To eliminate the effect of school and environment, non-gifted students were chosen from the same schools in which their gifted peers were attending. SAC is a state-funded institution providing special education for primary and secondary school gifted students, apart from their usual school time. These centers are examples of enrichment and grouping strategies for gifted students (Sak, 2010). The following steps are to be addressed for admission to the center: (1) firstly, teachers point their students out as candidates on an official website by using some observation forms (2) all nominated students take a group test simultaneously (3) a certain number of students who are ranked according to group test are assessed by an individual intelligence test; (4) the students whose total intelligence test score is above 130 are admitted to the center within the frame of quota allotted each year for the centers. Gifted students in these centers attend both their regular schools and the centers in addition to their regular school schedule. Therefore, gifted students who are in SACs can study and socialize with both their non-gifted peers in their schools and their gifted peers in the centers. In these centers, the education program includes the following five stages: orientation, supportive training, recognition of individual talents, development of special talents and projects. In the supportive training stage, gifted students are given training about social skills, problem-solving techniques, group study techniques, scientific research techniques, and social activities (Sak, 2010). Even though SACs do not have a special curriculum for STEM education; throughout these stages, gifted students are provided STEM-related activities. Thus, SAC's are crucial to offering some programs in STEM fields.

Gifted students in the sample were composed of 40.2% female and 59.8% male students, but gender was almost equally distributed in the non-gifted group (50.3% female; 49.7% male). Regarding school type, the public school percentage was higher than the rate of private schools in both categories. This higher proportion of public schools was an expected finding because more students were attending public schools than private schools in overall populations in Turkey. 71% of gifted students and 67.6% of non-gifted students were attending public schools. 95% of gifted, and 86.5% of non-gifted students, had a computer in their houses. Almost all students preferred to play computer games in their homes (97% of gifted students; 95% of non-gifted students). The mean age of participants was 10.4 years (Min=9, Max=12). To determine the amount of time that participants spend playing computer games, they were asked ''How many minutes per day do you play computer games?'' The mean time that gifted students were spending on computer games was 84 minutes (1.4 hours per day). Similarly, non-gifted students reported 88 minutes (1.46 hours) per day. Both gifted and non-gifted students took game recommendations mostly from their parents and friends (87% and 85% respectively). In other words, they selected computer games based on the advice of their parents and friends.

Data Collection

A self-report survey and the Computer Game Addiction Scale for Children were used for data collection. The first author of the scale gave permission to use this scale in this study.

Survey: A survey was created by researchers to get information about the students' current state of computer usage, game preferences, game types, and some demographic characteristics. Game preferences were categorized based on classifications of Deubel (2006) as action-adventure, fighting, educational, sports, war, competition, and others. Participants were given these categories, and they marked them based on their preferences. There were two game types in the questionnaire; single-player and multiplayer games. Multiplayer games involve co-playing in which more than one player can play in the same game environment at the same time.

The Computer Game Addiction Scale for Children (CGAS-C): Horzum et al. (2008) developed the–scale to measure computer game addiction levels in Turkish children. The scale consists of 21 items with four factors, that require respondents to report their thoughts towards the given statements, on the 5-Likert format from 1 (never) to 5 (always). The minimum score on the scale is 21, and the maximum score is 105. All items on the scale are positive statements. The results of factor analysis indicated that the scale, consisting of 21 items accounted for 45% of the total variance. The Cronbach Alpha reliability coefficient of the scale was found to be .85 (Horzum et al., 2008). In this research, Cronbach's Alpha was found as .89 for gifted students and .88 for non-gifted students.

Analyzing of Data

Required official permissions and parental consent were obtained from the relevant entities for gathering the data. Primarily, all students were informed about the content and the importance of the study. The students filled out the forms as a paper and pencil test over forty minutes in a class period. Gifted students completed the forms at the Science and Arts Centers, and non-gifted students were given the forms at their regular schools. In data analysis, initially, descriptive and correlational analyses were performed. Additionally, ANCOVA was used in comparing the computer game addiction levels in gifted and non-gifted students, and finally, multiple regression analysis was used in examining the computer game addiction levels regarding gender, friend groups, and game types in gifted students.

Results

The means, standard deviations, and the correlations for all variables are presented in Table 1. As shown, the CGAS-C was significantly and positively correlated to gender (*r* = .35), , computer game type (*r* = .23), daily (*r* = .42) and weekly playtime (*r* = .14), while negatively related to computer game friend (*r* = -.26).

Table 1. Means, standard deviations and correlations between variables

Variables	M	SD	1	2	3	4	5	6	7
1-CGAS-C	40.4	14.12	-						
2-Giftedness	.27	.44	.021	-					
3-Gender	.52	.49	.350**	.090*	-				
4-School type	.31	.46	-.006	-.032	-.009	-			
5-Comp. Game Type	.49	.50	.235**	-.057	.311**	.030	-		
6-Comp. Game Friend	.61	.48	-.259**	-.024	-.259**	-.093*	-.332**	-	
7-Daily Play Time	.94	1.34	.428**	-.074	.222**	-1.35**	.144**	-.088*	-
8-Weekly Play Time	1.60	2.48	.144**	.224**	.190**	.78	.159**	-.202**	.165**

Note. *n*=616 (165 gifted, 445 non-gifted). **p* < .05. ***p* < .01.

Table 2 shows the results of computer game choices of gifted and non-gifted students. The most preferred computer games were action-adventure (47.9%), strategy (39.1%), and football (23.1%) in gifted students. However, action-adventure (53%), educational (31.7%), and strategy (28.8%) games were the most favorite genres in the non-gifted group.

Table 2. Results of computer game preference of gifted and non-gifted students

	Gifted		Non-gifted	
Game Preferences	n	%	n	%
Action-Adventure	81	47.9	236	53
Strategy	66	39.1	128	28.8
Educational	32	18.9	141	31.7
Sports	39	23.1	104	23.4
War	37	21.9	87	19.6
Competition	33	19.5	98	22
Fighting	17	10.1	65	14.6
Other	13	7.7	62	13.9

Subsequently, a one-way analysis of covariance (ANCOVA) test was run to examine differences between the gifted and non-gifted students in computer addiction (CGAS-C) whilst controlling for the gender, school type, and game type. Before conducting an ANCOVA, a test of the homogeneity-of-slopes assumption was performed to determine the extent of the linearity. Based on analysis evaluating the homogeneity-of-slopes assumption, which indicated that the relationship between the covariates and the computer addiction variable differed significantly as a function of the independent variable, we proceeded with the ANCOVA analysis. The results indicated that there was no significant difference between gifted and non-gifted students in computer addiction. However, there was a significant difference in addiction scores between males and females whilst controlling the covariates. The results were presented in Table 3.

Table 3. One-way ANCOVA for CGAS-C comparing gifted and non-gifted students

	df	MS	F	*p*	η2
Giftedness	1	18.35	.107	.744	.000
Gender	1	10662.77	62.07	.000	.09
School type	1	77.104	.449	.503	.001
Game type	1	2725.77	15.868	.000	.025
Corrected model	4	4441.21	25.854	.000	.145
Intercept	1	40754.80	237.254	.000	.280
Error	609	171.777			
Total	614				
Corrected Total	613				

Note. *n*=616 (165 gifted, 445 non-gifted). Codes; Giftedness, non-giftedness=0, gifted=1; Gender, female=0, male=1; School type, public=0, private=1; Computer game type, single=0, multiple=1; Computer game friend, yes=0, no=1. R Squared=.145 (Adjusted R Squared = .140)

In the subsequent analysis, multiple linear regression was utilized to examine the relationship between CGAS-C and various predictors including gender, computer game friend, computer game type, and weekly and daily playing time in gifted students. The results of the correlational analysis indicated that gender, having computer game friends, computer game time, and playing time are correlated with CGAS-C of the gifted students.

Table 4. Correlation among Variables for Gifted Students

Variables	1	2	3	4	5	6
1.CGAS-C	–					
2.Gender	.32**	–				
3.Comp. Game Friend	-.16**	-.21**	–			
4.Comp. Game Type	.20**	.23**	-.36**	–		
5.Daily Play Time	.49**	.10	-.08	.28**	–	
6.Weekly Play Time	.35**	.19*	-16	.26**	.70**	-

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

The multiple regression analysis was found to be statistically significant $F_{(5, 163)} = 15.686$, $p<.01$, indicating that gender and daily playtime are significant predictors of CGAS-C in gifted students. This multiple regression accounted for 32% of the variability, as indexed by the adjusted R^2 statistic. The results are presented in Table 5.

Table 5. Multiple Regression Analysis for Gifted Students

Predictor	*b*	β	*t*
Gender	7.636	.268**	3.970
Comp. Game Friend	-2.203	-.078	-1.107
Comp. Game Type	-.644	-.023	-.316
Daily Play Time	7.802	.508**	5.543
Weekly Play Time	-.391	-.059	-.639

Note. n=165 (gifted) *p < .05. **p < .01. *Adjusted* R^2=.32

Discussion

This study aimed to investigate computer addiction levels of gifted students by comparing those with addiction levels of non-gifted students in primary school settings. The study revealed that gifted students preferred to play action-adventure, strategy, and football games but non-gifted students' preferences were action-adventure, educational, and strategy games. Therefore, action-adventure games were the game type most liked by both gifted and non-gifted students. Similarly, Şahin (2015) and Ustunel and Meral (2015) found that action-adventure was the most preferred game genre in Turkish gifted and non-gifted students in primary and secondary schools. The action-adventure genre might attract all the students because they contain actions and require quick decisions, reflexes, timing, exploration, and puzzle-solving. These challenges can make these games more appealing to children. Moreover, participants chose their games mostly based on family and friends' suggestions in the study, indicating that family and friends were the most influential groups on the game genre selection. Therefore, parents might recommend less harmful games for their children. This tendency might influence students' game preferences. This result also indicated that gifted and non-gifted students might have similar interests and preferences even though they have different cognitive, social and emotional capabilities and needs.

The study indicated no significant difference between gifted and non-gifted students in their computer game addiction levels, controlling for the gender, school, and game type. One of the explanations for this result might be parental control over computer use. Considering the participants' age, parents could be able to watch their children's preferences. Abelman (1995) pointed out that parents of gifted children had similar rules and regulations to other parents for television. Parents would monitor their children's time on computer games, as they monitor television-watching time. Another explanation might be that gifted and non-gifted students are in heterogeneous classes in the Turkish educational system so they spend a great deal of time together. This interaction might influence their activity preferences. In addition, experiencing achievements, discovering new information, and making new connections in games would be joyful and exciting for all students including the gifted and the non-gifted ones.

In the study, there was a significant difference between male and female students in their computer game addiction levels controlling for giftedness, school, and game type. Being a male positively predicted an increased likelihood of reporting game addiction. This result was consistent with other studies, which showed that in the general population, male students were playing games more frequently and more intensively than female students (Griffiths & Hunt, 1998; Hartmann & Klimmt, 2006, Won & Han, 2010). Similarly, some studies showed that boys had higher game addiction levels than girls in the general population in Turkey (Horzum, 2011; Şahin & Tuğrul, 2012; Zorbaz et al., 2015). One of the plausible explanations may be that male students have more opportunities to access computer games than girls do. Males were also found to spend more time playing computer games than girls (Rideout et al., 2010). Spending more time might lead to an increase in game addiction levels among males. Traditionally, playing computer games is considered a masculine stereotype, which also might affect the result. Moreover, females felt more uncomfortable with violence in computer games than males did (Thomas & Smith, 2004; Giles & Heyman, 2005). Another speculation would be parental attitudes towards their children's use of computers. Parents might put different restrictions in place depending on the gender of their children. Barcus (1969) showed that parents set fewer TV rules for boys than girls. Similar to the results of gender differences in addiction levels, gender is found to be a significant predictor of game addiction levels of gifted students. Being male also increases computer game addiction in gifted children.

According to the results, playing more computer games on a weekly basis (i.e., spread out) was not related to an increased likelihood of addiction. Instead, playing more computer games daily was related to addiction levels. An increased amount of computer playtime on a daily basis is one of the key symptoms of computer game addiction. Männikkö et al. (2015) indicated that increased gaming time was closely related to problematic use. On the other hand, these results would imply that computer gaming, just like most things, can be healthy in moderation, especially when it is spread out over time.

In conclusion, computer game addiction levels of gifted students were not significantly different than non-gifted students' levels in the study. On the other hand, male students had significantly higher game addiction scores than female students in both gifted and non-gifted samples. In addition, gender and daily playtime were found to be significant predictors of CGAS-C in gifted students. These results supported the fact that gifted students had similar game addiction patterns to non-gifted peers. For many students, though, these games are a social release and an integral part of their lives, however, the addictive potential of computer games should not be forgotten especially in students who spend their time gaming excessively.

There are considerable implications of the current findings. First, we, as adults, parents, educators, or professionals should consider the reality that computer games are part of children's lives. We cannot ignore its importance in their social, emotional, and academic lives. Wisely, incorporating computer games in teaching wisely would lead to favorable attitudes toward learning and STEM careers (Ball et al., 2020). While embedding games into technology-oriented STEM activities, educators should remain wary of potential risks of game addiction. Thus, this study implied the need to develop prevention programs for children to keep them from playing addictively, and to help them to overcome the adverse consequences of excessive computer gaming. Making adults aware of the close relationship between playing time and addiction risk would give them some tools to monitor and limit their children's time spent on gaming.

Limitations

Although the study revealed some considerable findings, it has some limitations. Firstly, the data about computer game addiction were collected using a self-reported scale that is mainly based on students' perceptions, which might lead to more positive than negative responses. In addition to self-report instruments, qualitative assessment, observation or other parties' views should be considered in the assessment of computer game addiction. Longitudinal design and follow-up studies would have strengthened the results by allowing the evaluation of changes over time. Another limitation related to the generalizability of these findings would be that the students were drawn from a convenience sample in Turkey. Also, the parents' views about their children's computer game use would have to be taken into account because children in the study were playing computer games mostly in their homes. Also, parental attitude towards computer games seems to be an important factor that should be taken into account in further studies. Bickham et al. (2003) found that age was a significant predictor of playing games. Thus, further studies should include a broader range of age to examine the effect of age on computer game addiction in gifted students. Gifted students in the study had attended a special program; therefore, other gifted students who do not get any special support should be involved in further research. Mazurek and Engelhardt (2013) showed that children with Autism Spectrum Disorders and

ADHD were at greater risk for problematic game use. Therefore, future research can focus on examining computer games in twice-exceptional students (i.e., gifted and ADHD or ASD).

Scientific Ethics Declaration

We, the authors, declare that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the authors.

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The Effects of STEM Education on the Students' Critical Thinking Skills and STEM Perceptions

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Abstract

Critical thinking and STEM career perception are important in 21th century and STEM education is necessary to promote middle school students' critical thinking skills and STEM perception. In this research we aim to research the effects of engineering design-based STEM education on the middle school students' critical thinking skills and STEM perceptions. In this case study, STEM activities were developed according the subjects of "Reflections in Mirror" and "Absorption of Light" and prepared activity booklet. The activities implemented with 30 seventh grade middle school students in Istanbul province for five weeks (20 course hours). While student solved the design problems in the housing estate and designed "Safe and Eco-Friendly House Estate", the teacher guided students in this process. To solve the problem/ground design challenge, they did five mini designs and five researches/experiments in six teams of five students. The quantitative data were performed California Critical Thinking Disposition Inventory (CCTDI) and STEM Perception Test as pre and post-test and analysed statically. Semi-structured interviews were performed to support quantitative data and analysed descriptively. STEM education developed students' critical thinking skills and STEM perceptions positively and also it had indirect effects on their career awareness.

Introduction

The concept of knowledge economy has been the focus of educational reforms in recent years (Ralls et al., 2020). With the increasing importance of the knowledge economy, it has become important to raise individuals who will add value to this economy, but the business world is concerned about whether the generation that will contribute to the workforce will meet the goals of the countries (Walton & Johnson, 2015). The growing generation has come to the fore as individuals, who have 21st century skills, who can offer solutions to daily and global problems, can think creatively and critically, contribute to innovation. (Johnson, 2018; Modi, 2011). Accordingly, the need of countries to develop learning in line with the demands of the information society has emerged (Organization for Economic Co-operation and Development [OECD], 2015). Science, Technology, Engineering and Mathematics (STEM) disciplines are a vital component in ensuring economic prosperity (Gough 2015; Murphy et al., 2018; Office of the Chief Scientist, 2014; Turkish Industry & Business Association, 2017; The Royal Society 2014; UNESCO 2015) has been the primary goal of countries to raise STEM professional awareness in the short term and to train competent STEM experts in the long term (Ralls et. al., 2020; Smith & White, 2019). Also, researches (e.g., Bybee, 2013; Johnson et al., 2015; Partnership for 21st Century Skills [P21]) show that 21st Century Skills are essential for a STEM literate society and a wide range of careers. It is noteworthy that many countries encourage the implementation of STEM education based on the integration of disciplines (Bybee, 2010; Guzey et al.2017; Hoeg & Bencze, 2017; Smith & White, 2019) to raise generation that have 21st century skills and STEM career.

STEM education is an approach that integrate science, technology, engineering, mathematics and has especially brought innovation to science education (Bybee, 2013). STEM is also called interdisciplinary because it is the creation of a discipline based on the integration of another disciplinary knowledge into a new whole (Lantz, 2009). Therefore, STEM education is also evaluated as a bridge between the education and career (Gillies, 2015; Gomez & Albrecht, 2014). The integration of disciplines has been discussed in variety of ways (e.g., design based, problem based, project based, inquiry-science and engineering implementation) in literature in STEM education (Park et al., 2018; Guzey et al., 2020). In all implementation of STEM education should be carried out the working processes of related disciplines (scientific inquiry, computational thinking, data processing or mathematical modelling, engineering design process) (National Research Council [NRC], 2012) and should focus on integrated STEM issues, real life problems, collaborative and doing learning, student-centered applications process evaluation and twenty-first century skills (Thibaut et al., 2018). Engineering plays a unifying role in STEM education, since engineering design process requires using the knowledge and skills of other STEM disciplines (Cavlazoglu & Stuessy, 2018; National Academy of Engineering [NAE] & NRC, 2009; NRC, 21010; NRC, 2012). For this reason, combining scientific inquiry and design- especially engineering design - activities in STEM education practices facilitates STEM integration at the K-12 education (Guzey et al., 2017; Guzey et al., 2019; Johns & Mentzer, 2016; Roehrig et al., 2021). These implementations are carried out within the context of design challenges, that provide an interdisciplinary context to learn science concepts (Wendell, 2008). In fact, design problems provide an interdisciplinary context to learn science concepts (Bybee, 2010). The individuals work on the solution of an authentic design problem with an interdisciplinary nature and thus, they manage the design process (Moore et al.,2014). Most generally they will manage the engineering design process stages: identify and define problems, develop possible solution(s), select best possible solution, construct a prototype, and test and evaluate the solution(s) (Wendell et al., 2010). In this process students are exposed to design-based challenges with which they can manage design processes. They will need scientific knowledge and skills to solve the given design challenge. In this process students engage develop solution to the engineering design challenge in authentic engineering experiences and establish conceptual integration between STEM disciplines. (Roehrig, et al., 2021).

Engineering design challenge is related a real-world problem and this problem is important for STEM disciplines' conceptual integration (Kelley & Knowles, 2016; Moore et al., 2014; Reynante et al., 2020; Sanders, 2009). Thus, the scientific research and inquiry process will be put to work. It includes establish a relationship between scientific inquiry and engineering design, confirmatory research inquiry and problem solving and an integral part of traditional science education (NRC, 2012). Thus, what is important in STEM education is not only to make a design or generate a product, but also to understand, realize, and get engaged in application areas of the knowledge and skills related to the discipline (Lachapelle & Cunningham, 2014; Lewis, 2005). Also, integrated STEM education requires to students to participate in twenty-first century skills (Roehrig at al., 2021) and some researches indicated that it affects positively students' knowledge and skills (Bybee, 2010; Gonzalez & Kuenzi, 2012; Meyrick, 2011). Despite these positive effects, it is clear that there is still a need to improve STEM teaching and learning from the current educational environment (Rall et al., 2020) and to understand the impact of them on student outcomes (Roehrig, et al., 2021).

One of the main reasons for the inception of STEM education is that "the young generation will acquire and use the 21st century skills" (NAE & NRC, 2009). Critical thinking, one of the important skills of the 21st century, is a skill required to keep up with the age we are living in (Schafersman, 1995) and is emphasized in science education curricula of many countries (Ministry of National Education, 2008; NAE & NRC, 2009; NRC, 2012). Critical thinking is the skills to evaluate all ideas for the solution of a real-life problem and to make a decision to solve the problem (Chaffee, 1994). For this reason, individuals become aware of and evaluate both their own and others' ideas, discuss and implicate in the critical thinking process (Chaffee, 1994; Kuhn & Dean, 2004). This process requires both problem solving and reasoning and decision making (Willingham, 2008) and is often expressed as: define the purpose of the problem, present questions and assumptions, gather data to try them, evaluate the data gathered with different points of view and draw conclusions for problem solving (Nosich, 2012) and thus it must be administered during the education process. There are concerns about how to gain or develop critical thinking skills in education (Duran & Şendağ, 2012; Hacıoğlu, 2017). For this purpose, designing learning environments that will enable students to think critically and implementing learning designs that will operate the critical thinking process (Bob, 2009; Duran & Şendağ, 2012; Ernst & Monroe, 2006; Hacıoğlu, 2017; Jonassen, 1997; Savery & Dufy, 1996) may indicate that there is still a need in education programs. In addition to emphasis put on critical thinking skills in STEM education, Hacıoğlu (2017) stated that critical thinking process and engineering design process included similar procedures. Hacıoğlu (2017) and Ure (2012) engineering design process, which executes STEM education, would make contributions to the development of students' critical thinking skills. Drew conclusions in the study carried out about engineering design process their critical thinking skills developed, and they even started to use the skills they acquired outside the classroom. It is considered that the association of critical thinking and engineering design process with these studies will make important contributions to the literature.

One of the other reasons for the STEM education is that young generation are component in STEM career fields (Bybee, 2010; NAE & NRC, 2009), because performing engineering design applications in STEM education gives students the opportunity to work as an engineer, learn the connections between science and engineering, and apply the scientific knowledge and skills they have acquired in the design problem (Guzey et al., 2019). Also, students can understand the nature of STEM disciplines, especially engineering, by carrying out the work processes of STEM professionals through the engineering design process (English et al., 2017; Fan & Yu, 2017). It is important to spend the effort required for career orientation for STEM disciplines during middle school when students plan their career goals (Almeda & Baker, 2020).

The middle school students' perceptions towards STEM fields are critically important for their future careers (Christensen & Knezek, 2017; Knezek et al., 2015). It is considered that STEM skills which students acquire at middle school level form a basis for a successful STEM career (Knezek et al., 2013). However, many middle school age students do not have positive perceptions towards STEM disciplines (Mills, 2013). Students have wrong and stereotypical judgements about the people who do STEM (Fralick et al., 2009; Gülhan & Şahin, 2018; Jung & Kim, 2014). Hence, students' perceptions towards STEM disciplines need to be developed. Despite the literature reveals that engineering education at K-12 level (Bybee, 2011; NAE & NRC, 2009; NRC, 2010; Sullivan, 2006) and STEM education (Gallant, 2011; Özkul & Özden; 2020; van Tuijl, C. & van der Molen, 2016) might have positive effects to develop students' STEM Perceptions, Engineering focused STEM implementation neglect in middle school (English, et al., 2017). Franz-Odendaal et al. (2016) in their research determined that the most important effect, which led students to STEM career, was the participation in STEM activities. Thus, it can be interpreted that the effects of STEM education on STEM perceptions are important research subject matter.

Although STEM education approach has become popular recently, the attempts to implement STEM education have been increasing both in national and international platforms. It is considered that the explanation of implementation process of the integrated STEM education which aims to develop the 21st century skills of the new raising generation is important for the individuals' career options (Bybee, 2000). The investigation of contributions of STEM education to students' critical thinking skills and career awareness will also set a good example for teachers and researchers to perform STEM education implementations. Some researchers in the field assert that it is important to increase students' awareness of learning the disciplines, but teachers who carry out STEM implementations have difficulties with their administration (Nathan et. al.,2013).

It is regarded that this research results will make contributions to the incorporation of engineering discipline along with technology and mathematics disciplines into science education and also will meet the need for the implemented educational activities expressed in the relevant literature (NRC, 2012). Moreover, it is considered that the study will make contributions to raising interdisciplinary awareness within the students about the importance of integration of engineering discipline into science education with regard to creating real-life contexts. In addition, the study results are important due to the development of students' critical thinking skills and perceptions towards STEM disciplines with regard to design based learning approach and also encouraging teachers for the actualization of design-based STEM education implementations.

The research aims at determining the effect of STEM education on the seventh grade students' critical thinking skills and STEM perceptions. In line with this purpose, the study sought answers to research question (RQ):

RQ1.Does STEM education affect the seventh grade students' development of critical thinking skills?
RQ2.Does STEM education affect the seventh grade students' development of STEM perceptions?

Method

In the research was used convergent parallel design mixed method. The purpose of this method is to simultaneously collect both quantitative and qualitative data, analysis them separately and compare the results (Creswell, 2014). In the quantitative part of the research, the single group pre-test & post-test experimental design and in the qualitative part of the research, case study was used. As case studies represent the analysis process, it aims at gathering detailed, systematic, and in-depth information. Triangulation was administered with the intention of supporting both qualitative and quantitative data and improving the trustworthiness of the study (Patton, 2002). In addition to this, in order to increase the trustworthiness of data analysis, two researchers analyzed and evaluated the data independently to enhance its credibility and thus member checking was done.

Participants

The participants consisted of 30 (13 girl, 17 boy) seventh grade students (12-13 years old) studying in a state middle school in Istanbul province in 2017-2018 school year. Convenience sampling was used for the selection of the population because of the convenient accessibility and proximity for the researchers between the classrooms. They have not been exposed to STEM education before.

Research process

First of all, STEM based activities in the literature were examined to develop STEM activities and the research related to the STEM education which would be implemented for the acquisitions of the subjects “Reflections in Mirror” and “Absorption of Light” for seventh grade middle school. When developing these activities, were taken into account integrated design-based approach, which depends on constructivist learning and situated learning and enables the integration of technology and engineering disciplines (Wendell, 2008). Design based approach is important to provide learning via real-world contexts and design process (Brown et al., 1989). The activity reflects the real-life problem on the house estate that have 700 detached houses with garden, one of the researchers and her family is experiencing. On this estate has occurred theft due to the security vulnerability. Due to the fact that the estate was built on an inclined area, the field of vision of the drivers is limited and accidents occur at the same place. The heating and electricity expenses of the estate have increased. The residents of the estate are experiencing problems for these reasons. This problem may be the problem of all students living in the same city. For this reason, it highly reflects the real-life context feature. Integrated STEM unit was designed adapting this problem to design challenge. This challenge is presented in a complex design problem case in the context of “Designing of Safe and Eco-Friendly House Estate”. If this design challenge is complex and big design problem and it requires all the knowledge and skills a unit, Wendell et al. (2010) suggested that STEM units should be created that include mini designs and mini researches design to overcome this challenge. In this direction, four mini designs and mini researches/ experiments have been created to enable students to acquire the knowledge and skills they need to achieve their grand design task (see Table 1), to perform the grand engineering design challenge related to “Designing of Safe and Eco-Friendly House Estate”. Then, STEM unit were built to implement the DBL process and to form the activities.

Two experts reviewed the activities. One of them reviewed the activities for their appropriateness for design-based learning and appropriateness for developing critical thinking, the other for appropriateness for design-based learning and STEM perceptions. The STEM unit was finalized by making changes in the instructions and contents of the activity, taking into account the feedback of expert. The “Reflections in the Mirror and Absorption of Light” unit STEM activities for seventh grade students presented Table 1 and described in detail below.

In accordance with the acquisitions of the “Reflections in the Mirror and Absorption of Light”, attention was paid that the context would continue throughout the unit and five activities including five design problems within the context of problem cases were developed under the theme of “A Design of a Housing Estate with Clean Energy and Safety” and students were asked to solve these problems in the housing estate called “Science Housing Estate” thinking like a scientist, an engineer, a technologist, and a mathematician. To implementation this activity, classroom was set up for STEM learning environment in that students worked collaboratively within the team and engaged for engineering design and scientific experiments. Six team work tables and one equipment table were set up in the classroom.

The process started with the challenge of “Designing of safe and eco-friendly house estate”. Within the framework of this design challenge, a problem case including a design problem was created for each activity. In each activity structured, the students attempted to achieve the design challenges by administering the engineering design process (Wendell et al., 2010) and following the instructions which would give them an opportunity for the scientific inquiry process by managing orientation, conceptualization, investigation, conclusion, and discussion phases implicitly in this process (Pedaste et al., 2015). An activity booklet containing instructions on the process was distributed to the students.

In the process, students conduct the engineering design process to perform both grand design challenges and mini design challenges. First, they discussed the problem and defined the great design task. In order to make it easier for students to understand the problem, a sketch of the house estate and photos of the areas where the problems occur are given. Mini design challenges were given to the students in order to present possible solutions. These design challenges included criteria and limitations. Students needed scientific knowledge to accomplish each design challenge. In order to reach this scientific knowledge, they conducted experiments, collected data and made conclusions by operating a guided research inquiry process. They offered solutions with the scientific results they obtained. They evaluated the proposed solutions as a group and evaluated them in the context of the criteria and limitations of the design challenges. They prototyped their best solution and tested it again in terms of criteria and limitations, discussing as a group whether they needed to improve their designs. In the last stage, students presented their designs and the process of creating this design to their classmates. By bringing together all the mini designs and mini researches results for the grand design, they continued the same processes for the grand design challenge.

Throughout the process, the teacher guides the students by asking their questions: "What are your suggestions for solving the problem? What did you do to achieve this? What did you find as a result of your research? How did you apply the research results to your solution suggestions? How did these results serve your problem? How did you decide the best solution? Does your protocol need improvement? Why is that? What kind of change should you make? How would you describe the design process?".

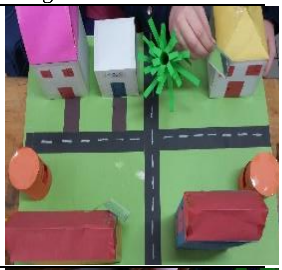
Table 1. Reflections in the mirror and absorption of light unit STEM activities for seventh grade students

Grand Design Challenge: Designing of Safe and Eco-Friendly House Estate

The grand design challenge is related a problem of house estates' residents and it need to redesign a house estate to answer the problem of the residents. House estate residents want to turn it into a clean energy and safe house estate. Students are expected to design a safe and Eco-Friendly House Estate, that will answer these problems:

- Since the theft has occurred due to vulnerability on this house estate, there is a need for a design that allows security guards to spy on more areas of the house estate.
- Due to the fact that the house estate was built on a slope, the field of vision of the drivers is limited and accidents occur in the same place. A design that will increase the field of vision of the drivers on slopes and intersections is required.
- The heating and electricity expenses of the house estate have increased. Designs that will save money on insulation and heating are required, where they can benefit more from renewable energy sources, the sun and wind.

Then, the mini design challenges and researches are performed to solve this complex problem, as follows.

Mini design challenges	Mini researches	Activity summary	Examples of student designs
1. Reciprocal mirror system design for safety: Observe the areas outside the housing estate	*Flat mirrors:* What are the characteristics of the flat mirrors? How does the image in the flat mirrors occur?	The students explore characteristics of flat mirror and image on flat mirrors. Then they design a prototype with flat mirrors system to observe the areas outside of the house estate. The students explore characteristics of flat mirror and image on flat mirrors. Then they design a prototype with flat mirrors system to observe the areas outside of the house estate. They place the flat mirror system they create in the relevant areas on the house estate model and test.	
2. Safety traffic mirrors design for safe house estate: Prevent the insecure entrance gates and accidents.	*Convex mirrors:* What are the characteristics of convex mirrors? How does the image in the convex mirrors occur?	The students explore characteristics of convex mirrors and image on convex mirrors. Then they design a prototype with convex mirrors to increase visibility in the entrance gates and ways of a house estate. The students explore characteristics of convex mirrors and image on convex mirrors. Then they design a prototype with convex mirrors to increase the field of visibility in the entrance gates and ways of a house estate. They place the convex mirrors in the relevant areas on the house estate model and test.	
3. Solar heated water tank design and positioning for eco-friendly house estate: Heat up water by using solar energy.	*Concave mirrors:* What are the characteristics of the concave mirrors? How does the image in the concave mirrors occur?	The students explore characteristics of concave mirrors and image on concave mirrors. Then they design a prototype with concave mirrors, that heat up water by gather sunlight into an area and ensures saving on heating, and placed it house estate model and test.	
4. House painting colors design eco-friendly house estate: Absorption of sunlight, heat isolation.	*Absorption of light:* How do different colors absorb light?	The students explore the relationship between the absorption of light and its colours. Then they design a prototype to absorb sun's heat energy by painting the houses and test to ensure saving on heating	
5. Colour wheel design for eco-friendly house estate: Let our colour wheel be our wind energy.	*Colour spectrum:* How do white colour occur from other colours?	The students explore how do white colours occur from other colours. Then they design a colour wheels as indicator of the amount of wind energy. They place and test these designs in places where wind energy will be used.	
Students apply their students to the grand design challenge through mini design and research. They design and explain their safe and eco-friendly house estate design.			

In the process and at the last stage, after completing each design task, students were provided to make presentations to other friends, ask questions or answer questions, and exchange views with the aim of developing critical thinking skills, as well as supporting the development of verbal communication skills. In order to improve their written communication skills at the end of the activities, they were asked to promote their designs with posters and product catalogs in order to contribute to their entrepreneurial skills and to reflect the science concepts they gained. After the designs were completed, they were asked to evaluate their solution proposals objectively in the context of criteria and limitations, and to develop critical thoughts about what they would change if they did it again. They wrote on their individual worksheets, critically and objectively, the strengths and weaknesses of their designs and the dimensions that need improvement. They scored and evaluated their designs with the help of the analytical rubric according to the design criteria (clarity of view, cost, durability, aesthetics, effective use of time).

In the seventh grade class where the activities were implemented, one of the researchers was assigned as a teacher and guided students during the implementation process of the activities. Before the implementation of activities, CCTDI and STEM Perception Test, providing the quantitative data of the research, were administered as a pre-test to the students in one class hour. Then, because students did not have any experiences about STEM education were distributed activity booklets to students and explained engineering design process and information related to their responsibilities and how the lesson would be executed. The implementation of the activities lasted 5 weeks/20 courses hours.

The students were encouraged for the process of implementation to work in groups and have in-group and intergroup communication. Heterogeneous groups were attempted to be created according to the achievement and gender during the formation of collaborative groups. Students' science course report grades in the first term were used as a basis for the achievement criteria. They were encouraged to work in groups (six groups/ each five students) and have in-group and intergroup communication. After they completed each mini design challenge and researches, they presented their design prototype to their peers, asked questions or answered the questions and exchange ideas with the intention of mainly developing critical thinking skills and also supporting oral communication skills. They were asked to evaluate the suggestions for the possible solutions objectively within the context of criteria and limitations and to develop opinions critically about what they would change if they could do it again.

Data Collection and Analysis

In this study, quantitative data via California Critical Thinking Disposition Inventory (CCTDI) and STEM Perception Test and qualitative data via semi-structured interviews were collected. The quantitative data were analysed statistical via SPSS-17, qualitative data also descriptively.

The California Critical Thinking Disposition Inventory (CCTDI), was used in the study to determine the effect of STEM education on students' critical thinking skills, developed by Facione & Facione (1992), revised by Facione et al. (1997) (as cited in Kökdemir, 2003). This test adapted to Turkish by Kökdemir (2003). The inventory rated on 6-point Likert type consists of 75 items and 7 sub-scales of truth-seeking, open-mindedness, analyticity, systematicity, self-confidence, and inquisitiveness. The scale's Cronbach Alpha reliability coefficient is 0.86 (Kökdemir, 2003).

STEM Perception Test, was used to determine the effect of STEM education on students' perceptions towards STEM disciplines, developed by Knezek & Christensen (1998) for STEM derived from Zaichkowsky (1985)'s questionnaire for information technologies (as cited in Knezek et al., 2013) adapted by Gülhan & Şahin (2016) to Turkish. Test consists five sub-scales: science, technology, engineering, mathematics, and career, uses 7-point (from negative [1] to positive [7]) scale like in semantics scale and test's Cronbach Alpha reliability coefficient is 0,891. The students were asked to evaluate five semantic adjective pairs for each of the five sub-scales. It was accepted that when the STEM perception score was high, the student's STEM perception was positive, so comparisons were made between the sub-scales and the total STEM Perception scores.

We statistical analysis package methods (Statistical Package for Social Sciences 17 (SPSS-17) were used for the analysis of the data obtained from CCTDI and STEM Perception Test. Shapiro Wilk test, Skewness, Kurtosis, results and Stem-and-Leaf Plot, Q-Q Plot graphs was used to test the normal distribution of the data. The dependent t-test was administered for the normally distributed data of CCTDI and CCTDI's all subscales, Wilcoxon signed rank test was used for the data of that are not normally distributed data of STEM Perception Test's subscales. p significance level was accepted 0,05 in order to reveal the significant differences of the results. Pre and post comparison of the data obtained from the CCTDI and STEM Perception Test were conducted.

Semi-structured interviews (according to Given, 2008), were carried out with the students after the implementations with the intention of supporting the data obtained from the CCTDI and STEM Perception Test to determine the effect of STEM education on students' critical thinking skills and perceptions towards STEM disciplines. Interview questions were developed by the researchers and were evaluated by two experts in the line the purpose of the study, the content of the activities and the age range of the participants. Consisted of the following questions: "What is your opinion about the process and contributions of the process?" and "Did the activities carried out throughout the process have an effect on your opinions/ideas about science, technology, engineering, and mathematics? For example, did they change your opinions about your career options?". The interview included two parts of questions: "Interview Questions about Critical Thinking" and "Interview Questions about STEM Perceptions" and throughout the interviews, the questions in Table 2 were asked to the students to elaborate their opinions when necessary. Semi-structured interviews were carried out with 6 students (3 female, 3 male), at least one student from each student group where implementations were carried out by one of the researchers and each interview lasted 7 minutes on average. The students chosen for the interviews were selected via maximum variation sampling (or sometimes called maximum diversity sampling) considering their achievements and genders.

Table 2. Semi-structured interview questions

Sub-scales		Interview questions related to the sub-scales
Critical thinking skill	Truth-seeking	How did you achieve solution way with the planning made with your friends?
		How did you choose the best solution offer for the problem solution?
	Open-mindedness	While presenting solution offers, have you only considered your own opinions or have you considered your peers' opinions?
		Are you open to the ideas of other people in daily life? Was it valid for these activities?
	Analyticity	How did you deal with the problems encountered?
	Systematicity	What did you pay attention while implementing your plan and creating your design?
		While actualizing your design, did you act either based on knowledge or intuitions?
	Self-confidence	Did you confide in yourself during the operations in the process?
	Inquisitiveness	Did your inquisitiveness about the knowledge related to the problem solution increase?
		Did you need information while solving the problem? Was there anything you were curious about?
STEM perceptions	Science	What did the activities make you think about science? Did your opinions about science change? Can you describe science in a few words?
	Mathematics	What did the activities make you think about mathematics? Did your opinions about mathematics change? Can you describe mathematics in a few words?
	Engineering	What did the activities make you think about engineering? Did your opinions about engineering change? Can you describe engineering in a few words?
	Technology	What did the activities make you think about technology? Did your opinions about technology change? Can you describe technology in a few words?
	STEM career	What did the activities make you think about STEM career? Did your opinions about STEM career? Can you describe STEM career in a few words?

Descriptive analysis technique, one of the qualitative data analysis methods, was used for the analysis of qualitative data obtained from the interview questions. In descriptive analysis, the data were read and organized under the pre-determined themes (sub-categories of critical thinking and STEM disciplines), the data were defined by supporting them with direct quotes and interpretations and comparisons were made on the results obtained.

Taking Hacıoğlu (2017) as reference for the evaluation of the responses given to the interview questions related to the critical thinking, they were analysed descriptively within the framework of critical thinking sub-scales in Table 3. Considering interview questions related to the perceptions about STEM disciplines, first of all, all the data were documented, and common codes were achieved. The expressions stated by the students in their responses to the questions related to the disciplines of science, mathematics, engineering, and technology were evaluated under the titles specified and results were obtained. Examples from the student responses to the interview questions about the subject were cited for the presentation of the results.

Table 3. Sub-scales of critical thinking disposition and evaluation of it considering its characteristics, and elements of descriptive analysis

Category	Sub-Category	Explanation
Sub-scales of critical thinking dispositions	Truth-seeking	Considering alternatives
		Tendency to search for truth
		Considering different opinions
		Asking questions
	Open-mindedness	Being open-minded and tolerant to different approaches
		Sensibility towards your own mistakes
		Giving importance to the ideas of others while making decision
	Analyticity	Paying attention to the possible problems/ conditions that will cause trouble
		Tendency towards reasoning with difficult problems and using objective evidence
	Systematicity	Research based on knowledge, planning, and detail
		Tendency to use a decision-making strategy based on knowledge and following a specific procedure
	Self-confidence	Confiding in your self-reasoning processes
	Inquisitiveness	Desire to get –learn unconditional information

The research process was attempted to be explained in detail for the reliability of the qualitative data analysis and the data were analysed and compared independently by the two researchers. The analysis process continued until consensus was reached between the intercoder (researchers).

Results

The results obtained as a result of the research were examined under two subheadings considering the research questions.

The Results Related to the Effects of STEM Education on Students' Critical Thinking Skills

The results, obtained from CCTDI and is related to the effect of STEM education on the seventh grade students' critical thinking skills, were presented the results obtained from CCTDI. CCTDI was implemented before and after the implementations to determine the effect of STEM education on the seventh grade students' critical thinking dispositions. Dependent samples t-test was administered to compare the students' pre-test and post-test scores related to the CCTDI and the results were presented in Table 4.

Table 4. The results for the comparison CCTDI pre-test post-test measurements of the students' scores

Scale-Subscale	N	X	SS	Sd	t	p
CCTDI Pre-test	30	208,37	235,145	29	-2,571	016*
CCTDI Post-test	30	235,14	311,765			
Truth-seeking	30	25,80	4,902	29	-2,684	,012*
	30	28,90	5,815			
Open mindedness	30	49,20	8,117	29	-3,005	,005*
	30	54,67	9,834			
Analyticity	30	44,97	8,451	29	-1,615	,117
	30	47,53	7,820			
Systematicity	30	23,83	5,173	29	-2,034	,051
	30	25,77	4,297			
Self-confidence	30	26,10	5,320	29	-,543	,591
	30	26,80	5,229			
Inquisitiveness	30	38,47	6,932	29	-,291	,773
	30	38,93	6,767			

*$p<.05$

When Table 4 is examined, it is regarded that there is a significant difference between the seventh grade students' CCTDI Pre-test and Post-test scores in favour of post-test ($t(30)=-2{,}571$; $p<.05$). As is regarded with the differences between the pre-test and post-test scores, as a result of the t-test, there is a significant difference in favour of post-test. This result can be interpreted that the effect of STEM education on students' critical thinking skills on the limitedness of the uncontrolled variables (being familiar with the questions, experiences and etc.,) is at medium level (.2<Cohen d=0.47<.8). However, it draws attention that students' both pre-test and pots-test scores are low.

When the scores which students got from the pre-test and post-test sub-scales of CCTDI was examined, it was determined that there was a significant difference between the seventh grade students' pre-test and post-test results in terms of the sub-scales of truth-seeking and open-mindedness in critical thinking disposition test in favour of post –test results but there was not a significant difference regarding the sub-scales of analyticity, systematicity, self-confidence, and inquisitiveness. The interpretation of this result is that on the limitedness of the uncontrolled variables (being familiar with the questions, experiences and etc.,), the STEM education has an effect on the seventh grade students' critical thinking dispositions regarding the sub-scales of truth-seeking and open-mindedness but it does not have any effects on the sub-scales of analyticity, systematicity, self-confidence, and inquisitiveness.

When all results obtained from the CCTDI are evaluated, they can be interpreted that the STEM education has made contributions to the development of the seventh grade students' critical thinking dispositions. While this development has positive effects on the development of truth-seeking and open-mindedness sub-scales of critical thinking dispositions, it does not have any effects on the development of sub-scales of analyticity, systematicity, self-confidence, and inquisitiveness.

The results, obtained from interviews indicate that all the students expressed their opinions about the process supported the data obtained from the CCTDI and explained the process by putting emphasis on the truth-seeking and open-mindedness sub-scales of critical thinking. Then, students mentioned systematicity, analyticity, inquisitiveness, and self-confidence sub-scales, respectively. Only S4 expressed his opinion by emphasising the development in all of the sub-scales of the critical thinking while making an explanation. Exemplary quotations related to sub-scales of critical thinking disposition presented in Table 5. When these results were compared to mean scores of quantitative data obtained with the CCTDI, they showed parallelism with them.

Table 5. Exemplary quotations related to sub-scales of critical thinking disposition

Sub-scales	Exemplary quotations
Truth-seeking	S6: As time went by, we wondered more about the best solution of the problem and we began to explore more and also we tried to decide whether or not the materials we used were good.
Open mindedness	S1: We shared opinions with each other to find solutions to the problem. If I acted considering only my own opinions, I would not be successful, that's why I really paid attention to others' opinions, too…
Analyticity	S4: At first, I did not put forward an idea. We were beginning with 80% imagination. But during the process we achieved the success with our designs by thinking upon how we should do and doing research.
Systematicity	S2: We evaluated everyone's opinion, combined our opinions, and generated a way for solution and implemented it. Considering the different opinions, we decided which one to use for the problem solutions and chose the best one.
Self-confidence	S5: We chose one of the practical and functional solution offers. Here, my opinions were generally chosen as the best solution. Normally, I would like them to be my opinions. I thought that mine were the best. In this study, although my opinion was chosen as the best solution, I told my peers to discuss their opinions, too.
Inquisitiveness	S3: While doing research, when we encountered something that we didn't know, we felt the need to explore them.

The Results Related to the Effect of STEM Education on Students' STEM Perceptions

The results, obtained from STEM Perception Test and is related the effect of STEM education on the seventh grade students' STEM perceptions, were presented in Table 6 and Table 7.

Table 6. The results for the comparison of students' STEM perception pre-test post-test measurements

STEM perception	N	X	SS	Sd	df	t	p	Cohen d
Pre-test	30	4,83	1,19	0,97	29	-2,22	,034	0,406
Post-test	30	5,22	0,99					

Table 7. The results related to the sub-scales of STEM perception test via wilcoxin signed rank test

Sub-scales	Pre-Post test scores	N	Mean rank	Rank total	z	p
Science	Negative ranks	10	16,00	160,00	-,698	,485
	Positive ranks	17	12,82	218,00		
	Zero differences	3				
Mathematics	Negative ranks	12	11,96	143,50	-1,356	,175
	Positive ranks	16	16,41	262,50		
	Zero differences	2				
Engineering	Negative ranks	10	12,05	120,50	-1,882	,060
	Positive ranks	18	15,86	285,50		
	Zero differences	2				
Technology	Negative ranks	10	10,30	103, 00	-2,069	,039
	Positive ranks	17	16,18	275,00		
	Zero differences	3				
Career	Negative ranks	12	14,75	177,00	-,038	,970
	Positive ranks	14	12,43	174,00		
	Zero differences	4				

When Table 6 and 7 was examined, it was determined that there was a significant difference between the pre-test and post-test measurements of the scores belonging to the technology sub-scale of the seventh grade students' STEM perceptions ($z=-2,069$; $p<.05$). Based on this result, it can be interpreted that STEM education caused a development with students' perceptions of technology and general STEM perceptions.

Table 8. Exemplary quotations related to STEM discipline and career perceptions

STEM perceptions	Exemplary quotations
Science	S6: I thought that science was only human body. In fact, I witnessed the development of technology, what we benefited from and what we produced." At the beginning, science seemed to be complex but as I get engaged in it, I am more curious and excited.
Technology	S4: For example, we benefited from technology to test heat insulation and used a thermal camera. I saw that it had an effect on facilitating everyday life. Moreover, we realized that heat insulation could be done not only with materials but also with colors.
Engineering	S1: The activities made me think that engineering is a difficult job. In the past I thought that engineers could make drawings, in fact I learned that they did a lot of things. I realized that engineering plays an important role in our lives. I even decided to become an engineer.
	S5: When I did not succeed in our designs, I lost my interest in engineering. However, people construct houses for other people, they make drawings and thus I respect them. But I don't like it.
Mathematics	S3: In mathematics, the teachers told us to draw an angle and calculate it and we did it. But, we did need them with our designs. We calculated the angle and by adjusting the angle via measuring the length and the angle, we placed the mirrors. By using mathematics, we revealed that it was fine and useful.
Interdisciplinary relation	S2: I understood that it was necessary and effective to use science and mathematics together. For example, engineers use mathematics and measure the size and make different, fun, and useful designs with them.
	S6: I can't work in one of these fields. I think that these are professions for talented and patient people.

The results, obtained from interviews and is related to the effect of STEM education on the seventh grade students' STEM perceptions, all students expressed their opinions about their perceptions towards science, technology, engineering, and mathematics. They determined that the STEM activities changed their perceptions towards science and technology's relationship with everyday life. S2 and S3 determined that he could have a career in the field of science, these opinions demonstrate that STEM education effected on their career awareness. All students mentioned their opinion associated with engineering design process and other STEM fields. In addition to this, S4 determined that as she had little interest in engineering and she did not want to be an engineer, she finalized her decision not to choose engineering as a career during the process and thus she mentioned career awareness. Exemplary quotations related to STEM perceptions presented in Table 8. When these results were compared to mean scores of quantitative data obtained from the "STEM Perception Test", they showed parallelism with them.

Discussion and Conclusion

The discussion, conclusion and suggestions of the study were presented under two headings considering the research questions.

Effects of STEM Education on Students' Critical Thinking Skills

As a result of the research, STEM education affects positively critical thinking skills, especially critical thinking's sub-scales "truth-seeking and open-mindedness", of the seventh graders. In other words, students' critical thinking dispositions enhanced thanks to the STEM activities implemented in the study. The study of Ure (2012) examined the effect of engineering design process on the critical thinking skills of the fifth grade high school students supports our study's results. Ure (2012) who discussed critical thinking sub-scales as organization, asking questions, planning the future, improvement, seeking opportunities, effective communication, and analytical thinking of problems revealed that students showed improvement in different critical thinking domains. Similarly, in the other researches are asserted that STEM education could be used to develop students' critical thinking skills (Duran & Şendağ, 2012; Robinson, 2016; Mater et al., 2020; Retnowati et al., 2020). The implementation period of this study is shorter than from period of implementation of the studies in the literature. This seen as a limitation, but it is not a limitation according to Garrett (2009)'s study in that stated that no significant connection between the performance time in developing critical thinking and critical thinking skills.

In line the results of the study revealed that students constantly sought truth to find the best solution offer during the process and while doing this, they constantly considered their group members' opinions and they frequently emphasized the sub-scales of truth-seeking and open-mindedness of critical thinking skills and engineering design process. This result is also related to the fact that the process of result a solution to a problem in the real-life context positively affects the development of students' critical thinking skills (Appamaraka et al., 2009; Duran & Şendağ, 2012; Ernst & Monroe, 2006; Hove, 2011; Jonassen, 1997; Savery & Dufy, 1996). When examined, these results can be explained with the fact that critical thinking process and engineering design process involve similar steps (Hacıoğlu, 2017; NAE & NRC, 2009, NAE, 2010). Moreover, they may be explained with the requirement that engineers must use critical thinking skills (Reed, 2010). During the engineering design process, while individuals attempt to deal with the problems, they manage critical thinking process implicitly and thus students' critical thinking skills develop (Carroll, 2014; Kwek, 2011; Robinson, 2016; Ure, 2012). It is considered that the management of the intertwined processes of engineering design and scientific inquiry in the study promotes this result (Hacıoğlu, 2017) and there are also research results which reveal that the inquiry-based activities develop students' critical thinking skills (Bybee, 2000). In addition to this, similarly, there are studies which suggest that seminars, workshops, conferences, and competitions organized and designed with the theme of science for STEM education which focuses on interdisciplinary learning and teaching develop students' critical thinking skills (Blake & Liou-Mark, 2015). Although it does not assess critical thinking skills directly, with regard to the teacher views about STEM education, teachers and prospective teachers determine that STEM education will make contribution to students' critical thinking skills (Hacıoğlu, 2017; Hacıoğlu et al., 2016, 2017). These results seem to support the study results directly.

Effect of STEM Education on Students' STEM Perceptions

As a result of the research, STEM education affects positively on the seventh grade students' STEM perceptions and particularly on their perceptions towards the STEM disciplines' relation with real life changed. There are also other experimental studies suggesting that STEM education had positive effects on STEM perceptions (Brown et al., 2016; Gülhan & Şahin, 2016; Knezek et al., 2013; Lachapelle & Cunningham, 2007; Martinez-Ortiz, 2008; Nite et al., 2014; Sarı et al., 2018; Whitehead, 2010; Zeid et al., 2014). It was found in the study that among the STEM sub-scales, a significant development was observed only with the technology sub-scale. In the literature, there are studies that reveal that K-12 engineering education has positive effects on the perception of technology (Lachapelle & Cunningham, 2007; Martinez-Ortiz, 2008). It is considered that the content of the activities is effective with the result. As a result of the interviews, it was found that some students perceived technology as electronic gadgets like computer before the activities; however, thanks to the activities, they determined that even mirrors were a product of technology. Remembering only computers when talking about technology causes semantic restriction (or narrowing) (Cunningham et al., 2005; Lantz, 2009; White, 2014; Winegar, 2000). Hence, the results demonstrating that STEM education developed perception of technology exhibit a positive effect regarding the perception of technology.

The interviews revealed that the process made contributions to students’ career awareness. As a matter fact, researches indicate that STEM education improve students' STEM career awareness and increase their tendency to choose professions in STEM fields for the future (i.e. Beier et. al, 2019; Çevik, 2018; Özkul & Özden, 2020). However, while some students opined that they would choose engineering, some students determined that they would not choose engineering profession. One student remarked that because STEM fields were difficult, he would not choose career in these fields. This result can be interpreted that the students raised awareness about the importance of engineering, but they have still some perceptions that these fields are difficult. In fact, it can be considered that this situation is a gain because STEM education does not make claim that everyone will be a STEM worker and it is obvious that this is not realistic (Gülhan & Şahin, 2016). After evaluating themselves as a result of STEM education, students decide whether or not they are suitable for the field and this is a positive result because it will prevent them from making wrong career choices in the future.

Limitations and Implications

Carrying out the study within the context of science course is a limitation because the activities were developed according to the engineering design-based STEM education and the learning outcomes of science course and the learning outcomes of mathematics and technology courses were involved in the planning as a skill. If such activities are implemented in the mathematics, technology courses and similar courses in the schools having flexible curriculum, a fully integrated STEM education can be implemented.

Recommendations

It was concluded in the research that STEM education had positive effects on the seventh grade students’ critical thinking skills and STEM perceptions. When the results of the study were evaluated, the following suggestions were made for the teachers and researchers:
1-) In order to develop critical thinking, one of the four basic skills (4C) of STEM education, students must be allowed to evaluate the relevant subject area, designs they make, and their own opinions and as well as their group members’ opinions at each stage of the process with an inquisitive perspective during the STEM activities.
2-) To increase the number of individuals working in the STEM fields, which is the ultimate goal of the economic dimension of STEM education, it is required that students’ perceptions of STEM fields must be correct. Thus, the implicit or explicit messages given during the STEM applications or by the teachers are of vital importance.

Scientific Ethics Declaration

We, the authors, declare that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the authors.

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Innovative Technology Applications in Science Education: Digital Holography

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Abstract

The use of technology in education gained importance in the 21st century and the use of innovative technologies in education-technology integration came to the agenda. This study examines students' attitudes, thoughts, suggestions and opinions about digital hologram, which is one of the innovative technologies. The method used in the study was sequential explanatory approach, which is a mixed research method in which quantitative and qualitative methods are used together. The study was carried out with 418 students from six different public secondary schools affiliated to the Provincial Directorate of National Education in the Aegean Region. During the application process of the study, biodiversity, cells and divisions, DNA and genetic code, systems in our body topics, which are included in the science curriculum of the 5th, 6th, 7th and 8th grades were supported with digital holograms in a five-week period. Digital hologram attitude scale (DHAS) and digital hologram reflection form (DHRF) developed by researchers were used to collect data. Independent samples t-test and one-way analysis of variance (ANOVA) were used in the analysis of the data obtained from DHAS, whereas content analysis was used in the analysis of the data obtained from DHRF. As a result of the research, students' attitudes towards digital hologram were found to be positive. In addition, students' attitudes towards digital hologram did not differ significantly according to gender, grade, and school, but they differed according to science course academic achievement score in favor of students with a score between 85-100. Moreover, students evaluated the digital hologram as a useful tool that can contribute to academic learning and can be used in science class in the topics such as solar system and planets, space research, and living creatures. Based on these results, it is recommended to use the digital hologram at all grade levels and for the topics covered by science curriculum.

Introduction

In the 21st century we are in, changes are experienced in almost every field depending on the development of technology and these are also reflected in the fields such as health, tourism, art and education. Thanks to technological advances especially in the field of education, learning and teaching settings are rearranged and technology is described as a tool assisting education (Dieuzeide, 1971). In this sense, it is considered as an integral part of education and education-technology integration is prioritized especially in science education (Inam, 2004).

Many different technological tools have been used in the education from the past to the present and still continue to be used depending on today's developments. The technologies used in the past, such as overhead projector, computer, simulation are replaced by innovative technologies such as augmented reality, virtual reality and digital hologram (Huang et al., 2016; Ingram & Jackson, 2004). Digital holograms, which are frequently mentioned in the recent periods, attract particular attention with their integration into education (Ghuloum, 2010). Digital hologram was described as records created by the three-dimensional interference of laser light waves (Jampala & Shivnani, 2014). The concept of digital hologram is also defined as mediators that can bring 3-D images of certain objects to different settings and ensure the continuity of the image even in the absence of these objects (Katsioloudis & Jones, 2018).

Digital holograms, which have been used in the fields such as medicine, art, tourism, manufacturing industry and entertainment, were recently entered into the agenda with their use in education and they are intended to be included in education considering their advantages (Harper, 2010). In this sense, the advantages of the use of digital holograms in education can be listed as providing realistic images to users, communicating through virtual images among people in different locations, allowing the inclusion of non-alive characters into the real world through digital holograms (Kalansooriya et al., 2015). In addition, it is known that the use of digital holograms in education has other advantages such as contributing to the education industry on a large scale, structuring future knowledge, and providing industrial development in education with innovative technologies (Mavrikios et al., 2019). When all these advantages are taken into consideration, the use of digital holograms in education came into question, especially in science education, which is thought to be easier to integrate technology (Khurmyet, 2016).

In science, it is predicted that the use of digital holograms, which enables us to obtain three-dimensional images, will be appropriate in the concretization of the abstract topics in science, such as microscopic creatures, extinct creatures, systems in our body, the nature and particulate structure of matter, biodiversity, cells and divisions, reproduction growth and development of living creatures (Seckin Kapucu, 2020). In this way, students were assumed to be able to better envision these abstract concepts that they hear in the class. In this sense, using hologram technology in the class is thought to make the topics recallable and provide fast learning opportunities for students (Aslan & Erdogan, 2017). Moreover, the use of digital holograms in the instruction of the topics covered in the science curriculum may offer students meaningful learning opportunities and digital holograms may increase the motivation of the students (Orcos & Magrenan, 2018). In addition, there are studies in the literature reporting that the use of digital holograms in education has direct effects such as facilitating learning, contributing to students' visualization and retention skills, being a technological teaching tool that can be easily used in classroom setting, and adaptation to future technology (Roslan & Ahmad, 2017; Sudeep, 2013).

Regarding the literature; Orcos and Magrenan (2018) investigated the effect of instructing cell division topic with digital holograms on meaningful learning. As a result of the research, the satisfaction levels of the students towards holograms were found to be high. It was also concluded at the end of the research that digital holograms can be a motivational teaching tool. Sudeep (2013) investigated the significance of digital holograms in learning settings. As a result of the study, it was concluded that digital holograms can be an effective teaching tool for the future. Okulu and Unver (2016) aimed to support teacher candidates' thinking and problem-solving skills with holograms. As a result of the research, teacher candidates’ astronomy knowledge was observed to increase with the products created by themselves in astronomy. In their study, Aslan and Erdogan (2017) talked about the necessities of using technology in education. They emphasized that with technologies such as hologram, topics can be more memorable for students and students can be provided with fast learning.

Regarding all this information, it can be said that digital holograms can be used in classroom settings and this innovative technology can be preferred as a teaching tool. At the same time, it is thought that digital holograms will make abstract concepts, especially the ones included in science education, easy to express and facilitate to explain the topics that are difficult to understand (Turk, 2020). In addition, with digital holograms it is expected that the shortcomings in science education, such as the provision of microscope, telescope, can be eliminated and students will be able to see the contents of the topics they want to examine, such as cell, solar system and planets, etc. in three-dimensions (Seckin Kapucu, 2020). Moreover, it is thought that the images obtained with digital holograms will allow the students to experience the feeling of reality and, accordingly, students can get real life experiences (Kalansooriya et al., 2015).

The review of the literature shows that the technologies used in science education usually contain similar activities and materials. Research on the integration of digital holograms into education, especially into science education and students’ attitudes on this issue are rare (Cabı, 2016; Huffstetter et al., 2010). Hence forth, with this study, it is thought that the use of digital hologram applications, which is quite rare in science education, will be promoted, and thus, the relationship between science and technology will be strengthened, digital holograms will be integrated into science classes and science education-technology integration will be addressed from a different perspective. Accordingly, this study aimed to examine student attitudes, thoughts, suggestions and opinions about the use of digital holograms in science class. For this purpose, the following sub-objectives were addressed.

- Is the digital hologram attitude scale used to measure students' attitudes towards digital hologram a valid and reliable scale?
- Is there a significant difference between the attitudes of students towards digital hologram, which is one of the innovative technologies, according to gender, grade, school and science course academic achievement score?
- What are the student opinions regarding the use of digital hologram in science class?

Methodology

Research Model

In order to determine the attitudes of secondary school students towards digital hologram, which is one of the innovative technologies, sequential explanatory approach model, which is a combination of quantitative and qualitative methods, was used in this study. The reason for choosing a mixed research pattern for the study is to ensure that the problem status is explained and interpreted in the best way using quantitative and qualitative data together, to reach strong evidences supporting each other and to perform an in-depth analysis with richer results (Rossman & Wilson, 1994). In the analysis process of sequential explanatory approach model, which is one of the mixed research designs, quantitative data was analyzed first, then the two data groups were combined and interpreted together, and the comments were discussed in the discussion section (Creswell & Clark, 2017).

Study Group

The study was carried out with a total of 418 students, 228 girls and 190 boys, from 5, 6, 7 and 8th grades, who were attending 6 different state secondary schools affiliated to the Provincial Directorate of National Education in the Aegean Region, during the fall semester of 2018-2019 academic year. Maximum diversity sampling method, which is one of the purposeful sampling methods, was used. Accordingly, the study group has been diversified according to gender, grade, school and academic achievement score variables. The demographic characteristics of the study group are shown in Table 1.

Table 1.Demographic characteristics of the study group

Variables		*f*	%
Gender	Female	228	54.55
	Male	190	45.45
School	School 1	105	25.11
	School 2	90	21.53
	School 3	83	19.85
	School 4	65	15.55
	School 5	38	9.10
	School 6	37	8,86
Grade	5th grade	123	29.42
	6thgrade	105	25.11
	7th grade	120	28.70
	8th grade	70	16.77

f = frequency

Regarding Table 1, 54.55% of the students constituting the study group were female and 45.45% were male. In addition, 25.11% of the students participating in the study were from school 1, 21.53% from school 2, 19.85% from school 3, 15.55% from school 4, 9.10% from school 5 and 8.86% from school 6. 29.42% of the students participating in the study were from 5th grade, 25.11% from 6th grade, 28.70% from 7th grade and 16.77% of them were from 8th grade.

Research Process

Science topics, in which digital holograms will be employed during the research process, have been determined before the process based on the gains in the science curriculum. First researcher prepared digital hologram videos on the topics specified for 5th, 6th, 7th and 8th grades. The topics specified were as follows: 5th grade, “extinct creatures” from the “biodiversity” topic of “human and the environment” unit; 6th grade, “structures and organs” included in the “support movement system, digestive system, and circulatory system” topic of “the systems in our body” unit; 7th grade, “comparison of animal and plant cells” from the “cell” topic of “cells and divisions” unit; 8th grade “the helix structure of DNA, gene and chromosomes” from “The structure and self-mapping of DNA” topic of “DNA and genetic code” unit. During the application process, 24 hologram videos prepared by the first researcher were used. Hologram videos prepared on the topics determined for each grade were presented to the students of the relevant grade. During the application process, the topics were instructed by the teacher of the course and supported by digital hologram videos prepared by the researcher. Hologram pyramids required for the use of digital hologram videos are designed by the students in the classroom. Students were given a ten-minute period in the lesson to design the hologram pyramids. During this period, the operation was smoothly processed by providing students with the information about the steps of hologram pyramid preparation. Then, hologram images on related topics were examined using the hologram pyramids prepared by the students. Digital hologram images used in the application process are shown in Figure 1-2-3-4.

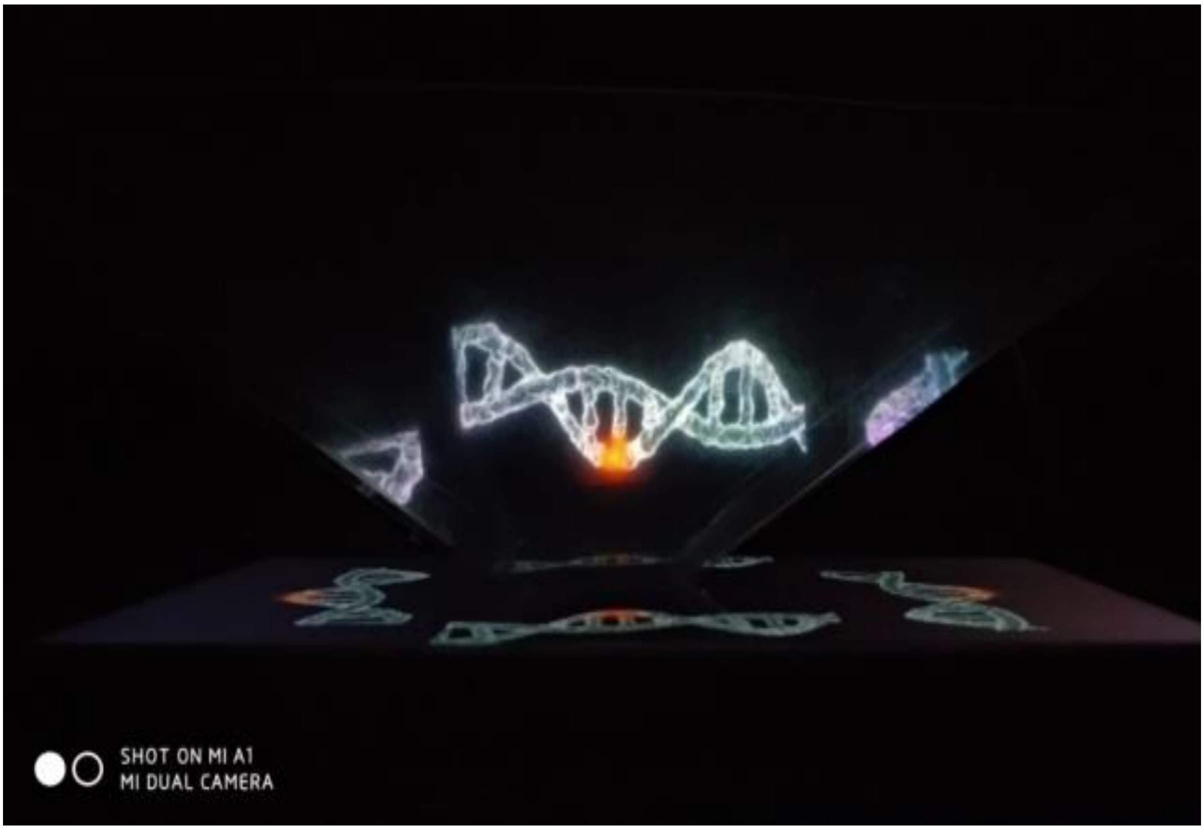

Figure 1. The Helix Structure of DNA

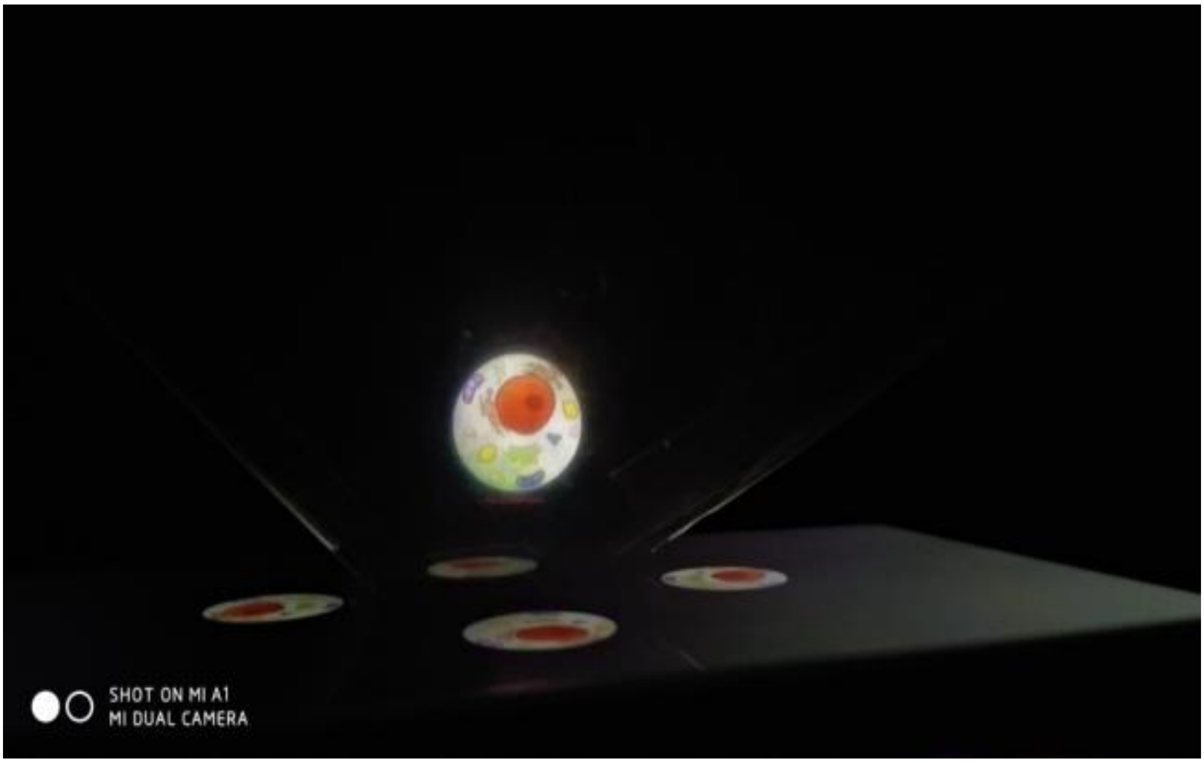

Figure 2. Animal Cell

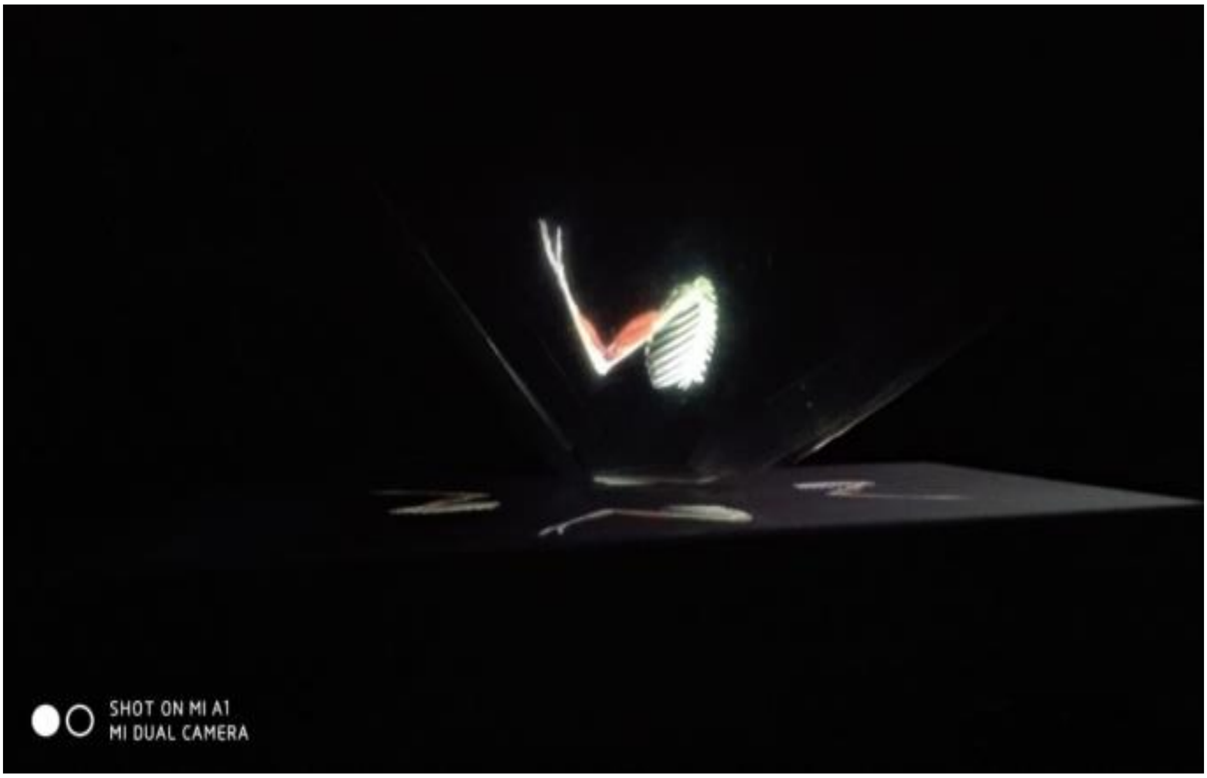

Figure3. Support and Movement System

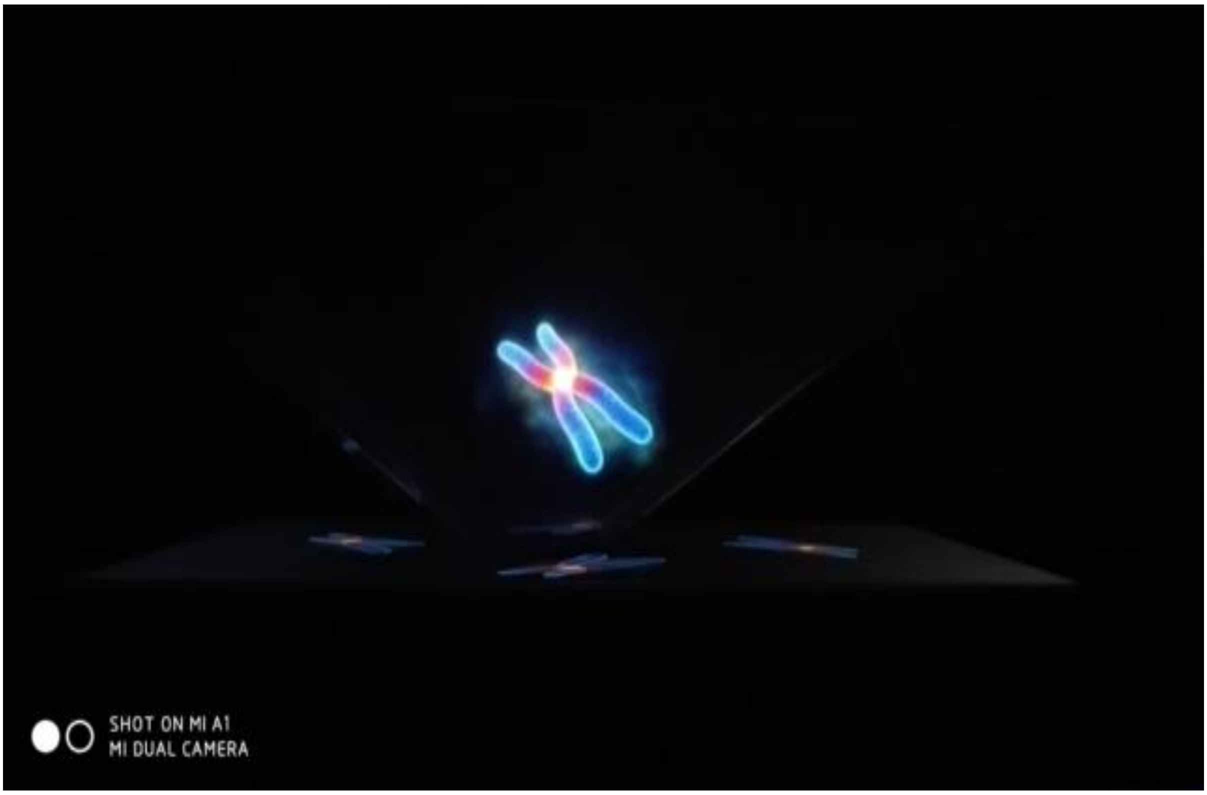

Figure 4. Chromosome

Data Collection Tools

Digital Hologram Attitude Scale (DHAS) developed by researchers was employed in the study to determine students' attitudes towards digital hologram. In order to determine students' thoughts, suggestions and opinions about digital hologram, Digital Hologram Reflection Form (DHRF) prepared by the researchers was used.

Digital Hologram Attitude Scale (DHAS)

In the first stage of the scale development process, the relevant national and international literature was reviewed. In addition, the previous scale development studies on the attitude towards technology, the use of digital holograms in education and the gains included in the science curriculum were reviewed. As a result of the review, the items that represent the attitudes towards digital hologram were specified and a pool of items was created with the statements that will measure these items. In the second stage of the scale development process, item pool, scale format and answering options were created. DHAS consists of two parts. The first part of the measurement tool includes students' personal information, gender, grade, school, and science course academic achievement score.

The second part is comprised of 28 scale items with 5-point Likert structure, created to determine students' attitudes towards digital hologram. Regarding the study group, using a Likert type scale was considered to be appropriate in terms of applicability and usefulness. The scale was arranged as 5-point Likert scale and the items included in the scale were scored as; 1 = “Strongly Disagree”, 2 = “Disagree”, 3 = “Neither Agree / Disagree”, 4 = “Agree” and 5 = “Strongly Agree”. Five levels were specified, where the lowest scores obtained from the scale was “1.00” and the highest “5.00” (Edwards, 1983; Seker & Gencdogan, 2014). Deciding on the format of the scale, expert opinion was consulted. A science education specialist, an information technology specialist, a science teacher and a measurement and evaluation specialist reviewed the items in the scale. Following expert opinions, necessary arrangements were made in the scale items. Exploratory factor analysis (EFA) was performed on the data obtained from DHAS in order to determine the factor structure and provide evidence for structural validity. Confirmatory factor analysis (CFA) was performed using LISREL 8.51 software to confirm the accuracy of the factor structure obtained from EFA. Cronbach's alpha internal consistency coefficient was calculated to provide evidence for the reliability of the entire scale.

Digital Hologram Reflection Form (DHRF)

DHRF prepared by researchers was used to collect qualitative data of the study. DHRF consists of two parts. The first part of the reflection form includes students' personal information, gender, and grade, whereas the second part consists of 7 open-ended questions prepared considering the purpose of the research, investigating students’ thoughts, suggestions and opinions about hologram applications. The prepared reflection form got ready to apply upon taking the opinions of a science education specialist, an information technologies specialist and a measurement and evaluation specialist.

Data Collection Process

Data collection process was completed in 5 weeks. In the first three weeks of the data collection process, the topics determined for each grade were instructed by the teacher and supported by digital hologram videos prepared by the researcher. In this process, hologram pyramids used to watch hologram videos were prepared by students. The instruction of the topic was supported with hologram pyramids and hologram videos prepared by the researcher for related topics. In the fourth and fifth weeks of the process, quantitative data was collected by administering DHAS on the students.

After the quantitative data were collected, three achievement groups were formed according to the science course academic achievement score for each grade, namely 5th, 6th, 7th and 8th grades. The achievement groups were based on 100-point system used by the Ministry of National Education. Students were grouped according to science course achievement score as: 85-100, 70-84.99, 55-69.99, 45-54.99 and 0-44.99. Then, students having a score between 84.99 and 100 were classified as successful, 55-69.99 as mediocre and 0-54.99 as unsuccessful. The purpose of this process is to reach students' opinions from each grade and achievement level and reflect maximum diversity in the sample. The same procedures were repeated for each grade, 4 students from 3 achievement groups of each grade were specified, and then DHRF was administered on a total of 48 students to collect the qualitative data.

Data Analysis

SPSS 22.0 and LISREL 8.51 softwares were used in the analysis of quantitative data obtained from DHAS. Data was entered into the program and was cleared. The normal distribution of the data was tested.

Table 2. Descriptive statistics of the items and factors

Items and factors		$\bar{X}$	df	Item total cor.
Factor 1-Intrinsic motivation				
I4	The topic of science course in which digital hologram activities are used attract my attention.	3.54	0.03	0.50
I2	I wonder how digital hologram activities will end.	3.25	0.02	0.57
I5	Using digital hologram activities in class increases my interest towards the course.	3.72	1.23	0.62
I3	Using digital hologram activities in class increases my curiosity towards the course.	4.01	0.04	0.46
I6	In order to design the digital hologram myself, it is enough to see it once.	2.19	0.03	0.71
Factor 2- Facilitating learning				
I27	I may not be able to learn every concept in the science class with a hologram.	2.68	1.14	0.30
I28	I can use digital holograms whenever I want.	2.03	1.26	0.29
I26	It is easy to learn new concepts with digital holograms.	2.59	1.33	0.32
Factor 3- Continuity of learning				
I8	Digital hologram activities help me discover new knowledge.	2.52	1.05	0.43
I7	I can make research about the usage areas of digital hologram activities.	2.28	1.07	0.35
I9	The design process of the digital hologram draws my attention.	2.09	0.04	0.66
Factor 4- Technological motivation				
I14	It is fun to create images with digital holograms.	3.45	1.01	0.59
I13	Being in touch with technology in the courses gives me pleasure.	3.17	0.03	0.46
I15	Making digital holograms in the classroom excites me.	2.36	0.02	0.54
Factor 5- Real life experiences				
I19	I can produce solutions for different problems with digital hologram activities.	2.77	1.04	0.58
I11	I like the image formed in digital hologram applications to be in vivid colors.	2.15	0.02	0.71
I10	I can understand what the image formed in digital holograms is.	2.68	0.03	0.67
I20	I may need help if I want to use digital hologram applications in a course other than science.	1.02	1.20	0.33
Factor 6- Technological proficiency				
I16	I believe that I can easily learn the challenging topics with digital hologram applications.	4.01	1.06	0.23
I12	I can teach digital hologram application to others.	2.04	1.12	0.37
I18	I can perform digital hologram activities I learned alone.	1.96	1.11	0.44
Factor 7- Diversity of use				
I24	Digital hologram applications make me think of imaginary concepts as real.	3.99	1.19	0.65
I25	I'm curious about the next digital hologram activity.	3.20	1.27	0.64
I21	I know that digital hologram applications are used in different fields.	2.72	0.02	0.74
Factor 8- Physical properties of hologram				
I23	Colorful holograms increase my interest towards the activity.	2.08	1.08	0.59
I22	I can easily find the materials used in digital hologram design.	2.95	0.03	0.63
Factor 9- Keeping up with the developments				
I17	I am pleased to learn new information through digital hologram applications.	3.09	1.09	0.40
I1	I follow scientific developments about digital hologram applications.	4.18	0.03	0.72

$\bar{X}$ *=arithmetic mean*
df =degree of freedom

In order to determine the reliability and validity of DHAS, factor analyzes was performed and Cronbach alpha coefficients representing item-scale correlation were calculated. EFA and CFA factor analyzes were used in analyzing the data and the dimensions of the scale were specified. At the same time, items to be included in the scale were determined by correlation-based item analysis. In addition, the average score of each item in DHAS was calculated. Regarding the evaluation of the arithmetic means of the items included in the attitude scale, the range intervals were determined as 4/5 = 0.80 by using the formula of "Range Width = (Sequence Width)/(Number of Groups to be Made)". Hence, 1.00-1.79 range corresponds to “Strongly Disagree”, 1.80-2.59 “Disagree”, 2.60-3.39 “Neither Agree/Disagree”, 3.40-4.19 “Agree”, and 4.20-5.00 to “Strongly Agree” (Tekin, 1996).

Afterwards, negative items were reverse coded, the average scores of students' attitudes towards digital hologram was calculated and students' attitudes were interpreted according to the corresponding score range. At the same time, independent samples t-test was used to compare students' attitudes towards digital hologram according to gender, and one-way analysis of variance (ANOVA) was used in performing three and more group comparisons in terms of academic achievement score. Levene test was used to test the homogeneity of the variances before the analyzes. Levene test’s result was over 0.05, therefore the variances were assumed to be homogeneous and LSD test, which is one of the common post-hoc multiple comparison tests, was preferred to determine the source of the significant difference in the multiple comparison of average scores (Buyukozturk, 2013).

Content analysis was employed to analyze the qualitative data collected by DHRF. The main purpose of content analysis is to reach the information related to the concepts that can explain the collected data. In this study, qualitative data was analyzed in four stages: coding data, creating themes, organizing codes and themes, and identifying and interpreting the findings (Yıldırım & Simsek, 2008). In the qualitative analysis, DHRF data were transcripted first. All qualitative data was reviewed by the researcher. The responses of the students participating in the research were coded by thematic coding and content analysis tables were created. In order to support the themes and codes created by content analysis with examples, quotations from student opinions were included. Students' opinions on digital holograms were analyzed by two researchers, then inter-coder reliability was checked. Cohen Kappa's correlation coefficient between the coders was calculated using the formula (KAG) = Agreement / (Agreement + Disagreement) on the total scores obtained from the evaluations of both researchers (Miles & Huberman, 1994). Cohen Kappa's correlation coefficient was approximately $\kappa = .75$, which indicates a good consistency between raters. Cohen Kappa coefficient between 60 and 70 is an indication that the correlation coefficient between the raters/observers is good (Sencan, 2005).

Results

This section includes the findings obtained in line with the objective and sub-objectives of the research. The results of the findings obtained from DHAS within the scope of the study are shown. The items grouped under each factor, factor names and descriptive statistics of the factor items are shown in Table 2. Regarding Table 2, the item total correlations of DHAS items vary between 0.23 and 0.74. Cronbach alpha coefficients were calculated in order to provide evidence for the reliability of 28 items included in DHAS. Cronbach alpha coefficient of the whole scale was found to be 0.96. The reliability coefficients of DHAS factors are shown in Table 3.

Table 3.Reliability coefficient of DHAS and its factors

Factors	Number of items	Cronbach alpha
Intrinsic motivation	5	0.95
Facilitating learning	3	0.85
Continuity of learning	3	0.89
Technological motivation	3	0.90
Real life experiences	4	0.85
Technological proficiency	3	0.78
Diversity of use	3	0.80
Physical property	2	0.80
Keeping up with the developments	2	0.85
Overall	28	0.96

Regarding Table 3, the reliability coefficients of the factors were found to be as follows: Intrinsic motivation – 0.95, Facilitating learning - 0.85, Continuity of learning – 0.89, Technological motivation – 0.90, Real life experiences – 0.85, Technological proficiency – 0.78, Diversity of use – 0.80, Physical property – 0.80, and Keeping up with the developments – 0.85. The reliability coefficients obtained for each factor are 0.70 and above, which is an indicator of the reliability of the scale; hence the reliability coefficients being between 0.80-1.00 is seen as an indicator of the high reliability of the scale (Buyukozturk, 2013; Kalayci, 2005).

The factor structure of DHAS was tested by confirmatory factor analysis, which tests of the compatibility of the factor structure formed by EFA with the data (Tabachnick & Fidell, 2007). CFA was performed using LISREL 8.51 software to verify the nine-factor structure obtained by EFA and fit statistics were calculated for the nine-factor model. Regarding the fit indices of the model that is subjected to confirmatory factor analysis, chi-square value (X^2 = 416.78, N = 418, df = 314, p <0.05) was observed to be significant. However, since the probability of significant analysis results increases as the sample size increases, it is recommended to check X^2/df ratio for large samples; the ratios lesser than five are accepted as an indicator of compliance (Kline, 1998; Sumer, 2000). The fit index values of the scale for CFA are shown in Table 4. Regarding Table 4, the value obtained by dividing the chi-square fit index to the degree of freedom was found to be 1.3273, which is smaller than 3, indicating a perfect fit (Kline, 1998; Sumer, 2000). In addition, comparative fit index (CFI) was found to be 0.95 indicating a perfect fit, and goodness of fit index (GFI) was found to be 0.93, indicating a good fit (Hu & Bentler, 1999; Schumacker & Lomax, 2010). At the same time, The Root Mean Square Error of Approximation (RMSEA), which is 0.028, indicates a perfect fit (RMR), which is 0.036 indicates a good fit (SRMR), which is 0.047, indicates a perfect fit (Brown, 2006; Hu & Bentler, 1999).

Table 4. CFA fit indexes for DHAS

Fit indicators	Achieved values	Acceptable values
X^2/df	1.3273	$2 \leq X^2/df \leq 3$ (Kline, 1998; Sumer 2000)
CFI	0.95	0.95≤CFI≤0.97 (Hu & Bentler,1999)
GFI	0.93	0.90≤GFI≤0.95 (Schumacker & Lomax, 2010)
RMR	0.036	RMR<0.08 (Hu & Bentler, 1999)
SRMR	0.047	0.05<SRMR<0.10 (Brown, 2006)
RMSEA	0.028	0.00<RMSEA<0.05 (Hu & Bentler, 1999)

X^2/df = chi-square/degree of freedom

Findings of the analysis of students' attitudes towards digital hologram according to several variables

Descriptive tests were used to discover students' attitudes towards digital hologram. The average of the scores that students got from DHAS was found to be 78.05 and the standard deviation was 13.06. The average of their attitude towards digital hologram corresponds to 3.46 at the Likert-type scale. Accordingly, the average is within the range of 3.40-4.19, corresponding to the expression "I agree" and it can be said that students' attitudes towards digital hologram are generally positive (Tekin, 1996).

Independent groups t-test was used to determine the differentiation of students' attitudes towards digital hologram according to gender. Regarding t-test results, the average score of female students was $\bar{X}$= 80.63 and male students was $\bar{X}$= 75.35. But, the difference of students' attitudes towards digital hologram was found to be insignificant according to gender (p> 0.05). ANOVA test results shows, the attitude of the students towards digital hologram were observed not to differ significantly according to grade ($F_{(3.414)}$=1.141; p>0.05). The findings are shown in Table 5.

Table 5.ANOVA test results of students' DHAS scores according to grade

Source of the variance	Sum of squares	df	Average of squares	F	p
Inter-groups	529.242	3	176.414	1.141	.236
Intra-groups	64028.365	414	154.657		
Total	64557.607	417			

df =degree of freedom *F =comparison of variances* *p =significance*

Independent samples single factor ANOVA was used to determine the differentiation of students' attitudes towards digital hologram according to the school they attend. The findings of the ANOVA test performed are shown in Table 6.

Table 6.ANOVA test results of students' DHAS scores according to school

Source of the variance	Sum of squares	df	Average of squares	F	p
Inter-groups	1432.849	5	286.569	1.796	.089
Intra-groups	65748.793	412	159.584		
Total	67181.642	417			

Regarding ANOVA test results in Table 6, the attitude of the students towards digital hologram were observed not to differ significantly according to school ($F_{(5.412)}$=1.796; p>0.05). Independent samples single factor ANOVA was used to determine the differentiation of students' attitudes towards digital hologram according to science course academic achievement score. The findings are shown in Table 7.

Table 7.ANOVA test results of students' DHAS scores according to science course academic achievement score

Source of the variance	Sum of squares	df	Average of squares	F	p
Inter-groups	2578.674	4	644.668	3.829	.016
Intra-groups	69372.416	412	168.379		
Total	71951.090	416			

Regarding Table 7, the scores from DHAS were observed to differentiate significantly according to students' science course academic achievement score ($F_{(4.412)}$=3.829; p<0.05). Hence, Levene test was performed to check the homogeneity of the variance. Levene test result was 0.86> 0.05, therefore the variances were assumed to be homogeneous, then LSD test was applied in order to specify the groups between which the difference was observed, and the findings are shown in Table 8.

Table 8. LSD test results applied to students' DHAS scores according to science academic achievement score

Comparison of the groups	p	Significant Difference
Excellent-unsuccessful	.04	Excellent > unsuccessful Excellent > mediocre
Excellent -mediocre	.02	
Excellent -good	.36	
Mediocre- unsuccessful	.71	
Good- unsuccessful	.54	
Pass- excellent	.069	

p =significance

Regarding Table 8, the significant difference in academic achievement score among the groups was found to be in favor of students with an excellent science course academic achievement score (85-100). Accordingly, it can be said that the attitude of the students with excellent academic achievement scores towards digital hologram is higher than unsuccessful (0-44.99) and mediocre (55-69.99) students.

Findings about students' opinions on the use of digital hologram in Science course

Students', thoughts, suggestions and opinions about digital holograms was collected via DHRF prepared by the researcher. There are seven open-ended questions in the reflection form. DHRF was applied to 48 students in total, 4 students in each of the 3 success groups determined for each grade. All qualitative data was reviewed by the researcher. Content analysis tables were created by coding the responses of the students participating in the research by thematic coding method. To support the themes and codes created by content analysis with examples, quotations from student opinions were included. Codes such as P1, P2, P3 were assigned to each participant while quoting statements. The themes, categories, codes and frequencies about the use of digital holograms in science class are shown in Table 9.

The answers given by students regarding the use of digital holograms in science class were grouped under three themes as thoughts, practices and suggestions (Table 9). The categories under the theme of thoughts are "hologram applications" and "technological applications in science class".

Table 9.Themes, categories, codes and frequencies about the use of digital holograms in science class

Themes	Categories	Codes	*f*
Thoughts	Hologram applications	Useful	9
		Real-like	7
		Impressive	5
		Funny	5
		Motivating	4
		Interesting	4
		Striking	3
		Instructive	2
		Scientific	1
		Thinking tangibly	1
		Exciting	1
		Intriguing	1
		Convenient	1
	Technological applications in science class	Facilitating learning	14
		Facilitating understanding	11
		Making lessons fun	8
		Supporting academic achievement	4
		Creating lifelike setting	1
Practices	Previous usage	No/ I didn't use	30
		Yes/I used	6
	Impact on Learning	Academic learning	22
		Learning with fun	11
		Academic motivation	7
		Active participation	2
		Cooperative learning	1
Suggestions	Topics	Solar system and planets	9
		Space researches	8
		Living creatures	6
		Particulate structure of matter	4
		Systems in our body	2
		Electricity	2
		Periodic system	2
		Cycles of matter	1
		Seasons	1
		Nature events	1
	Other courses	All courses	16
		Mathematics	11
		Social Sciences	5
		Only Science	3
		Information technologies	2
		English	2

f = frequency

The code mostly mentioned in the category of hologram applications is "useful". Accordingly, it can be said that students find the hologram applications useful. A participant on this issue said, "Science lessons with holograms were really good. It should be used because better, useful lessons are instructed with holograms (P3)", another opinion supporting this was, "I found the hologram applications good. I think it will also be useful for my lessons and my future (P7)". Another frequently mentioned code of hologram applications category is the real-like. A participant regarding the holograms being real-like said, "It is very realistic. What we see in the hologram is retained and what we want to examine can be examined in more detail thanks to the holograms (P15)", whereas another participant supported this opinion as, "I think Hologram application is very realistic, so people will learn 3-D things like real (P29)". Another category under the theme of thoughts is technological applications in science class. The codes included under this category are facilitating learning, facilitating understanding, making lessons fun, supporting academic achievement, and creating lifelike setting. The most frequently mentioned code of the category is “facilitating learning”. Accordingly, it can be said that the students mostly evaluate the use of technological applications in science course as providing convenience in learning. A participant expressed her opinion on this issue as, “If hologram application is used in science class, it will be better for me because I understand better with images. I can learn the topics easily (P38)”, whereas another participant said, “I think the use of technology in science class is very positive, it would be nice if we use it from now on, it could make it easier for us to learn the lessons (P6).”

The practices theme includes “previous usage” and “impact on learning” categories. Previous usage category consists of the codes “No/ I didn’t use” and “Yes/I used”, where “No/I didn’t use” is the mostly mentioned code. A participant said on this issue, “I have not use it before. But I liked it very much and will use it from now on (P13)”, another one expressed his opinion as, “I have never used them before but from now on if I don’t understand a topic, I will try to understand it by making holograms (P32).” This code was followed by “Yes/I used”. A participant said, “Yes, I have used it before. We designed and built the hologram pyramids in a Tubitak project (P39)”, another participant's opinion was “I used it. A teacher has told about holograms and I was interested, then I watched the videos and made and used them at home (P28)”. Another category under the application theme is the impact on learning, which includes “Academic learning”, “Learning with fun”, “Academic motivation”, “Active participation” and “Cooperative learning” codes. The code mostly mentioned under this category is observed to be academic learning. A participant said, “I will understand the topics in science class better if holograms are used. I understand more easily with holograms because it is the course that I usually have difficulty in understanding. No question remains in my mind (P29)”, another opinion supporting this was “I usually understand better with shapes, pictures, including the questions. Since there are beautiful visuals in the holograms, I can say that they will contribute a lot to my learning (P33). ”

Suggestions theme includes the “topics” and “other courses” categories. The codes under the topics are: “Solar system and planets”, “Space researches”, “Living creatures”, “Particulate structure of matter”, “Systems in our body”, “Electricity”, “Periodic system”, “Cycles of matter”, “Seasons” and “Nature events”. The most mentioned code of this category is observed to be “Solar system and planets”. A participant said, “I would like it to be used on the sun and planets. I am both curious about it, and I think that with holograms I can see them in a colorful and radiant way and make observations (P12)”, whereas another participant's opinion was, “We can see the phases of the moon in motion with holograms. It will be notable. Seeing the light or dark sides of the moon at each stage. Holograms make the topic memorable (P21)”. The other category of suggestion theme is other courses, which includes “All courses”, “Mathematics”, “Social Sciences”, “Only Science”, “Information technologies” and “English” codes. The most mentioned code of other courses category is all courses. A participant expressed her opinion as “I’m in favor of the use of holograms in all courses, I think all courses are suitable for using holograms (P7)”, another participant said, “I think it would be nice in every class. The child, who understands only one lesson, will understand the others as well, the interest towards other courses will increase, the grades will improve, student will be better. Holograms can be used in any lesson (P34)”.

Discussion and Conclusion

In this study, it was aimed to analyze students' attitudes towards the use of digital hologram in the instruction of the topics in the science class and students' thoughts, suggestions and opinions about the use of digital holograms. For this purpose, data obtained from DHAS and DHRF developed by the researcher were analyzed. Quantitative data from DHAS were supported by qualitative data from the DHRF, ensuring consistent results.

In order to test the validity and reliability of DHAS developed by the researcher, content and structure validity, item total correlation, and Cronbach alpha internal consistency coefficient were calculated and the factor structure of the scale was tested with factor analysis and accordingly, it was confirmed that the model has an acceptable fit.

As a result of the study, according to the findings obtained from DHAS, it was concluded that students' attitudes towards digital hologram did not differ significantly by gender. Similarly, Bakr (2011) and Bush (1995) have not find a significant difference between attitudes towards technology and gender. At the same time, students' attitudes towards digital hologram did not show a significant difference according to grade. However, the attitude scores of 5th grade students towards digital hologram were found to be higher than those of 6th, 7th and 8th grade students. In addition, students' attitudes towards digital hologram were observed not to differ significantly according to schools they were attending. Students' digital hologram attitude scores differed significantly according science course academic achievement score. Regarding the findings obtained from the multiple comparison test performed to determine the source of this difference, it was concluded that the students with excellent achievement score had higher digital hologram attitude score than the students who were unsuccessful and mediocre. In the study of Birgin and Zengin (2016), a significant difference in students' attitudes towards technology was reported in favor of students whose course grade was between 85 and 100.

Students' thoughts, suggestions and opinions about digital hologram were reviewed via DHRF, and the findings obtained indicated that students had generally positive opinions about the use of technological applications in science class. At the same time, students evaluated the digital holograms as useful and realistic. Regarding the studies in the literature, it was concluded that digital holograms facilitate understanding and learning and contribute to students' learning by making fun. In addition, there are studies indicating that the use of digital technologies in the classroom setting makes the lessons interesting and contributes to students' understanding the course more easily (Arioglu & Uzun, 2008; Cagiltay et al., 2001). Moreover, the inclusion of technological equipment in classroom settings was considered to facilitate the education as the technology facilitates the daily life and meet the needs of education (Van Wyk & Louw, 2008). Students suggested that hologram applications can be used in the topics such as solar system and planets and space research of the science course. In addition, digital hologram applications can be used not only in science class but also in all other courses and especially in mathematics. This finding overlaps with the finding of Gul and Yesilyurt (2011), who reported that students wanted to use digital technologies as much as possible in the courses. In addition, the use of technology in the classroom setting was observed to offer a rich learning and teaching environment for both students and teachers (Delen & Bulut, 2011; Guzel, 2011).

Recommendations

In line with the results obtained from this study, the following suggestions can be submitted: It is recommended to include the use of technological equipment in the world of education and to benefit from the advantages provided by technology. At the same time, instead of computers, smart boards, simulations etc., which are frequently used in education, innovative technologies such as digital hologram, which have been mentioned recently and included in this study, can also be used and students can be given the opportunity to be in touch with these technologies. Accordingly, it is recommended that educators are informed about these technologies and studies should be carried out in order to use innovative educational technologies in the world of education and bring them to classroom settings. As a result of the research, students' opinions towards the digital hologram indicated that holograms can facilitate the understanding and learning of the lesson. Hence, innovative technologies such as digital hologram can be used in classroom settings instead of mockups and models used in the instruction. These technologies, which are carried to classroom settings, can expand students' perspectives on technology. In addition, it is recommended to use digital holograms that provide a sense of reality in science education for the concretization of abstract concepts, or in the fields such as space researches, solar systems, sky observations, which are considered to be impossible for students to observe in daily life.

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The Effect of Virtual Laboratory Applications on 8th Grade Students' Achievement in Science Lesson

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Virtual experiments

Abstract

The aim of this study is to reveal the effect of using virtual lab application in science teaching on students' academic achievement and students' views on virtual lab application. The study group of the research consists of 62 students studying in the 8th grade of a secondary school in Antalya in the 2019-2020 academic years. Mixed method design was used in the research. In the quantitative dimension of the study, the control group and the experimental group taught with virtual laboratory applications were compared in terms of achievement. The qualitative dimension of the study was composed of the data obtained from the interview forms conducted with the experimental group students after the application and the data obtained from the observation forms made during the application. Research results revealed that virtual laboratory applications increased the academic success of the experimental group students. On the other hand, it has been shown that virtual laboratory applications contribute to students' meaningful learning by enabling the concretization of abstract subjects, and that these applications positively support students' interest, excitement and motivation towards the science course because they are found attractive.

Introduction

The age of information and technology, in which we live in, affects societies on the basis of all sectors from production areas to consumption areas and contributes to the development of societies along with the globalizing world. Thanks to the scientific developments, developments in education and educational technologies have become a part of modern education approach (Karasar, 2012). The use of developing technological applications in obtaining scientific knowledge also affects learning-teaching methods and strategies (Say & Pan, 2017). For this reason, technology-based teaching methods are used instead of the traditional teaching methods used today during the learning-teaching process. This situation is an indicator of the progress experienced in the field of education (Ekici et al., 2007).

The innovations and developments in education aim to simplify the concepts that seem complicated in education and to achieve permanent learning by doing, in accordance with the constructivist approach (Tekdal, 2010). With the development of technology, it has become necessary to use multimedia supported teaching activities that can activate the cognitive, affective and psychomotor structures of students in learning environments (Harwood & McMahon, 1997). Therefore, ensuring that the classroom environments are updated in accordance with technology so that students who actively use technology in daily life do not break away from education and training will ensure that the education and training process that will take place is up-to-date and more effective (Kaya & Aydın, 2011). When the literature is reviewed, it is possible to say that technology-supported educational researches using technology in education are gathered under certain headings. We see that one of them is computer-aided education, in which learning outcomes are given to learners using computers, and the other is simulations specific to gains developed with applications such as Java and Macromedia Flash (Duman & Avcı, 2016). Apart from these two applications, another technological tool used is virtual laboratories where students can perform their experiments by following the instructions given to them, just like in a real laboratory. In virtual laboratories, different from computer aided applications and simulations, it is possible to design virtual experiments suitable for many achievements in science education (Duman & Avcı, 2016).

Many definitions have been made for virtual experiments in the literature. Virtual experiments are defined as computer software for learning / teaching that enable learners to make scientific inquiries with a virtual experiment setup prepared with virtual laboratory materials (Özdemir, 2019). De Jong et al. (2013) describe the virtual experiment as a computer software in which observations or measurements are carried out with simulated laboratory materials, on the other hand, Yi et al. (2005) define the virtual experiment as a visual learning environment where the learners use virtual objects representing the experimental materials through the use of mouse and keyboard on the computer. Thanks to the developments in information technologies, it is possible to conduct experiments in virtual laboratories that can achieve results with realistic accuracy in a virtual environment with prepared simulation software. Virtual laboratories where simulation software is used are a new technology that is used with a focus on education where theoretical knowledge can be transformed into practice (Tatlı & Ayas, 2011).

The simulation software used in virtual laboratories is a teaching method in which the student can change the parameters of the experiment and perform the experiments exactly. It is seen in the literature that virtual experiments have contributed to science education, especially physics and chemistry education. There is a certain period of time for the experiments performed in the traditional laboratory, during which the student has to complete the experiment. However, since there is no such time shortage in virtual experiments, students can be more comfortable in designing experiments, analyzing the results and interpreting them (Bell, 1999; Finkelstein et al., 2005). Özdemir (2019) has developed a virtual experiment to be used in the discovery of the electron and teaching the Thomson Atom Model based on experimental findings and questioning. In the study, which was not intended to examine the students 'thoughts about this virtual experiment, it was concluded that this virtual experiment contributed to the students' understanding of the Thomson atomic model, and on the other hand, it was understood that the students thought that the virtual experiment made modern physics subjects, which they found complex and abstract, understandable by simplifying and concretizing. Again, as a result of the studies by Duman and Avcı (2016) that they used laboratory applications suitable for the gains in the “States of Matter and Heat” unit of the 8th grade science lesson, it was seen that virtual laboratory applications were more effective in student achievement and in ensuring the permanence of the knowledge learned compared to the traditional teaching approach.

When the studies on the use of virtual laboratory applications in education are examined, while it is observed that these applications have contributed positively to the academic success of students (Tekdal, 2002; Kici & Sof, 2005; Qing Yu et al. 2005; Domingues et al., 2010; Chen, 2010; Duman & Avcı.2016; Özdemir, 2019), increased students’ motivation for the lesson (Arjamand & Khattak, 2013; Stefanovic, 2013) and made individual experiments possible for students unlike some real experiments which cannot be done individually and pose danger (Bozkurt & Sarıkoç, 2008), it is also seen that they provide the opportunity to carry out dangerous and costly experiments under laboratory conditions without danger and at much less cost (Bozkurt & Sarıkoç, 2008; dos Santos et al., 2010; Tankut, 2008: Tekdal, 2002).

The purpose and importance of the research

Today, rapid developments in hardware and software in computer systems have made the use of graphics important in education. The software used in education is so developed that the information that is difficult to obtain in the real world with simulations are obtained easily in a high quality, cheap and fast manner (Uğur, 2001). Virtual laboratories with simulation software on the basis are a new technology that is used for education, where theoretical knowledge is transformed into practice (Tatlı & Ayas, 2011). With this new technology, it is possible for every student to learn by doing and living by making experiments which cannot be done due to the hardware deficiencies such as lack of laboratories or materials in school or their difficulty or danger of being implemented in real life, easily and economically and also in a shorter time.

In this study, a virtual laboratory application was carried out within the scope of the science lesson in order to increase the quality of the students' learning process and their interest in learning science. It is thought that the teaching-learning process of a subject within the scope of science lesson with virtual experiment increases the importance of this study in terms of science education. In this study, it was aimed that students discover the variables that affect solid, liquid and gas pressure by experimenting with virtual laboratory application and analyze the relationship between these variables. In line with this goal, it was aimed to determine how virtual experiments supported by the 8th grade science lesson pressure unit virtual laboratory technology affect students' academic achievements and their interests and motivations towards science learning. For this purpose, answers to the following questions were sought:

1. Is there a significant difference between the pre-test scores of the experimental group in which the virtual laboratory method was applied and the control group where the science curriculum prescribed method is applied?

2. Is there a significant difference between the post-test scores of the experimental group in which the virtual laboratory method was applied and the control group to which the science curriculum prescribed method is applied?
3. What are the opinions of the students in the experimental group about the application of the virtual labs method?

Method

Research Model

In this research, mixed method research design was used. Mixed method research offers researchers an alternative approach in reaching the goals of "depth and detail", which are the weaknesses of quantitative research methods, and "generalization and prediction" for which qualitative research methods are weak (Yıldırım & Şimşek, 2013). The mixed research method design allows researchers to use both qualitative and quantitative approaches / methods in a single study (Cresswell & PlanoClark, 2014). In this study, the convergent parallel design, one of the mixed method research designs, is used. In this research design, qualitative and quantitative data, which are equally important, are collected together and analyzed separately. In the last context, similarities and differences between quantitative and qualitative findings are compared and interpreted. In this way, efforts are made to achieve much better results (Creswell & Plano Clark, 2014).

In order to compare the academic achievements of the students in the experimental group in which the virtual laboratory application was used in the science course teaching and the preferred control group students of the science curriculum prescribed methods, an experimental with pretest-posttest control group was chosen.

Table 1: Research pattern

Groups	Before Application	Method of Application	After Application
Experiment	Pre-Test (Test1)	Virtual Laboratory	*Post-Test (Test1) *Interview Form
Control	Pre-Test (Test1)	The science curriculum prescribed methods	*Post-Test (Test1)

In order to support the quantitative data of the study, the opinions of the students in the experimental group about the virtual laboratory application were taken and the qualitative documents created during the application process were used.

Study Group

The study group of the research consists of 8th grade students studying at a secondary school in Antalya in the 2019-2020 academic years. A total of 62 students, 31 in the experimental group and 31 in the control group, participated in the study. Groups were appointed through unbiased election.

Table 2. Number of students participating in the study

Groups	Female	Male	Total
Control Group	14	17	31
Experiment Group	11	20	31
Total	25	37	62

The process of performing experimental procedures

This research was conducted with 8th grade students in a secondary school in Antalya. After determining the subject (pressure) to be used in the experimental process of the study, the virtual laboratory application to be used regarding the subject was determined and the virtual experiments to be used during the application were determined from the Education Information Network (EBA) and the Phet web page. Before the application, the students in the experimental group were informed about the virtual laboratory application. The application process was carried out by the same teacher in the experimental and control groups. In addition, 3 pre-service science teachers took part in the application process as observers. While the same subjects were taught by making virtual experiments in the experimental group, the control group was taught on a textbook basis. During the three-week unit in the experimental group, virtual experiment applications were given at appropriate places. The photographs taken during the virtual laboratory application to the experimental group are shown in Figure 1.

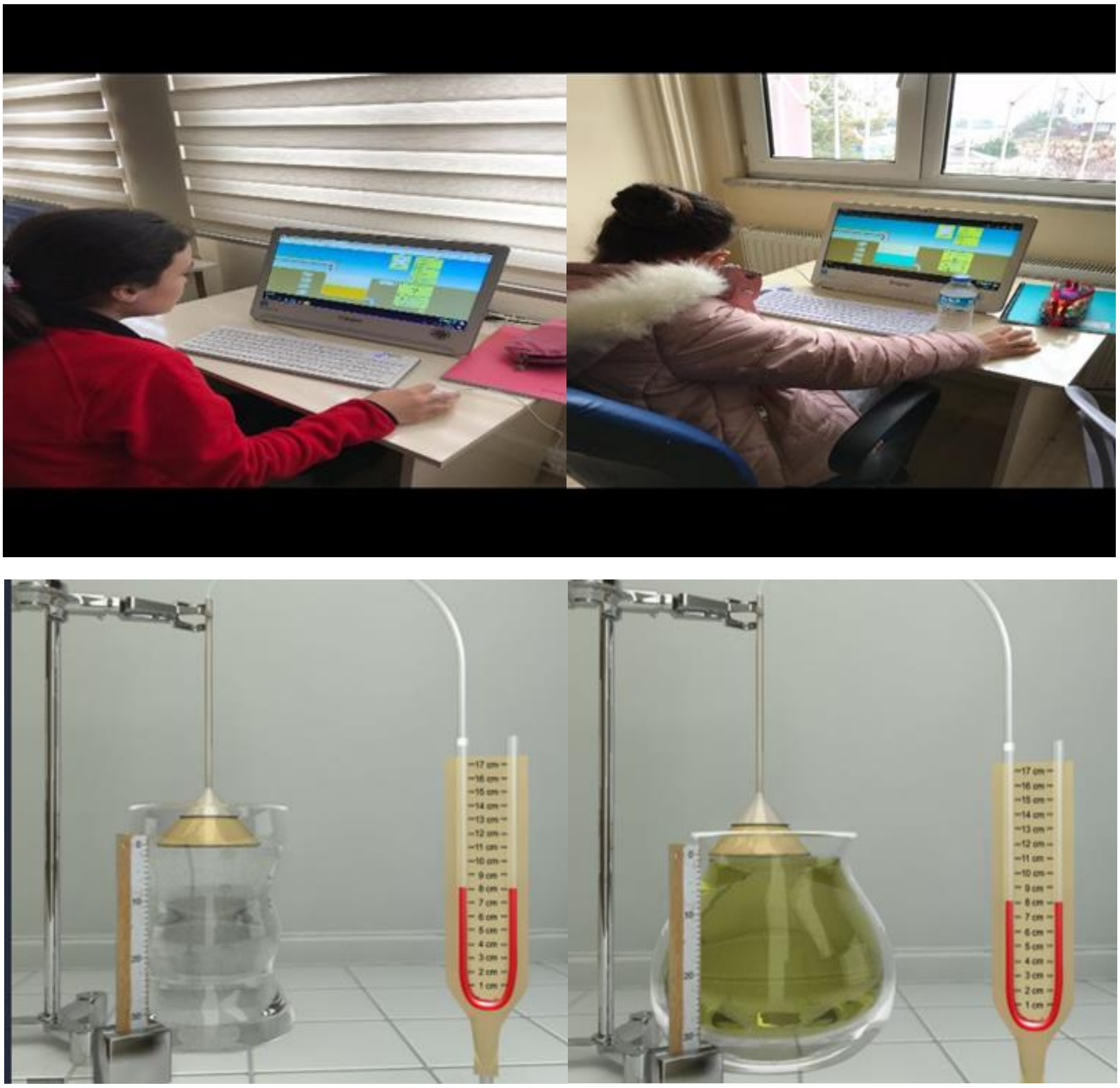

Figure 1. Examples of the applications made by the experimental group students

Reliability and Validity of Data Collection Tools

In the study, the achievement test prepared for the pressure unit in the science lesson, semi-structured student interview form containing student views about the application, and observer diaries were used as data collection tools.

Achievement Test

In the research, multiple choice test including 20 questions was prepared to cover all the gains of the 8th class pressure unit in order to apply it to the experimental and control groups as a data collection tool. In terms of the adequacy of the test questions in measuring the unit gains, whether there were scientific errors, and the comprehensibility of the questions as language, a total of five experts, two science educators, three science teachers, were consulted. The questions were revised in line with the opinions of the experts. The final version of the achievement test was solved by three 9th grade students and feedback was received from the students about whether they understood the questions, and according to the feedback received, very small revisions were made in the test and the achievement test was finalized. The final version of the test was applied to 200 ninth grade students at another school. The KR-20 reliability coefficient of the success test was found to be 0.86.

Interview Form

In the research, interview questions consisting of open-ended questions were prepared by reviewing the relevant literature in order to learn the thoughts of the experimental group students. The interview form prepared was evaluated by two field experts and revised according to the feedback received from them. In order to determine the comprehensibility of the questions in the form, three seventh grade students were asked, and the questions were finalized according to the feedback received. The questions in the interview form were directed to the students in the experimental group.

Observation Form

During this application, an observation form drawing attention to the basic points of the application was prepared for the prospective science teachers who go to schools to make observations. In the light of the items in this form, the prospective teachers were asked to make observations by taking into account the main headings of the virtual laboratory practice, students' interest in the lesson, the course teacher's process of realizing the virtual lab application, and to write their observations under the relevant item in the form.

Data Collection Process

Before the application, an achievement test was prepared to cover the acquisitions in the curriculum on the subject of Pressure and to suit the levels of the students. The achievement test was applied as a pre-test to the students in the experimental and control groups before the research. The achievement test, which was prepared after the lessons with the science curriculum prescribed methods, was applied to the experimental group students with virtual laboratory applications and the students in the control group as a post test. In order to support the quantitative data, the opinions of the teacher of the lesson and the students in the experimental group about the virtual laboratory application were taken, and the observations of the pre-service teachers were used during the process.

Analysis of Data

Analysis of Quantitative Data

Quantitative data were obtained with the success test prepared on the subject in the study. The data of the research were analyzed by t test.

Analysis of Qualitative Data

Descriptive analysis and content analysis techniques were used to analyze the qualitative findings of the research. The main framework for the qualitative data to be collected in the descriptive analysis was determined depending on the research problem, and after making relevant inferences from the data, direct quotations were made from the interview and observation data. Inference from the data collected during the descriptive analysis phase was supported by direct quotations. In the content analysis phase, the qualitative data collected were collected under certain categories. At this stage, the main themes that were determined based on the categories for qualitative analysis were included. Analyzes were made under these main themes, and the analyzes were supported with the quotations obtained in the descriptive analysis (Yıldırım & Şimşek, 2013).

Findings

In this section, quantitative and qualitative findings will be given under separate headings.

Quantitative Findings

According to Table 3, it is seen that the mean score of the experimental group students is 37.25, while the control group students is 33.54. Independent t-test was used to compare the pretest scores of the groups. There was no significant difference between the pretest mean scores of the groups (p> 0.05).

Table 3. Comparison of experimental and control group pretest scores

Groups	N	Mean	Sd	t	p
Experiment_pre-test	31	37,25	12,09	1,131	0,263
Control_pre-test	31	33,54	13,67		

After the application, the academic achievement test was applied to the control and experimental groups as a post-test. Analysis results of the posttest results of the groups are given below.

Table 4. Comparison of experimental and control group posttest scores

Groups	N	Mean	Sd	t	p
Experiment_post-test	31	62,90	16,62	3,236	0,002
Control_post-test	31	48,70	17,88		

According to the data of Table 4, it is seen that the mean score of the experimental group students is 62.90 and the control group students is 48.70. Independent t-test was used to compare the posttest scores of the groups. There was a statistically significant difference between the posttest mean scores of the groups (p< 0.05).

Qualitative Findings

After analyzing qualitative data through content analysis, two main themes were determined. These themes are: the effect of virtual lab application on cognitive domain and the effect of virtual lab application on affective domain. These two main themes are categorized as 1-Cognitive Domain 2-Affective domain. Other determined sub-themes are presented in paragraphs within these main themes.

Cognitive Domain

The cognitive domain theme contains findings that support the quantitative findings of the research. The findings on the quantitative dimension show that the virtual laboratory application positively affects the learning of the students in the cognitive field. Qualitative findings obtained in our study also support this result. From the data collected in this section, it is revealed that the virtual laboratory application 1-) concretizes abstract subjects, 2-) provides meaningful learning.

Abstract-Concrete

In the virtual lab application, the students discovered the variables that affect the fluid pressure by experimenting. During these trials, the students also used their scientific process skills. By changing the independent variable, they observed its effect on the dependent variable. Meanwhile, they expressed the variables that should be kept constant as the controlled variable and kept it constant. The students' designing their own experiments led them to see that an abstract concept became concrete and their learning became easier. Figure 2 shows the virtual laboratory application that students have created to observe the variables affecting fluid pressure. The opinion of Student 1 on this subject is given below.

> Student 1:…with the experiment we conducted in the virtual laboratory in the lesson, I have experimented and observed the factors affecting fluid pressure by changing the type and depth of the fluid. The computer screen comes to life right now. I think I learned very well as I learned the fluid pressure issue on the computer myself. I have never touched the liquid, but I still learned the fluid pressure.

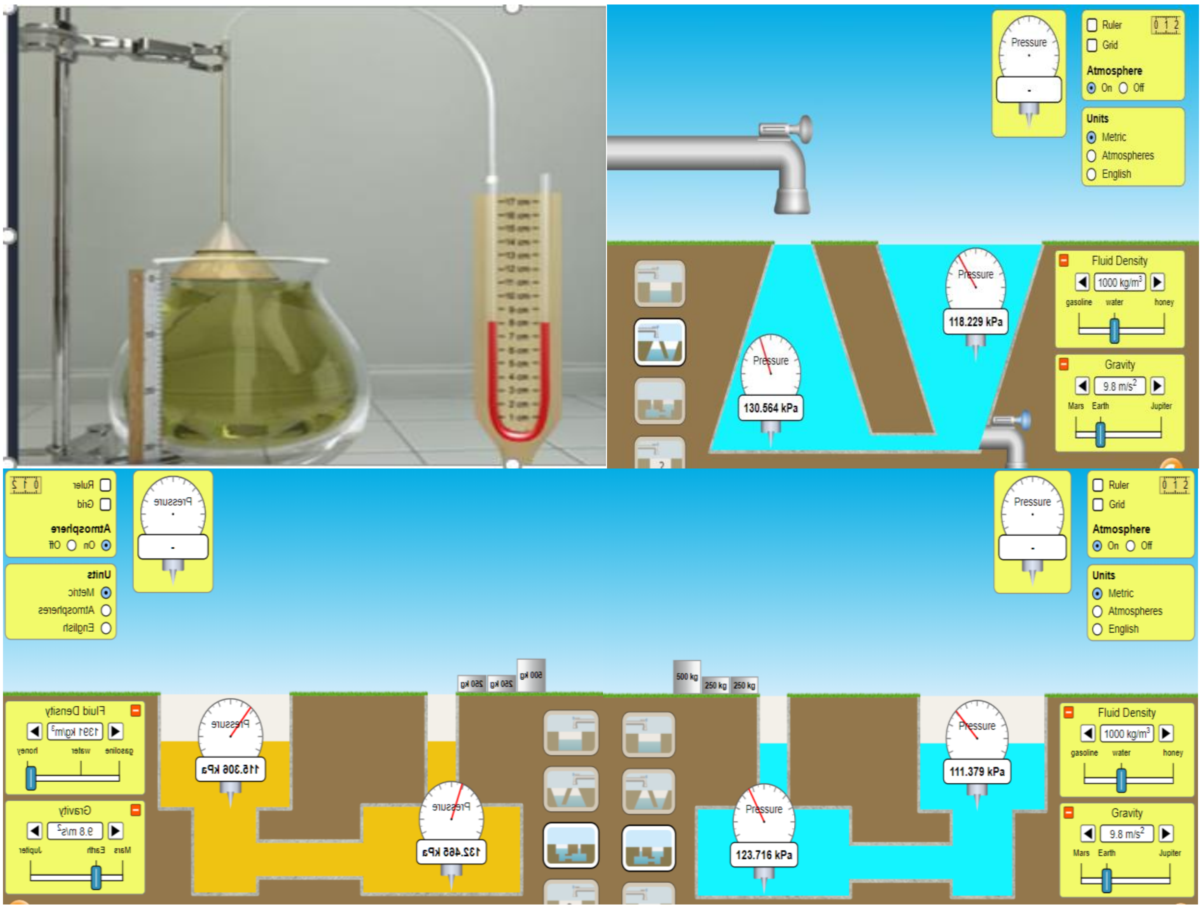

Figure 2. Screenshots of one of the experimental group students showing the variables that determine fluid pressure.

Observer A's notes on this subject also support this finding.

> Observer A:… the students were thrilled that they were going to design a virtual experiment in the virtual lab application. All had curious looks in their eyes. When I started practicing the experiment, the lesson became very enjoyable. All of them took notes by experimenting in virtual experiments on their computers. In this lesson, the teacher posed questions measuring whether liquid and solid pressure had been learned. All of the students who took the floor gave correct answers to the teacher's questions. (05.11.2019).

Meaningful learning

It is seen that the students' conducting the learning process with the virtual laboratory enables them to learn meaningfully the effect of the factors affecting the pressure, especially the solid and liquid pressure, which is an abstract topic. The experimental group students found themselves successful in solving the questions about the pressure unit in other tests, apart from the post-test application. They were able to adapt what they learned to other problem situations they encountered. The opinion of Student 2 on this issue is given below.

> Student 2:… I knew the factors that affect the pressure, but this knowledge was merely memorization. However, I understood the subject better by practicing with virtual experiments, for example by trying the effect of changing the type of fluid and seeing the result.

> Student 3:… I think I learned well by really understanding the subject. The teacher's lesson was much more enjoyable with these experiments.

Observation notes of Observer B also support these findings.

> Observer B:… After the virtual laboratory practice, the students were very successful in answering the questions asked by the teacher. We can say that the application made contributes to students' meaningful learning (08.11.2019).

Affective Domain

Virtual laboratory applications increased students' motivation and increased their interest in science lesson. The opinions of Students 4, 5 and 6 on this issue are given below.

> Student 4:… I would love to do virtual experiments in other units this year as well. With virtual experiment applications, the lessons are more fun and enjoyable.

> Student 5: ... this activity was very nice, I think we both had fun and followed the lessons with pleasure.

> Student 6:… I had never seen virtual lab experiments before. An app that was interesting and made us learn better, I was looking forward to the day of science lesson.

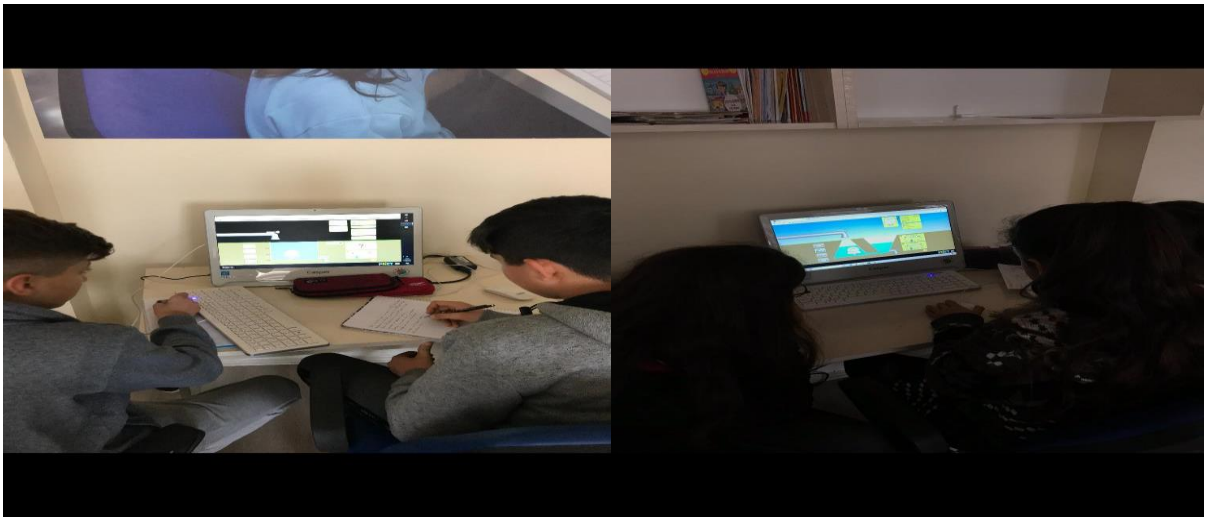

Figure3. Examples showing students' interest in virtual lab application

Observation notes of Observers A and B also support these findings.

> Observer A:… the students are very excited before the lesson starts and look forward to the start of the lesson as soon as possible. It is impossible not to see the effect of the last lesson. (12.11.2019).

> Observer B:… the students are so focused on the computers that one is in the virtual experiment that changes variables while the other records the results. They draw conclusions by making comments between them. (15.11.2019).

Discussion

In this study, it has been shown that virtual laboratory applications increase the academic success of students. This result of the study supports the conclusion of Duman and Avcı (2016) that the virtual laboratory applications applied to the experimental group students during the teaching of the "States of Matter and Heat" unit in the 8th grade science lesson have a positive effect on the academic success of the student and the retention of the learned information. At the same time, this result of the research coincides with the results of other studies in the literature (Bozkurt & Sarıkoç, 2008; Chang, 2000; Çömek, 2003; Kolomuç, 2009; Karagöz et al., 2016; Olgun, 2006; Özdemir, 2019). It also supports the results of the studies that show that students learn more easily and better in the teaching-learning process, which is supported by virtual experiment applications that emerged in these studies.

Another result of the study was that virtual laboratory applications enabled students to learn by embodying abstract subjects. In Özdemir's (2019) study of "Use of virtual experiments as learning activity in modern physics course: A case of cathode ray tube experiment" with science undergraduate students, it is understood that virtual experiment applications allow effective learning and by simplifying and concretizing the complex and abstract physics concepts of virtual experiments. The inference of Özdemir (2019) is similar to the result that the virtual laboratory applications emerging in this study contribute to the meaningful learning of abstract subjects.

Another result determined as a result of the research is that virtual laboratory applications increase students' interest and motivation to science lesson. Studies in the literature show that similar to the results of this research, in learning environments organized with virtual laboratory applications, students are more interested, curious and excited in the learning process, and students have positive opinions against virtual laboratory applications (Arvind & Heard 2010; Bozkurt & Sarıkoç, 2008 Ceylan & Seçken, 2019; Duman & Avcı 2016; Mırçık & Saka, 2016; Aşıksoy & Islek, 2017; Sarı et al. 2019).

Conclusion and Recommendations

When the quantitative and qualitative data of the research are evaluated together, it is seen that the virtual laboratory application contributes positively to the academic success of the students. In addition to the statistical results of the research data, the qualitative findings obtained in the study show that the educational process carried out with virtual laboratory applications contributes to students' learning by concretizing abstract subjects. In this case, it shows that it is possible for students to learn an abstract subject meaningfully with the virtual laboratory. Another conclusion that can be drawn in the light of the qualitative findings obtained in the study is that the virtual laboratory application increased the interest, curiosity and motivation of the students in science class. Other researchers can develop virtual versions of existing experiments in the fields of physics, chemistry, and biology in science education at different educational levels and investigate the effects of these experiments on students' learning. In order to popularize the use of virtual laboratory applications, courses and seminars can be organized within the scope of in-service training for teachers to prepare and use these applications.

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