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Three-dimensional printers: A study of student perceptions and attitudes

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Abstract

Three-dimensional printer (3D) technology has started to take place in every field of life day by day. When the relevant literature is reviewed, the concept has mostly been analyzed in terms of different production areas, and studies in the field of education are limited. The study provides a systematization of the current literature, which is insufficient, and the available information is disorganized. The study will raise awareness for further research in terms of technology-enhanced school learning. The purpose of this study is to determine the observations of the students who will experience 3D printer technology while creating an object, to reveal the pre-training and post-training processes, and to explore their thoughts after the application regarding 3D printer technology. Additionally, the study aims to determine whether the students differ according to their characteristics. The sample of the study consists of students who visited the 3D Design Center to receive three-dimensional printer training. The study was conducted between January and June 2018. In the study, data were collected using the traditional survey method. Data were collected from 600 students. As a result of the study, the students stated that 3D printer technology is interesting and exciting, and that they did not find this training boring.

Keywords: attitude, perception, quantitative research, 3D printer technology.
Jel codes: M10, M30, M31

1. Introduction

The technological systems that continue to evolve day by day affect the daily lives of people and continue to impact the economy and industry. Prototyping with 3D printer technology has been observed to be part of the development in these new technological areas, where people and businesses are interested in wearable technology, virtual reality, intelligent robotic systems, and artificial intelligence. These printing technologies can be used in various fields. Three-dimensional printer technology has been used in educational institutions in recent years to create effective and innovative learning processes. Three-dimensional printers, which enable students to create their own 3D printing projects, also allow students to gain experience in many areas such as project management and technical skills. Moreover, such projects give students a real sense of what professional life looks like and provide them with the ability to transform the knowledge gained in theoretical lessons into practical skills (Erk, 2014; Richardot, 2018). As a result of the use of three-dimensional printer technology in educational institutions, students can transition from passive and non-creative thinking to geometric, active, and creative thinking (Stefan and Matt, 2015). Integrating three-dimensional printers into the education system enables the future workforce to combine technical specialization in design, computing, and computer use with human characteristics such as flexibility, empathy, and creativity (Baker, 2016).

In this study, middle and high school students will experience three-dimensional printer technology through prototype design and printing. The aim of the present work is to ascertain the students' observations and gather their opinions on three-dimensional printer technology, as well as to determine whether there is a difference in their thoughts based on personality differences. The relevant literature indicates that studies on three-dimensional printer technology are limited in the field of education, and information about these technologies is disorganized (Ford and Minshall, 2019). This research is important for contributing to the relevant literature, as there is not enough research on three-dimensional printer technologies in the current literature, and the available information is disorganized.

2. Literature Review

The practical application of three-dimensional printer technologies in educational institutions enables students to better comprehend course subjects through experience, thus contributing to more effective and rapid information assimilation. In this regard, using three-dimensional printer technologies allows students to experience the entire project implementation process at all stages, from the initial idea to the three-dimensional design and production of the final object. It also encourages active participation during lessons and simplifies the study of complex topics. For instance, to examine the physical structure, working logic, and mathematical ratios of a wind turbine, students can print the wind turbine using a three-dimensional printer (McBride, 2017).

At the present time, it is evident that the Do-It-Yourself approach is increasingly adopted in the education system. By this new approach, the application of the three-dimensional printer technology makes a great contribution by allowing students to discover their own innovative features. Along with the “Do-It-Yourself” learning approach and three-dimensional printers, students are able to print objects that interact with their own interests as a product, to develop student’s; imagination and to adapt them to manufacturing technology (Brown and Hurst, 2012). Educational institutions include three-dimensional printing technologies in their educational processes while making the lessons more interactive, they support the students to comprehend information more quickly and to be interested in STEM (Science, Technology, Engineering, Mathematics) fields (Chamberlain and Meyers, 2015; Kostakis et al., 2015).

Three-dimensional printers are also used at the primary school level. The production of prototypes by primary school students using three-dimensional printers contributes to the development of their creative skills and contact with the future advanced technology (Smeekes, 2015). With the usage of this technology at the secondary school education level (MakerBot, 2017) i) students acquire professional design skills, ii) simulate real-world engineering problems, iii) with advanced design skills, prepare for high school education, and iv) give secondary school students the necessary critical thinking skills to realize an idea. Knowledge gained in secondary education is vital for the continuation of student’s success. During the years of secondary education, students can very quickly forget what they have learned. Materials used in a lesson with content such as science, technology, engineering, and mathematics should be creative, provided in a way that engages students, or an appropriate environment should be created that allows them to adapt their materials to lessons based on their imaginations. Completing projects using three-dimensional printers enables students to examine a part in its entirety throughout the whole process from the first idea to three-dimensional design and resulting with the final product. Thus, it will be easier to integrate students into STEM subjects, the information will be more permanent in mind, and more consistent solutions will be produced for real-world scenarios and problems (Walker, 2016). The Three-dimensional printer technologies play an important role in engineering design projects that require physical prototyping at high school education level and in developing student’s understanding of science and mathematics (Bull et al., 2014). For instance; this technology has been used to describe the atomic structure in the field of science in 10th grade chemistry classes and it has been found there is a positive relationship between student’s learning and subject (Chery et al., 2015). In the physics class, Japanese high school students learned the voice frequency by producing three-dimensional printed police whistles (Masato et al. 2018). In technology and engineering, students were trained in calculation, design, and technology skills using versatile games such as Minecraft by applying of three-dimensional printers. As a result of the study, student’s motivation to focus on computing, design and technical skills has increased and it has been found that maker communities cause affordable three-dimensional printers to occur in the market and teachers should take advantage of technological opportunities they can use efficiently (Roscoe et al., 2014). The use of three-dimensional printers in universities; while producing teaching and research opportunities, it also enables students to become familiar with technology that affects almost every industrial area (Pryor, 2014). The availability of low-cost three-dimensional printer equipment opens up potential for practical laboratories using additive manufacturing in all primary, secondary and post-secondary school. These laboratories are not only involved in traditional engineering designs, but also biological sciences (molecular modeling), medicine (orthopedic implants and tissue engineering), fashion design (clothing, shoes and jewelry), sports science (protection equipment), law enforcement and archeology (bones and works), interior design (space and facility planning) and architectural (scale models) are also used in design projects (Scott et al., 2012). There are several advantages of three-dimensional printer's introduction in the field of education. These are as follows: (Owen, 2017; Linneman, 2017; Thurn et al., 2017; Vries et al., 2017; Pearce, 2017); i) providing students with the ease of interactive learning, ii) developing their problem solving skills, iii) supporting creativity and innovation, and iv) low-cost accessibility. In addition to the stated benefits of this technology, there are a number of issues that require attention. Firstly, due to the lack of legislation and regulations related to this technology, children can easily, inexpensively, and very quickly obtain some hazardous materials using three-dimensional printers such as weapons, aircraft parts, military vehicles and consumables, counterfeit parts for commercial or defense operations, drug or chemical weapons. It is important to set software limitations and parental controls to prevent all these hazardous processes (Pîrjan and Petroşanu, 2014). Moreover, in educational institutions, which have three-dimensional printer, students may be eager to produce hazardous tools such as plastic weapons, utilizing instructions on the internet besides books and magazines (Association, 2014). At this point, educational institutions should take necessary measures in advance. The main studies and obtained findings with three-dimensional printer technologies in the field of education are as follows:

• Production of anatomy science resources using three-dimensional printer technologies: Research conducted by McMenamin et al. (2014), was aimed to make correct copies of human anatomical materials using three-dimensional printer technologies and to be used as teaching materials. The technology was found to play an important role in the teaching of pathology, veterinary anatomy, the production of zoological specimens, and the reproduction of rare museum samples.

• Three-dimensional printing and acoustic teaching program: It was aimed to increase the student's apprehension of mathematics and science courses and development of acoustic musical instruments by students (Leitman and Granzow, 2016). In the course of the study, the development and production of a prototype jet engine, an automobile differential and a robot arm was carried out using three-dimensional printer technology, and it was found that this technology has a positive effect on the mental, professional, and social development of students.

• A study by Ozsoy (2019) aimed to examine the adaptability of three-dimensional printer technology to vocational education. Thus, it is expected that students will become more qualified, technically advanced and have a positive impact on the future goals of the country's industrial strategy. In the course of the study, the development and production of a prototype jet engine, an automobile differential and a robot arm was carried out using three-dimensional printer technology, and it was found that this technology has a positive effect on the mental, professional and social development of students.

• In a study by Kekhan and Ozcan (2018), it was found that the use of three- dimensional printer technology plays an important role in describing detailed and complex topics for students, and interaction in the classroom with students can be easier while ensuring student interest and participation in the lesson using this technology. In this way, it became clear that students can define their career goals, and acquire valuable skills. As a result, the study aimed to draw attention to the fact that it is important to integrate this technology into educational life, since it is not common.

• Three-dimensional Modeling and Printing in History / Social Science Classes: Maloy et al. (2017) conducted research with high school students to determine the impact of three- dimensional printing technology on history and social science courses. They have integrated three-dimensional printing and modeling into curricula in world geography, US history and state/citizenship knowledge. As a result of the study, it was stated by teachers and students that it is difficult to present social research concepts with three-dimensional printed objects. However, it was observed that three-dimensional technique had a positive effect in terms of showing ideas about history subjects, but teachers and students noticed that this program was difficult to use. And, with the elimination of the essential expertise deficiencies, they changed their views on the importance of three-dimensional printing technology on topics of history and social studies where the interaction between teachers and students increased. In addition, student's use of three-dimensional printing technologies in history and social studies lessons allows them to participate more actively in the lessons and effectively influence their motivation.

• Three-dimensional fossils for K - 12 education: Fossils and the science of paleontology provide an effective advantage for integrating STEM teaching and learning. In a study by Grant et al. (2017) suggested integrating fossils and paleontology into the K-12 curriculum using three-dimensional printing technologies. In addition, the study envisions that students will be able to contribute to discovering their thoughts by integrating topics of interest and knowledge with three-dimensional printing technologies.

• Three years: Analysis of the impact of three-dimensional technology in STEM- based courses; the foundations of the research were set in 2013 by Perez et al. (2017). The aim of the study is to reduce the rate of using whiteboards or blackboards in engineering classes, as well as to create a physical three-dimensional model representation of some of the most frequently used concepts with this technology in the first semester to engineering classes. The study analyzes whether the use of this technology is costly in the school environment. The research results are as follows; i) improving student performance, ii) the cost of this technology in the first year is 2300 dollars, and in subsequent years the cost will gradually decrease, iii) students design very interesting projects.

• 3D Printing MEMS design and manufacture as an effective training tool: Microfabrication technology is a built-in manufacturing technique for small and high-precision MEMS (Micro Electric-Mechanical Systems) devices. Dehla and Rasel (2015) conducted a semester study involving assignments and project modules that aimed at preparing talented, innovative and career-ready engineers with a deep understanding of manufacturing and modeling process of MEMS components. Using three-dimensional printing technology, they aimed to offer a series of lesson modules designed as a highly efficient and inexpensive teaching tool for modeling and simulating the microfabrication process and design of MEMS device design. The study mentioned that microfabrication technology is an effective production technique for small and high-precision MEMS devices, and these operations are performed in a clean room using expensive high-vacuum equipment. However, the high cost of clean rooms relevant equipment limits access to many campuses and tests. The study found that through the use of three-dimensional printing this area can be better understood without imitating the production process of MEMS devices and investing a significant amount of time and money in a clean room.

In this study, it is aimed both at conceptualizing the three-dimensional printer technology which has been analyzed from an engineering perspective in the relevant literature, and at contributing to on the use of three-dimensional printer technology in education. For this, the following research questions have been created:

1. What are the student's observations during three-dimensional product design and printing?

2. Do students' perceptions of three-dimensional printer technology (pre-training, post-training process, post-training) differ depending on the characteristics of the students?

3. Do students' attitudes regarding three-dimensional printer technology differ depending on the characteristics that students have?

4. What are the student's assessments on the experience of three-dimensional printer technology?

3. Data & Methodology

In the study, survey was used as a data collection tool. Data collection was carried out using the traditional survey method. After the related literature research, a survey was created. The survey consists of five parts. The first section consists of demographic questions. The second section introduces questions aimed at revealing the experience of working with three-dimensional printers. The third section measures the perception of three-dimensional printer technology, and the fourth measures the student's observations during product design and printing. The last section has questions that measure attitudes towards three-dimensional printer technology. The questions in the third and fourth sections are taken from Schnedeker (2015). The questions about the 3D printer technology attitude scale in the last section are prepared on the basis of the scale developed by Barmby et al. (2007). The 5-point Likert scale is used for the survey questions in the third and fifth sections. Data collection was carried out from January to June 2018 using the traditional method of interviewing middle and high school students who came to the 3D Design Center. The data collection process was carried out in three stages. The initial stage; Students who came to the design center received mostly 15 minutes of instruction from experienced trainers. Through this 15-minute instruction, students received a general introduction to what three-dimensional printer technology is, where it is used, what the technology can do, what raw materials are used, what three-dimensional design programs are available, what printing technologies are used besides the sample applications with three-dimensional printer. After this introduction, students were asked to answer questions about demographic features in the first section of the survey, the first four questions of the three-dimensional printer technology experience in the second section, and the perception of the three-dimensional printer technology in the third section of the survey before the training. In the second stage; the teachers gave a 25-minute training on the use of the three-dimensional design program which is important for the students coming to the design center to prepare a keychain prototype for three-dimensional printing. At this training students explored the following steps: selecting solid body, embossing inwards, ovalizing borders, drilling holes, making text values in three dimensions, adding models from outside, combining two three-dimensional designs. The steps of saving in .STL format has been transferred to students. After the training, students were given time to observe the 30-minutes design program more attentively, after the 30-minutes free time experience of the students, the questions were created to analyze the perception for the third part of the survey. At the end of the three-dimensional printer training process all the questions were answered. Finally, expert teachers designed and printed 1 keychain with three-dimensional printer technology along with the students. The keychain design was made in 25 minutes, after the completion of the keychain design, teachers explained students, how to print the keys using 3D printers, which file format is used, how to use a 3D printer interface, which additive manufacturing technology and raw material will be used and how long will it take. The keychain prototype was printed in 25 minutes. After the completion of the processes containing the key factors to consider while using 3D printers, the post application questions were asked. These questions revolved around student's observation during design and printing, these questions aided in measuring the attitudes about the 3D printer technology. A total of 300 high school and 300 middle school students participated in this survey. However, when the surveys were analyzed, it was determined that there were 125 surveys that were answered randomly and had flaws; these surveys are excluded. All evaluations were carried out on 475 surveys that helped in conducting this study

Cronbach Alpha coefficient was used to measure the reliability of the scales in the study. It has been revealed that the Cronbach Alpha coefficient of the student's attitude scale regarding three-dimensional printer technology is 0.92. The fact that it is higher than 0.60 indicates that the scale is reliable (Sekaran and Bougie, 2016).

The analysis of Three Dimensional Printer Technology Perception Scale has also shown its high reliability. Thus, the values of student's perception during the pre-training (0.93), post-training (0.92) and post-of-application (0.93) periods go between $0.80 < \alpha < 1$ of the Cronbach Alpha values. The reliability of student's perception of three-dimensional printer technology during the pre-training, post-training period and post-of-application also indicates structural validity. One of the methods used to analyze structural validity is nomological validity. Nomological validity represents that the scale dimensions show significant relationships with each other and a common meaning. The nomological validity of the scales used in the study was evaluated in the correlation matrix. The results of the correlation analysis are presented in Table 1.

As may be seen from Table 1, there is a statistically significant relationship between the scales used in the research. The significance of the coefficients between the scales is an indication of nomological validity (Torlak et al., 2014). It is important to note that, Correlation values should be less than 0.80 to prevent multiple linear connection problems. This constitutes an indicator of decomposition validity (Byrne, 1984). The low correlation coefficient between the attitude variables presented in Table 1 also contributes to the scales validity.

Table 1. Nomological validity results of the scales used in the research

Variables	**1.**	**2.**	**3.**	**4.**
Three Dimensional Printer Technology Pre-Training Perception	1			
Three Dimensional Printer Technology Post-Training Perception	.274**	1		
Three Dimensional Printer Technology Post-of-application Perception	.130**	.214**	1	
Attitude	.012	.049	.093*	1

**. p< 0.01, *.p<0,05

Source: Created by authors

4. Findings

4.1. Descriptive Statistics

Approximately 53% of the participants are female students, and 42% are between the ages of 13-15. In addition, approximately 57% of the participants are middle school students. The majority of the participants (97.9%) study in public school and about 39% are 7th grade students. Approximately 40% of the participants are people with an income of 2500 and below. As for parental education level, it is evident that 37% of the education level of the mother's is primary school, whereas 35% of the education level of the fathers' is high school.

87.2% of the participants have not ever experienced three-dimensional printer technology and 73.3% have not ever used a computer-aided design program before. Participants took three-dimensional printer training mostly on Tuesdays (32%) and mostly between 10:00-12:00 hours (66%). After the training, 79.4% of the participants demonstrated enthusiasm with the provided training, they expressed their intention to mention and recommend the provided training to their friends or people around them. When students' response is analyzed whether to retake such a training in the future, the vast majority stated that they would like to retake such a training.

4.2. T-Test Analysis

It is evident that the pre-training perception, post-training perception, post-application perception and attitude of the participants regarding three-dimensional printer technology did not differ significantly in terms of gender variable (p> 0.05). In addition, it is seen that the perception of the participants post-of-application of three-dimensional printer did not make a significant difference in terms of education level (Table 2).

Table 2. T-test analysis results.

Variables	n	Mean	Standard Deviation	t	p
Pre-Training Perception					
Female	250	1.87	1.18	0.536	0.95
Male	225	1.94	1.15		
Post- Training Perception					
Female	250	3.25	1.16	0.34	0.63
Male	225	3.30	1.03		
Post-of-Application Perception					
Female	250	4	1	0.79	0.42
Male	225	4	0.94		
Attitude					
Female	250	4.10	0.82	0.03	0.23
Male	225	4.25	0.75		
Post-of-Application Perception					
Middle School	270	4	1	0.44	0.71
High School	205	4	0.94		

Source: Created by authors

4.3. Mann Whitney U Test Analysis

Mann Whitney U Test was carried out whether the participant's perception of three-dimensional printer technology pre-training, post-training and their attitude towards three-dimensional printer differ in terms of education level. When Table 3 is analyzed, the average of the scores given by high school students to the perception of three-dimensional printer technology pre-education and education process is significantly higher than secondary school students. In terms of student's three-dimensional printer technology attitude, their educational level, the mean average of the scores of the middle school group is significantly higher than the high school students (p = 0.00).

Table 3. Mann whitney u test analysis regarding the education level of the participants

Variables	Middle School	High School	Z	p
	Mean/Sum of rank.	Mean/Sum of rank.		
Pre-Training	1.75/214	2.10/268	-4.432	0.00
Post-Training	3.17/225	3.41/254	-2.332	0.02
Attitude	4.3/261	4/206	-4.351	0.00

Source: Created by authors

4.4. Anova Analysis

Anova analysis was carried out whether the perceptions of three-dimensional printer technology at the post-of-application differ in terms of age level. Analysis results are shown in Table 4. When Table 4 is analyzed, it can be seen that the perceptions of the participants at the end of the application regarding three-dimensional printer technology did not show a significant difference in terms of age level (p> 0.05).

Table 4. Anova analysis regarding age

Variables	10-12 Age Mean / Std. Deviation	13-15 Age Mean/ Std. Deviation	16 and+ Age Mean/ Std. Deviation	F	p
Post-of-application perception	4.08 (0.99)	3.93 (0.95)	4.12 (1.01)	1.879	0.15

Source: Created by authors

Anova analysis was carried out whether the perceptions of the participant's post-training three-dimensional printer technology training process and post-of-application differ in terms of grade level. When Table 5 is analyzed, it can be concluded that the intention of three-dimensional printer technology and the perception of three-dimensional printer technology after application do not differ significantly in terms of class levels (p> 0.05).

Table 5. Anova test regarding grade level

Variables	5th-10th Grade Mean/ Std. Deviation	7th-8th Grade Mean/ Std. Deviation	9th-10th Grade Mean/ Std. Deviation	11th-12th Grade Mean/ Std. Deviation	F	p
Post-Training	3.14 (1.29)	3.18 (1.05)	3.34 (1.04)	3.46 (1.05)	2.125	0.09
Post-of-application	4.02 (1.08)	4 (0.94)	3.88 (0.94)	4.2 (1)	1.845	0.13

Source: Created by authors

4.5. Kruskal Wallis H Test Analysis

Kruskal Wallis-H test was carried out whether the perception of the participants pre-training, post-training process and attitude expressions differ in terms of the age variable. The results of the test are shown in Table 6. According to Table 6, averages of scale scores according to the age levels of the participants were compared and a significant difference was obtained in terms of the rank averages of pre-education perception. In order to see from which group pairs the significant difference between the groups in the scales, the groups were compared in pairs with the Mann Whitney U test and it was determined from which groups the difference originated. According to this; It is seen that the perception of the three-dimensional printer technology of the participants is significantly higher than those in the age group of 16 and over compared to the group of 10-12 and 13-15 (p =

0.001, p = 0.002). It is seen that students' attitudes towards three-dimensional printer technology are significantly higher in the 10-12 age group and 13-15 age group compared to the 16 age group (p = 0,000, p = 0,002).

Table 6. Kruskal wallis-h test regarding age

Variables	10-12 Age Mean/ Std.Deviation	13-15 Age Mean/ Std.Deviation	16 + Age Mean/ Std.Deviation	$\chi 2$	p
Pre-Training	1.77 (214)	1.77 (226)	2.17 (271)	15.223	0.00
Post-Training	3.23 (235)	3.13 (218)	3.49 (265)	10.129	0.00
Attitude	4.26 (266)	4.25 (248)	3.99 (202)	16.543	0.00

Source: Created by authors

Kruskal Wallis-H Test was carried out whether the participant's perception of three-dimensional printer technology pre-training and three-dimensional printer technology attitude expressions differ in terms of grade levels. The results are shown in Table 7. According to the analysis findings; it can be seen that the perception of the participant's three-dimensional pre-education and the mean scores of the scale differed significantly in the grade level (p <0.05). In the light of these findings, the average rank of the scores given by 11-12 class students to the pre-education perception of 3D printer technology is significantly higher than the 5-6 grade level (p = 0.008). In addition, it was found that the average rank of the scores given by 9-10 grade students to the pre-education perception of three-dimensional printer technology is higher than the 7-8 grade level (p = 0.003).

In terms of grade levels of student's attitudes towards three-dimensional printer technology, the average rank of the scores given by the 9-10 and 11-12 grade level to the attitude towards 3D printer technology is higher than the 5-6 grade level. According to findings; it is concluded that the attitudes of 9-10 and 11-12 grade level students towards 3D printing technology are significantly higher than the 5-6 grade level (p = 0.002, p = 0.005). Additionally, the average rank of 7-8 grade student's scores on 3D printer technology attitudes is higher than the 9-10 and 11-12 grade level (p = 0.001, p = 0.005).

Table 7. Kruskal wallis-h test regarding grade level

Variables	5th-6th Grade Mean/Std. Deviation	7th-8th Grade Mean/Std. Deviation	9th-10th Grade Mean/Std. Deviation	11th-12th Grade Mean/Std. Deviation	$\chi 2$	p
Pre-Trainig	1.89 (225)	1.68 (209)	1.98 (256)	2.20 (277)	22.603	0.00
Attitude	4.28 (0.85)	4.28 (0.75)	3.97 (0.82)	4.06 (0.79)	4.188	0.006

Source: Created by authors

5. Discussion and Conclusion

Technological developments make life easier for both people and institutions and save time and cost. Savings for institutions are experienced not only in production sector but also in service sector. A characteristic example of this is the education field where teachers can use a variety of the relevant technological tools in the classroom to enhance the traditional ways of teaching and to keep students more engaged. The positive effect of technology on student's success, interaction and motivation is confirmed by numerous researchers, for example (Uzel and Hangül, 2010; Domingo and Garganté, 2015).

There is presently much concern about the fact that traditional teaching techniques are gradually changing and education systems are evolving towards a "do it yourself" approach (Brown and Hurst, 2012). One reason for this evolution is the technological development. For instance, these developments have given rise to the emergence of the so-called generation Z ('digital natives'), a new generation growing up with new technologies and developing rapidly. Technology has become a necessary part of their lives. (Bakırtaş et al., 2019). The fact that these individuals who were born to the world in 2000 and after use the technological tools intensively also changed their expectations regarding the learning environments.

The present research is aimed to reveal the effect of modern technology in the field of education. It was conducted among middle and high school students taking part in three-dimensional printer technology-training at Izmit Municipality's Three-Dimensional Printer and Design Center. The findings obtained are thought to have both theoretical and practical significance. Thus, the high level of student's satisfaction in the design center (79.4%) and their high willingness to re-take such a training in the future can be interpreted as an indication that three-dimensional printer technology attracts students. It is clear that these findings are parallel to the related literature (Baytak et al., 2011; Grant et al., 2017). Student's perception of three-dimensional printer technology was evaluated as the pre-training, post-training and post-of-application perception. It was found that the level of participation in expressions created to measure students' perception at the pre-training stage is low. This finding is an expected result since the participants have not experienced this technology before. After transferring information about the three-dimensional printer technology and design from the expert trainers, it is clear that the level of participation in the expressions related to the student's perception of the post-training process has increased partially. For all that, it was found that the level of participation of the students in expressions aimed at measuring the perception of the practice made by them increased gradually. It can be concluded that these findings support the fact that the practices in education affect the learning levels of students positively (Kwon, 2017; Maloy et al., 2017).

When student's attitude towards three-dimensional printer technology is analyzed, it is clear that most of them have a positive attitude towards three-dimensional technology education. In this context, students stated that the training as interesting, exciting, not boring and easy; on the other hand, they described themselves as successful, easily learner and creative. Compared to other education, this education caused the students to love this education more with their techniques, to want to re-take this education in school and look forward to a new education for this education. These findings are in line with the related literature (Yıldırım, 2018; Stefan and Matt, 2015).

It was found that there was no significant difference in terms of student's three-dimensional printer technology pre-training, post-training, and post-of-application perception and attitude. This finding can be interpreted by the similarity of technology trends of students who were born and raised in technology era. While it was found that there was a significant difference in terms of pre-training, post-training perception and attitude regarding this technology depending on age levels of the students, there was no significant difference regarding the perception at the post-of-application. This finding was not significant in terms of the ages of students since each student who came for a training had a chance to implement what was transferred. In the related literature, it has been demonstrated that practical learning has increased both the academic success, interest, and motivation of students (Dehla and Rasel, 2015; Perez et al., 2017). It is concluded that there is no significant difference in terms of students' level of education at the post-of-application stage, and there is a significant difference in terms of pre-training, post-training perception and attitude. It has been found that the 3D printer perception of high school students at the pre-training and post-training stages is higher than secondary school students, but the attitude of secondary school students are higher than high school students. It is confirmed by the related article (Kahveci, 2010). It is analyzed that there is no difference in students' perception of the three-dimensional printer technology post-of-application, post-training stages and this technology has a significant difference regarding the pre-training perception and attitude. The finding regarding the grade level can be interpreted as that students' understanding and comprehension skills vary depending on their grade levels.

Study has some limitations. The first is that the research is carried out only in one province and one design center. Future studies can be carried out in different provinces, institutions and cultures. Secondly, this research was conducted with students at secondary and high school levels. Future studies can be carried out on individuals with different grade levels. Moreover, in the study, keychain prototype design and printing was made by using FDM technology which is a three-dimensional printer technology type. Different types of three-dimensional technology, product prototype design and printing can be analyzed with future studies. This study aimed at students' three-dimensional printer education experience, perception and attitude were analyzed. Further studies might analyze three-dimensional printer technology based on different variables. In the light of the findings of the study, approximately 70% of the participants stated that they comprehend three-dimensional printer technology education interesting, exciting, not boring, they grasp it easily and willing to retake this training in their schools. Educational institutions could take into account these findings and provide this technology to use in related courses. Thus, it might boost students' interest and motivation in the related courses. Moreover, using this technology especially in the implementation of STEM subjects will give a great advantage for educational institutions. (Chamberlain and Meyers 2015; Tillman et al., 2014; Chong, et al., 2018).

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