Journal for the Education of Gifted Young Scientists, 10(2), 173-205, June 2022
e-ISSN: 2149- 360X
jegys.org

youngwisepub.com
gencbilgeyayincilik.com

Research Article

3D printers as an educational tool in gifted education: effective use, problems and suggestions

Cüneyt Akyol[1]*, Mutlu Uygur[2] and Tugba Yanpar-Yelken[3]

Mersin University, Faculty of Education, Curriculum and Instruction Department, Turkey and Nigde Aksemseddin Science and Art Center, Nigde, Turkey

Article Info

Received: 19 March 2022
Revised: 25 April 2022
Accepted: 9 May 2022
Available online: 30 June 2022

Keywords:
3D Printers
3D Design Programs
Gifted Students

Abstract

Nowadays, when the production of knowledge is increasing rapidly, new production technologies have become extremely important to create useful products. The changing human needs and desires to produce many products in a short time enable countries to produce different technologies and integrate them into daily life. The aim of this research is to investigate teachers' and students' views on the educational contributions of using 3D design programs and 3D printers A mixed research method was used within a convergent parallel design. For the quantitative part of the study, a survey was conducted with 108 students. Then, 10 gifted students were randomly selected among the students participating in the survey and interviews were conducted. Interviews were also conducted with 3 teachers worked in Science and Art Centers (SACs) where educated gifted students in Turkey. The data were collected and analyzed through questionnaires and semi-structured interviews. According to the results of the research, it appears that 3D design technologies play an important role in the development of students' knowledge and skills, students use these technologies quite a lot when producing projects or designing the products of their projects, and this situation motivates them in the project production process. In addition, appears that students can print their own course materials to learn.

To cite this article:
Akyol, C., Uygur, M., & Yanpar-Yelken, T. (2022). 3D printers as an educational tool in gifted education: effective use, problems and suggestions. *Journal for the Education of Gifted Young Scientists*, *10*(2), 173-205. DOI: http://dx.doi.org/10.17478/jegys.1105484

Introduction

Technological developments facilitate designing useful products and ensure the realization phases of these products by reducing the duration of access to knowledge and determining new production techniques. Developed countries are societies that produce knowledge and transform this knowledge into new technologies. One thing is true that technology develops rapidly and makes life easier by discovering creative solutions to human needs. Considering the working logic of 3D printers and the change over time, it seems inevitable to benefit from this new technology in many areas (Yıldırım et al., 2018).

Human needs are also changing with the changing world. Therefore, creating new designs in products has become mandatory to satisfy the changing needs of people. The visuality, functionality, and practicality of products come into prominence in preferring products. From this perspective, the design of existing products has gained significance. To add new functional features in products, it is aimed to visualize and transfer products into drawings and transform these drawings into tangible, sensible, and marketable products. However, the use of mental processes stands out in designing products. Designing involves higher-order mental processes such as discovering differences, imagining, inquiring, creative thinking, critical thinking, and reasoning Ministry of National Education of Turkey (MNET) (2006).

[1] Corresponding Author, PhD Student, Science Teacher for Gifted, Mersin University, Faculty of Education, Curriculum and Instruction Department, Turkey and Nigde Aksemseddin Science and Art Center, Nigde, Turkey. E-mail: cakyol51@gmail.com ORCID: 0000-0002-8576-6421
[2] Dr., Classroom Teacher, 24 Kasım Primary School, Mersin. E-mail: mutluygur@gmail.com, ORCID: 0000-0002-7756-2576
[3] Prof.Dr., Mersin University, faculty of Education, Department of Educational Sciences, Mersin, Turkey. E-mail. tyanpar@gmail.com, tyanpar@mersin.edu.tr, ORCID: 0000-0002-0800-4802

Why Used 3D Printers at Talent Development?

Transformation of the created designs increases both the cost and storage costs. At this stage, 3D printers, which transform 3D designs developed in computer environments into products, provide considerable facilitation to those who design innovative products. The costs of 3D printers have decreased in recent years and will start being used in homes in the near future. Seen as the technology of the future, 3D printers can print out a component you imagine by modeling in computer environments in a matter of hours and eliminate the storage costs. The US president, Barack Obama, noted that 3D printing technology "will create the next industrial revolution" (http://www.hurriyet.com.tr/sanayide-3-boxedyut-devrimi-yasanacak-22592939). The preparation time of designs and their molds, which required several months of work in the past, has been reduced to a few days. When we examine the utilization areas of 3D printers in the world and their examples, they are utilized in many areas, such as:

- Artificial organ production in medical field.
- In the production of artificial tissues using the method of 3D bio-printing with living cells.
- The use of 3D printed components in warplanes in defense industry.
- In the production of products capable of combining vanilla, mint, apple, cherry, and melon flavors with sugar and chocolates in food production.

NASA also sent 3D printers to the international space station to assist astronauts and increase their capabilities.

Utilization Areas of 3D Printers

The current understanding of the workforce requires individuals to have knowledge in many fields. The emergence of a new field of engineering through a combination of several fields of engineering stem from the requirements of this new era. For instance, it may have emerged to educate competent individuals in mechatronics, mechanics, and electronics areas. This workforce often requires more engineering skills. STEM Education, especially in the fields of technology and engineering, has aimed for children to study interdisciplinary from a younger age and the concept of "MAKER" has been put forward at many points where it has deficiencies. In Turkish, however, the word maker is described as "yapan". Characteristics such as inquisitive, creative, solution-oriented, patient, explorer, enthusiastic, skillful, global, and designer are sought in an individual called maker (http://www.makerhareketi.com/). All STEM-related disciplines are considered together as a whole.

3D printers, whose name has been frequently heard in recent years, are used in many sectors. Yıldırım and Çelik's (2018) study also showed that 3D printers have a very wide range of uses and have the potential to be used in almost all areas of science. Productions take place in many areas such as space technologies, manufacturing technologies, health technologies, food production, construction industry, and so forth. Extremely rapid developments are taking place in the aerospace and aviation industry with the utilization of 3D printers. With 3D printers, the prototypes of products in the aerospace and aviation sector can be printed and the one-to-one working principles of the parts can be easily examined, and training on maintenance and repair processes can be carried out practically. In this context, students have examined the technical structure of the differential in details and learned about its tasks and structure. Therefore, graduate students will be able to easily perform maintenance and repair operations on shafts, differentials, and axles in vehicles (Özsoy, 2019). As in all spheres of life, 3D printers are being used in medicine evermore. 3D printers can be used for preoperative examinations in fracture treatments. "The utilization of 3D models offers surgeons advantages by increasing their abilities to perform preoperative simulations. The three-dimensional modeling technique reduces the screw malposition during surgery and increases intraoperative safety by reducing the surgery duration" (Kızmazoğlu et al., 2019).

3D Printers and Education

It also seems that 3D printers are widely used in the field of education. 3D printers are not new technologies. However, their prevalence in daily utilization took some time until the 2000s (Yıldırım, Yıldırım, & Çelik, 2018). Many science and art center students became acquainted with 3D printer technologies, especially in 3D printer ateliers established in science and art centers since 2016. In these ateliers, students learn various design programs in practical ways, and make the products they design tangible by printing them on 3D printers. Further, 3D printers seem to have just started being frequently utilized in activities in The Scientific and Technological Research Council of Turkey Science (STRCTS) and Society Projects. For instance, in a project called the Nature's STEM with Art, carried out in 2016 and 2018 to enable students discover science, technology, mathematics, and engineering applications with artistic elements in the nature, students were offered an opportunity to design available elements in nature, using the 3D design programs and getting their printouts (https://doganinsanatlastemi.weebly.com/).

There are various 3D Design programs. The TinkerCad and AutoCAD programs, commonly used in science and art centers, are used widely. Buhler et al. (2015) classified the 3D design programs from simple to complex as in the following.

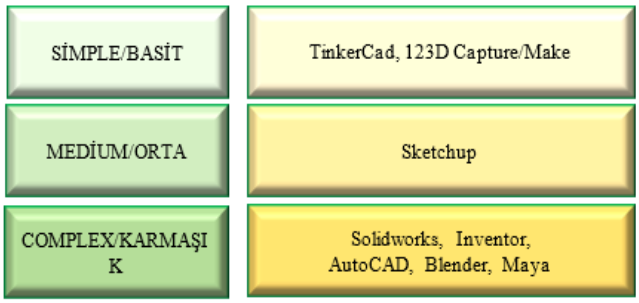


Figure 1

Classified the 3D Design Programs from Simple to Complex (is adopted from Buhler et al. (2015)

Çetin, Berikan, and Yüksel (2019) carried out a formative assessment of students' experiences in the 3D design process and found that students made progress in terms of establishing a part-whole relationship and design skills after the 3D design education.

In their content analysis study on the instructional use of 3D printers, Yıldırım et al. (2018) reported that 3D printers were mostly used in the fields of health and technology, whereas insufficient research was conducted in education. Many studies conducted in education in different countries reported that material design and development stood out more, but few reported that laboratory development stood out more.

Doğan and Uluay (2020) studied the preservice teachers' experiences of using the TinkerCad program. They found that preservice teachers had no difficulty in using this program and that it could be used in science courses.

The 3D design programs and printers are considered as new technologies. As its mechanical structure consists of moving parts, various malfunctions occur and continuous adjustments must be made. In their study with middle school students and their mathematics teacher in a small class with no prior experience with printers, Dickson et al., (2020) noted that the efforts of the students and the teacher to solve the unstructured faults provided them with preliminary evidence for the problems that would occur in the future, and this affected their course achievement.

Given the working principles of 3D printers and the introduction of their varieties in the market in recent years, the number of studies conducted in this area will increase and this technology will be used in many different fields (Yıldırım et al., 2018).

3D design programs mostly operate online and facilitate creating virtual classrooms, allowing students to work collaboratively. Studies concerning the experiences of preservice teachers and students (Doğan & Uluay, 2020; Çetin, Berikan, & Yüksel, 2019) show that the 3D design programs increase students' collaboration, curiosity, and creativity, and that preservice teachers generally hold a positive attitude towards them. Given the models printed by 3D printers appeal to many sense organs, they ensure that learning is permanent (Güleryüz, Dilber, & Erdoğan, 2019).

In the coming years, 3D printers will be used in many courses, especially in technology design, science, and mathematics courses. Today, 3D printers, which are used in many fields, are expected to be used in a wide range of areas, from producing course materials in lessons to printing products specially designed for students' projects. As seen in the studies given above, the purpose of the technology brought by 3D printers is to improve the quality of human life. In this respect, it is very important for a country to produce technology. Finding buyers for the produced technology is directly related to the design. Hence, the vision of the technology and design course curriculum is stated as follows:

"Educate individuals who are aware of problems, generate solutions, have a developed sense of creativity and imagination, construct and express their thoughts, learn to learn, question, are entrepreneurial, open to change and development, and have a developed sense of responsibility to build make their future and that of the society more livable" (MNET, 2006, p.5).

While introducing the concept of Society 5.0, Japan advocates the necessity of Society 5.0 to seek for solutions to its social problems and combat global challenges such as depletion of natural resources, global warming, growing economic disparity, and terrorism. Despite being within the scope of Japan's growth strategy, Society 5.0 corresponds with the 2030 Sustainable Development Goals, jointly approved by 193 member states at the UN Sustainable Development Summit, considering the goals Japan set out (TEDMEM, 2020, p.5). The following figure shows that

3D printer technology is among the main targets of the Japanese government in line with society 5.0 and sustainable development goals.

Figure 2

Sustainable Development Goals and Society 5.0 for SDGs (Fukuyama, 2018)

In addition to STRCTS survey studies, a research study was conducted by the Ministry of Science, Industry, and Technology within the scope of the Turkey Productivity Development Map Project in 2016 with approximately 10,000 enterprises to determine the awareness levels of enterprises regarding industry 4.0 (TEDMEM, 2020). The figure below shows the state of awareness of enterprises about technologies related to the fourth industrial revolution. Research findings show that 3D printing technologies are the area in which enterprises with 20 or more employees have the most intensive knowledge by 49%. In contrast, 51% of enterprises were unaware of these technologies.

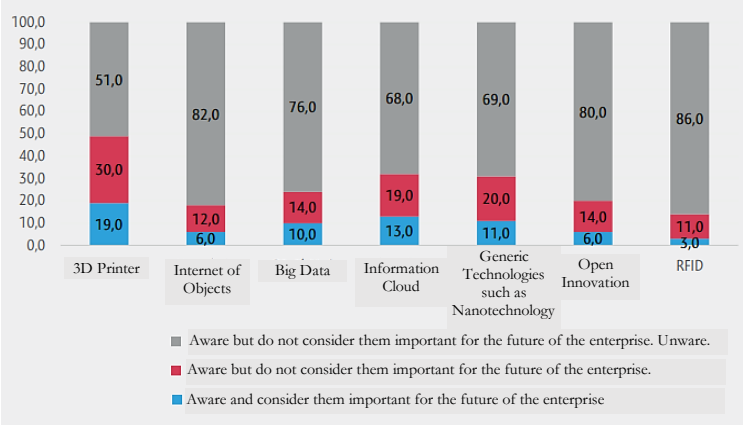


Figure 3

The State of Awareness of Enterprises About Technologies Related to the Fourth Industrial Revolution

Considering the usage of 3D printers in educational environments, they are not among the prioritized technology preferences. The fact that 3D printers appeared a short while ago for the end-user market is one of the primary factors behind why they are not often preferred in the field of education today (Demir et al., 2016). In recent years, they have been in frequent use in science and art centers. The biggest reason for this is the increase in the number of 3D printer ateliers in proportion to the number of science and art centers opened in recent years. There is a limited number of studies in our country on the utilization of 3D printers or the evaluation of products produced with these printers. It seems that studies in Turkey are mostly conducted with university students (Yavuz et al., 2020; Karaduman, 2018; Özsoy, 2019). There are also studies on the educational use of 3D printers in the literature (Choi & Kim, 2018; Chien, 2017; Yamamoto, Hosoda, Satou, Ishiko, & Sawadaishi, 2018; Yıldırım, Yıldırım & Çelik, 2018; Yavuz, Büyükekşi, & Çolakoğlu, 2020).

As the utilization of the technology is new in education and the number of 3D printers is gradually increasing in ateliers opened in science and art centers, conducting this research is very significant. Besides, no study has been conducted to determine the views of students about the 3D design process. Only one study explored the views of students regarding the use of 3D printers. This research is the first study to determine the views of students and teachers doing activities in science and art centers. Therefore, this study is expected to contribute to the literature in terms of obtaining student and teacher views and determining their perspectives on this technology. The purpose of the research is to explore and examine the views of teachers and students on the educational contributions of 3D design programs and 3D printer utilization in a Science and Art Center in Central Anatolia. In respect to this general purpose, the problem statement and sub-problems were formed as in the following.

Problem Statement

What are the views of gifted students and their teachers about using 3D printers as an educational tool?
Teachers and students usage of 3D printers as an educational tools?

Sub-problems

- What are the views of gifted students and their teachers about **effective usage** of 3D printers as an educational tools?
- What are the views of gifted students and their teachers about **encountered problems** at using 3D printers at educational/teaching process?
- What are the **suggestions** of gifted students and their teachers about usage of 3D printers as an educational tools?

Methodology

Research Model

In this research, a mixed-methods research design, described as the combination of quantitative and qualitative methods, approaches, and concepts, was employed (Creswell, 2009). In mixed-methods studies, the aim is to complement the weaknesses of one method by the strengths of the other by using quantitative and qualitative methods together. This way, the validity and reliability of the data collected through both methods will increase (Creswell & Plano Clark, 2011, p.9). As 3D printers are a newly developing technology and have just started to be used in schools, a mixed-method research where quantitative and qualitative data were collected and the findings were synthesized together, was employed in this study to carry out an in-depth and multifaceted examination of students and teachers' views. In this study, which is mostly quantitative-based, a convergent parallel design of mixed-methods research was used. The reason for using this design in the study was to qualitatively evaluate the data obtained quantitatively and to synthesize both data. The research stages were carried out as in the following.

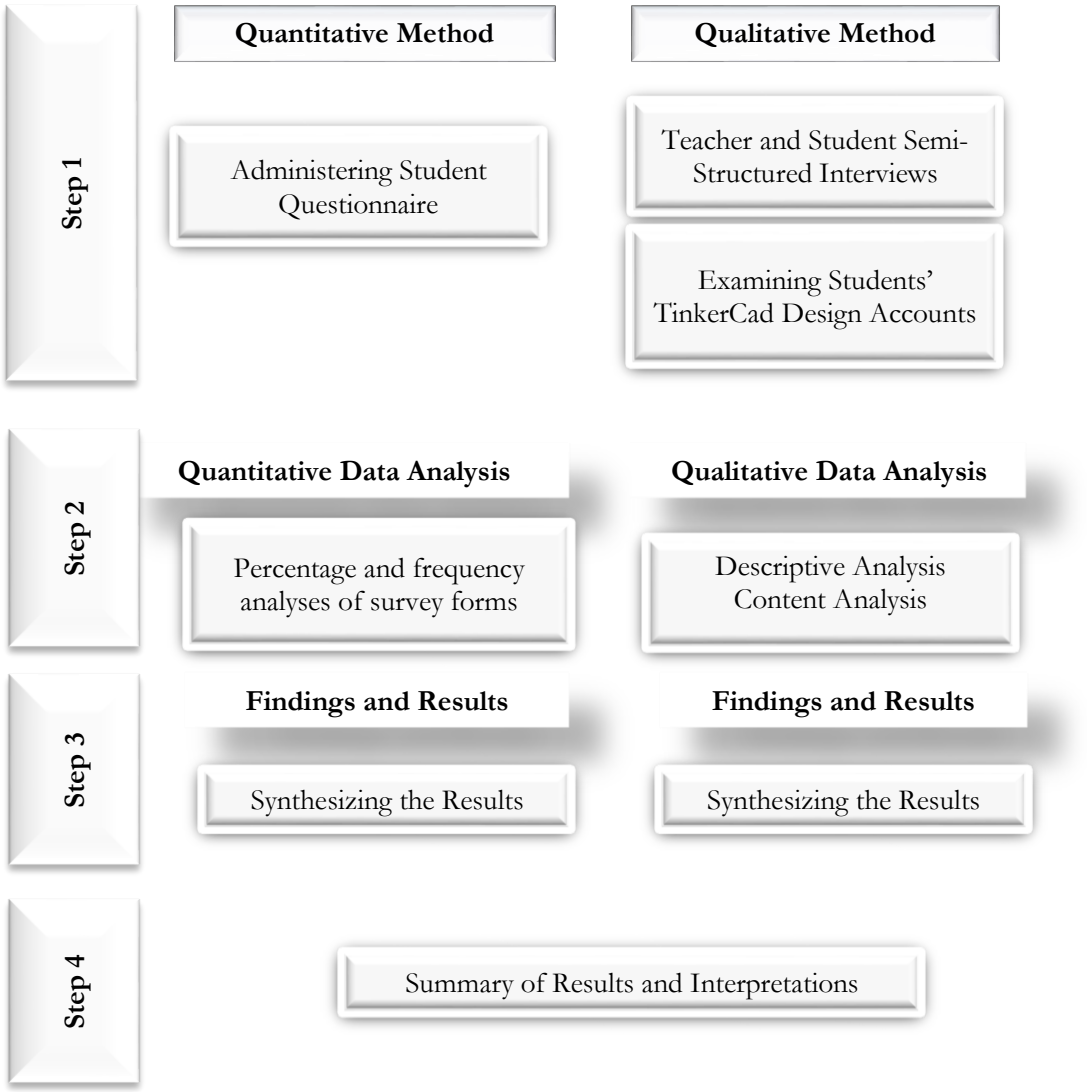


Figure 4

Quantitative + Qualitative Application Process

Validity and Reliability

The validity and reliability for this study were addressed under four headings.

A long-term interaction with participants was established in the research process. In addition, the participants' confirmation and verification of their views were obtained. And, three types of data collection tools were utilized in the study, semi-structured interview, questionnaire, and document analysis. This way, the internal validity of the study was ensured. In addition, expert opinions were obtained and data collection, analysis, and findings plus conclusion and discussion were examined by two experts, and a consensus was reached. Direct quotations were provided in the findings section and the participants' views were directly quoted. In order to make the study transferable, a purposeful sampling method was selected. The reason for the sample selection was that students and teachers had carried out activities using 3D programs and 3D printers for at least half a semester. The target universe of the study comprised 275 students studying at a science and art center in Anatolia, whereas the accessible universe comprised 120 students and three teachers who had experience in 3D programs and printers.

Findings related to the interview and questionnaire forms were presented directly and two researchers' opinions were obtained for the coding consistency. Two researchers separately analyzed the codes, categories, and themes and reached a consensus. In cases where no consensus was made, the coding consistency was examined by computing Miles and Huberman's compliance percentage (Huberman, 2002). Two experts examined the consistency between the study data and results by comparing the results of the study with the data. The steps of validity and reliability studies are given below.

Table 1

The Steps of Validity and Reliability Studies

Validity	**Internal validity Plausibility**	**Obtaining the views of experts**
		Participant confirmation
		Long-term interaction
		Direct quotation
	External validity Transferability	Describing the data collection tools and processes
		Describing the data analysis process
		Describing the characteristics of the study group
		Describing the selection procedure of the study group
		Describing the implementation process of the study
		Describing the researcher's role
		Describing the rationale for selecting the method used
		Describing the validity and reliability measures
		Purposive sampling
Reliability	Internal reliability Consistency	Using a recording device and preventing data loss
		Presenting the findings without interpreting
		Two researchers controlled for the inter-coder consistency
	External reliability Confirmability	Discussing the data in the result section in an appropriate manner
		Checking the consistency between the data
		Checking the data by a third expert

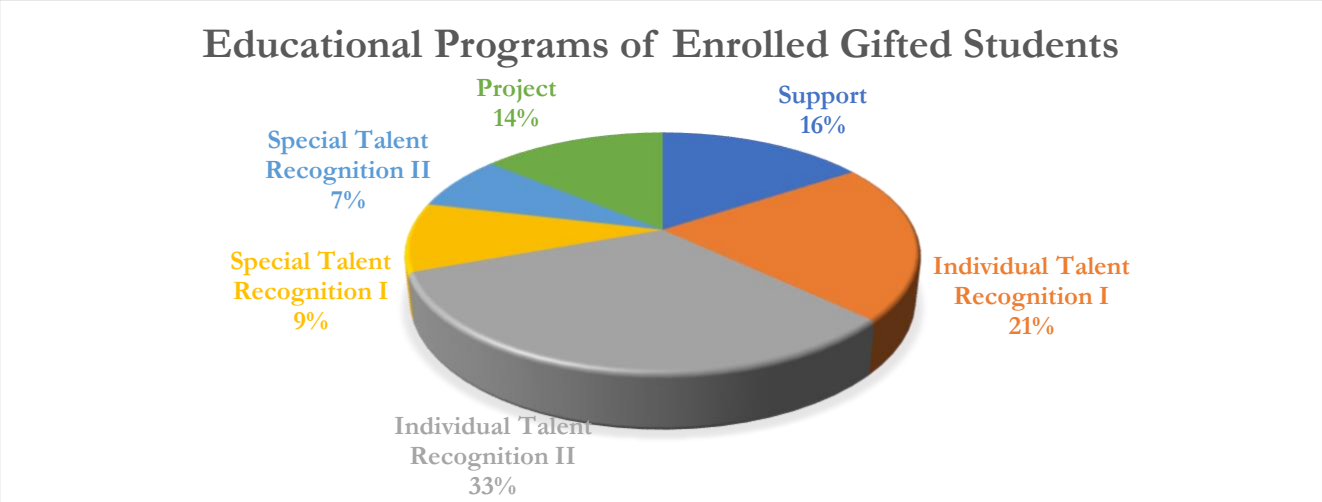
Study Group

A criterion sampling type from purposive sampling techniques was used in this research to determine the study group. Purposive sampling helps discover and describe phenomena and events in many cases (Yıldırım & Şimşek, 2011; 107). Purposive sampling enables conducting an in-depth investigation by selecting information-rich cases depending on the purpose of a study (Büyüköztürk et al., 2016:90). In criterion sampling, the criteria are determined and all likelihoods are plied per these criteria. The criteria could be pre-prepared or determined by the researcher (Yıldırım & Şimşek, 2013). The reason behind choosing the criterion sampling of purposive sampling in this study is the criteria that students and teachers have at least half a semester of experience in 3D design programs and printers. The study group of this research comprised teachers and students receiving education at a science and art center in the Central Anatolia Region in the 2020-2021 school year. Likewise, in the qualitative part of the study, teachers and students included in the interview were determined according to the same criteria and the semi-structured interviews were conducted while collecting the data using questionnaires. Four interviews were conducted in-person and six through online platforms. This is because the science and art centers switched to face-to-face education for a short time and then suspended education due to the pandemic. When selecting the students interviewed, students continuing with their courses and having experience in 3D printing and design were determined on voluntary basis. Ten students and three teachers, who were interviewed, were coded using pseudonyms and complying with ethical rules. Students were coded as IY^{D} in the Support Education Program, MA^{B}, LA^{B}, YU^{B}, RL^{B}, and AO^{B} in the Individual Talent Recognition Program (ITR), $ÜO^{Ö}$ and $UY^{Ö}$ in the Special Talent Development Program (STD), FA^{P} and $UÜ^{P}$ in the Project period, and teachers were coded as RZ^{T}, EA^{F}, and ZZ^{T}. Questions were asked during the interviews to determine the participants' demographic characteristics and their characteristics were determined. The demographic characteristics of the participants are shown in Table 2.

Table 2

The Demographic Characteristics of the Participants

Participant Student	Attending Period	Gender	Participant Teacher	Branch	Gender
IY^{D}	Support	Male	**EA^{F}**	Science	Male
MA^{B}	ITR	Female	**RZ^{T}**	Technology Design	Male
LA^{B}	ITR	Female	**ZZ^{T}**	Technology Design	Male
YU^{B}	ITR	Female			
RL^{B}	ITR	Female			
AO^{B}	ITR	Male			
ÜO^{Ö}	STD	Female			
UY^{Ö}	STD	Female			
FA^{P}	Project	Male			
UÜ^{P}	Project	Male			



ITR: Individual Talent Recognition Program **STD**: Special Talent Development Program

One hundred and eight students, who participated in the survey, 13.9% were in the Support Education Program, 53.7% in the ITR, 9.3% in the STD, and 15.7% in the Project period.

Data Collection Tools

Please create a title for your Questionary for example: Views about Using 3D Printers as an Educational Tools Questionnaire

Views about Using 3D Printers as an Educational Tools Questionnaire

The questionnaire and semi-structured interview forms developed by the researchers were used in the research. Steps relating to the questionnaire study are given in the following figure.

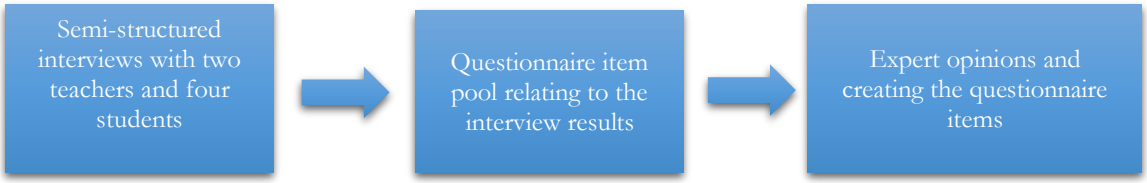


Figure 5

Steps Relating to the Questionnaire Study

The questionnaire prepared for students consisted of 36 items. In the questionnaire development process, the preliminary data were collected with open-ended questions from four students. Eight open-ended questions were emailed to the students in writing due to the pandemic period. Students were determined as ITR, STD, Support, and Project period students, and this way, the questionnaire items were developed with the views of students pursuing their education in different periods at science and art center. The sample open-ended questionnaire questions are "For

what purpose do you use 3D printers and programs?" and "How does using 3D printers make you feel?" As such, a 42-item questionnaire was devised based on student responses, researchers' experiences, and literature review, and then five experts were consulted. The number of items was reduced to 36 after making necessary revisions based on expert feedback. The last version of the questionnaire was examined by three experts and it was ready to use after final refinements. Two of the consulted experts were Professors in educational sciences, one was Associate Professor, one was Assistant Professor, and the other expert was a technology design teacher with around six years of experience at a science and art center who conducted studies with 3D design and programs. Further, the semi-structured interview forms used for teachers in the research consisted of seven questions. When preparing the interview questions, data were collected from two technology design teachers through an open-ended survey method, and the collected data were evaluated by three researchers and the questions were prepared by reviewing the literature. These questions were evaluated by five experts and finalized by making revisions per their feedback. Moreover, the semi-structured interview form prepared for students consisted of six questions. The questions prepared for students underwent the same processes. The following figure shows the preparation process of the semi-structured interview forms prepared for students and teachers. Two open-ended questions were added to the questionnaire form and students' views and suggestions were also obtained in the questionnaire. This way, the data triangulation was ensured.

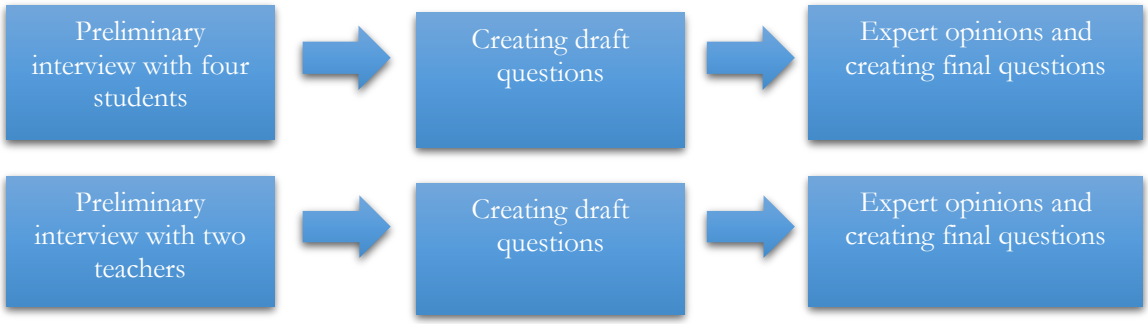


Figure 6

Steps Followed While Preparing Teacher and Student Interview Questions.

Teachers were asked the following open-ended questions: For what purposes do you use 3D design programs and 3D printers in the science and art center (SAC)? What do think about the effect of 3D design programs and 3D printers on SAC support, IRT, STD, and Project students' achievement and motivation? Likewise, students were asked open-ended questions such as what do you think about the effect of 3D design programs and 3D printers used in the SAC on your course achievement? How does using 3D printers make you feel?

Data Collection Process

Some interviews were conducted in-person with students and teachers, whereas some were conducted online. This was because SACs had decided to carry out in-person education at the beginning of the data collection process and then they switched back to distance education due to the pandemic conditions. In this process, five students and one teacher were interviewed in person, but five students and two teachers were interviewed in online environment. In-person interviews were conducted in a quiet environment by talking face-to-face. Student interviews lasted 10-15 minutes. The data collection processes with the questionnaire and interview forms were carried out collaterally. While the questionnaires sent to students through Google form were being completed, the interviews were continued with students. Starting by getting necessary permissions, the process lasted six weeks. Likewise, teacher interviews were also conducted within this period. Teacher interviews lasted 20 minutes on average. Face-to-face interviews were conducted in a quiet environment in a conversational atmosphere and permissions were obtained for the voice recorder. Online interviews were conducted on the date and time specified by the participants through a program frequently used in distance education.

Data Analysis

The study has both quantitative and qualitative dimensions. Percentage and frequency analyses of the data obtained from the questionnaire in the quantitative dimension of the research were conducted. In this respect, the resulting findings were given in the form of frequencies and percentages. Further, the data collected in the qualitative dimension were analyzed through a content analysis method. Conducting content analysis is appropriate when there is no sufficient prior information regarding the research topic (Lauri & Kyngas, 2005). Elo and Kyngas (2007) suggest organizing the data through open-coding, creating categories, and summarizing processes. The reason behind using a content analysis in this study was to uncover the cause and effect relationships and to carry out an in-depth analysis.

In the qualitative dimension of the study, responses given to each question were transcribed. After transcribing the data, the contexts of questions asked in questionnaires and interviews were used when analyzing the data. Responses given to the questions were presented directly, without making any changes. Considering the responses, the codes of questions related to or similar to each other were created and categories were derived. For example, responses such as *the printing is slow* and *the print button is small* that teachers provided to a question regarding the use of printers were considered as codes and evaluated under the "limitations of printers" and this category was included in the theme of *disadvantages of printers*. The data were analyzed by creating themes out of categories. Two randomly selected experts separately carried out the coding process to ensure the internal reliability of the research. This way, Miles and Huberman's (1994) consistency reliability of each item in the open-ended questions form were examined in the content analysis. The reliability values of over 70% indicate that the research is reliable (Miles & Huberman, 1994). The reliability values of students and teachers' views relating to each theme are given in the following table.

Table 3

The Reliability Values of Students and Teachers' Views Relating to Each Theme

	Qualitative Data Content of the Views Form	Miles & Huberman Reliability Value	Miles & Huberman Reliability Percent (%)
1	Views on courses where 3D design programs and printers are used	.100	100
2	Views on the utilization purposes of 3D design programs and printers	.96,42	96
3	Views on programs used in SAC	.100	100
4	Views on the effect of 3D design programs and 3D printers on students	.94,73	95
5	Views on how 3D design programs and 3D printers make students feel	.97,22	97
6	Views on disadvantages of 3D design programs and 3D printers	.92,85	93
7	Views on advantages of 3D design programs and 3D printers	.100	100
8	Views on student opinions and thoughts concerning 3D design programs and 3D printers	.100	100
9	Views on teachers' purposes of using 3D design programs and 3D printers	.87,5	88
10	Views of teachers on advantages of 3D design programs and 3D printers	.90	90
11	Views of teachers on disadvantages of 3D design programs and 3D printers	.93,3	93
12	Views of teachers on 3D design programs and 3D printers taught in SAC	.100	100
13	Views on the effect of 3D design programs and 3D printers taught in SAC	.93,75	94
14	Views on how 3D design programs and 3D printers taught in SAC make teachers feel	.100	100
Average		**96.12**	**96**

Ethic

In the research, the data were collected on a voluntary basis. Individuals unwilling to participate in qualitative and quantitative data collection processes were not included in the research. Personal information collected in the research was only used by the researchers and not shared with anyone else or institutions. No personal identification information was requested from the participants. Necessary permissions were obtained beforehand from the National Education Department to administer the questionnaire to students in the SAC and to conduct the semi-structured interviews. In addition, parent permissions for students participating in the interviews were obtained through official ways by the researchers. Abiding by ethical rules, the names of the participants owning the data were not given and three-letter codenames were given instead. As interviews were conducted with students under 18, verbal permissions were obtained from the parents. Student interviews were conducted after their parents were informed and they were contacted once again for confirmation.

Findings

Quantitative Findings

Table 4

Demographic Information of the Participants

Participant Characteristics	*f*	%
Gender		
Girl	50	46.3
Boy	58	53.7
Age		
8-10 ages	23	21.2
11-13 ages	60	55.6
14-16 ages	17	15.8
17-18 ages	8	7.4
Attending Programs at SAC (Supportive Education for Gifted)		
Support Stage of Education Program	17	15.7
ITR Stage of Education Program	58	53.7
STD Stage of Education Program	10	9.3
Project Stage of Education Program	15	13.9
Attending School Type at Formal Education		
Primary School	17	15.7
Secondary School	76	70.4
High School	15	13.9
Attending Duration to SAC		
1-2 years	21	19.4
3-4 years	52	48.2
5-6 years	35	32.4
Total	108	100

ITR: Individual Talent Recognition Program **STD**: Special Talent Development Program

Per participant characteristics given in the table, f = 50 (46.3%) of SAC students were girls and f = 58 (53.7%) boys. Moreover, 23 students were 8-18, 60 were 11-13, 17 were 14-16, and 8 were 17-18 years old. And f = 17 (15.7) students were in Support, f = 58 (53.7) in ITR, F = 10 (9.3) in STD, and 15 (13.9) in project period. When we looked at school types attended, f = 17 (15.7) students attended to primary school, f = 76 (70.4) to secondary school, and f = 15 (13.9) to high school or schools of similar level. Of these students, f = 21 (19.4) attended SAC for 1-2 years, f = 32 (48.2) for 3-4 years, and f = 35 (32.4) for 5-6 years.

Table 5

Views About the Aims of the Usage of 3D Printers

Items: Aim of Usage	SD		D		U		A		SA	
	f	%	f	%	f	%	f	%	f	%
The 3D design programs and printers we use in SAC help me generate different solutions to the problems I face in daily life.	1	0.9	1	0.9	16	14.8	46	42.6	44	40.7
Activities conducted with 3D design programs and printers we use in SAC increase a sense of curiosity.	2	1.9	0	0	4	3.7	30	27.8	72	66.7
I think the 3D printers are used per their intended purpose.	3	2.8	1	0.9	7	6.5	30	27.8	67	62
I have the opportunity to examine and investigate the outputs I have obtained using 3D programs and printers as tangible and 3D objects.	1	0.9	2	1.9	13	12	38	35.2	54	50

SD: Strongly Disagree, **D**: Disagree, **U**: Undecided, **A**: Agree, **SA**: Strongly Agree

The percentage and frequency table related to the questionnaire items on understanding the purposes of using 3D design programs and 3D printers in SAC directed to students is presented above. According to the table, f = 44 (40.7%) of students strongly agreed with the statement that 3D design programs and printers in SAC help generate

different solutions to daily life problems, f = 46 (42.6%) agreed, f = 2 (1.8) disagreed, and f = 16 (14.8%) were undecided. Further, f = 72 (66.7%) of students strongly agreed with the statement that the 3D design programs and printers used increases my sense of curiosity, f = 30 (27.8%) agreed, f = 4 (3.7%) were undecided, and f = 2 (1.9%) strongly disagreed. However, f = 67 (62%) of students strongly agreed with the statement on whether the 3D printers are used for intended purposes, f = 30 (27.8%) agreed, f = 7 (6.5%) were undecided, f = 1 (0.9%) disagreed, and f = 3 (2.8%) strongly disagreed. Moreover, f = 54 (50%) of students strongly agreed with the statement "I have the opportunity to examine and investigate the outputs I have obtained using 3D programs and printers as tangible and 3D objects.", f = 38 (35.2%) agreed, f = 13 (12%) were undecided, f = 2 (1.9%) disagreed, and f = 1 (0.5%) strongly disagreed.

Table 6

Views About the Preparations for the Usage of 3D Printers

Items: Preparations for Usage	SD		D		U		A		SA	
	f	%	f	%	f	%	f	%	f	%
I would like to take additional courses to feel more prepared for the 3D design programs and printers we use in SAC.	4	3.7	15	13.9	35	32.4	28	25.9	26	24.1
I come to the course by getting preparation before working with 3D design programs and printers.	2	1.9	12	11.1	28	25.9	45	41.7	21	19.4
Preparations made before using 3D printers in SAC take most of my time.	24	22.2	54	50	25	23.1	3	2.8	2	1.9
When I have free time, I watch videos about the utilization of 3D design programs and 3D printers.	17	15.7	32	29.6	26	24.1	29	26.9	4	3.7

SD: Strongly Disagree, **D**: Disagree, **U**: Undecided, **A**: Agree, **SA**: Strongly Agree

According to the percentage and frequency table related to the questionnaire items directed to students to understand whether the utilization of 3D design programs and 3D printers required preparation, f = 26 (24.1%) of students strongly agreed with the statement *I would like to take additional courses to feel more prepared* and f = 28 (25.9%) agreed. However, f = 35 (32.4%) of students were undecided, f = 15 (13.9%) disagreed, and f = 4 (3.7%) strongly disagreed. And, f = 21 (19.4%) of students strongly agreed with the statement *I come to the course by getting preparation before working with 3D design programs and printers*, f = 45 (41.7%) agreed, f = 28 (25.9%) were undecided, f = 12 (11.1%), and f = 2 (1.9%) strongly disagree. Further, f = 24 (22.2%) of students strongly disagreed with the statement *Preparations done before using 3D printers in SAC take most of my time*, f = 54 (50%) disagreed, f = 25 (23.1%) were undecided, f = 3 (2.8%) agreed, and f = 2 (1.9%) strongly agreed. Of these students, f = 17 (15.7%) strongly disagreed with the statement *When I have free time, I watch videos about the utilization of 3D design programs and 3D printers*, f = 32 (29.6%) disagreed, f = 26 (24.1%) were undecided, f = 29 (26.9%) agreed, and f = 4 (3.7%) strongly agreed.

Table 7

Views About the Contribution of 3D Design Programs and 3D Printers to Students

Items: Contributions of the Outcomes	SD		D		U		A		SA	
	f	%	f	%	f	%	f	%	f	%
The 3D design programs' working online helps me to work in collaboration with my friends.	2	1.9	10	9.3	17	15.7	32	29.6	47	43.5
I take on more active roles in lessons by using 3D design programs and 3D printers in SAC.	2	1.9	4	3.7	11	10.2	45	41.7	46	42.6
The 3D design programs and 3D printers in SAC develop my creativity.	1	0.9	1	0.9	4	3.7	21	19.4	81	75
I think the 3D design programs and 3D printers in SAC make abstract subjects or content concrete.	1	0.9	3	2.8	15	13.9	53	41.9	36	33.3
Most 3D design programs' working online (internet connection) provide me facilitations in many issues.	4	3.7	8	7.4	19	17.6	41	38	36	33.3
Using 3D design programs and 3D printers in SAC helps me enter into the production process.	2	1.9	1	0.9	15	13.9	44	40.7	46	42.6
Using 3D design programs and 3D printers in SAC helps gain different perspectives.	2	1.9	2	1.9	7	6.5	41	38	56	51.9
3D design programs and 3D printers in SAC motivate me more in the lesson.	1	0.9	4	3.7	21	19.4	36	33.3	46	42.6
The products produced using 3D printers motivate me towards creating projects.	1	0.9	1	0.9	9	8.3	51	47.2	46	42.6

SD: Strongly Disagree, **D**: Disagree, **U**: Undecided, **A**: Agree, **SA**: Strongly Agree

To understand the contribution of 3D design programs and 3D printers to students, f = 2 (1.9%) strongly disagreed with the statement, *the 3D design programs' working online help me work in collaboration with my friends*, f = 10 (9.3%) disagreed, f = 17 (32%) were undecided, f = 32 (29.6%) agreed, f = 47 (43.5%) strongly agreed. Moreover, f = 2 (1.9%) of students strongly disagreed with the statement, *I take on more active roles in lessons by using 3D design programs and 3D printers in SAC,* f = 4 (3.7%) disagreed, f = 11 (10.2%) were undecided, f = 45 (41.7%) agreed, and f = 46 (42.6%) strongly agreed. Of these students, f = 1 (0.9%) strongly disagreed with statement, *the 3D design programs and 3D printers in SAC develop my creativity*, f = 1 (0.9%) disagreed, f = 4 (3.7%) were undecided, f = 21 (19.4%) agreed, and f = 81 (75%) strongly agreed. Likewise, f = 1 (0.9%) of students strongly disagreed with the statement, *I think the 3D design programs and 3D printers in SAC make abstract subjects or content concreate*, f = 3 (2.8%) disagreed, f = 15 (13.9%) were undecided, f = 53 (41.9%) agreed, and f = 36 (33.3%) strongly agreed. Also, f = 4 (3.7%) of students strongly disagreed with the statement, *most 3D design programs' working online (internet connection) provides me facilitations in many issues*, f = 8 (7.4%) disagreed, f = 19 (17.6) were undecided, f = 41 (38%) agreed, and f = 36 (33.3%) strongly agreed. Moreover, f = 2 (1.9%) of students strongly disagreed with the statement, *using 3D design programs and 3D printers in SAC helps me enter into the production process*, f = 1 (0.9%) disagreed, f = 15 (13.9%) were undecided, f = 44 (40.7%) agreed, and f = 46 (42.6%) strongly agreed. Also, f = 2 (1.9%) of students strongly disagreed with the item *Using 3D design programs and 3D printers in SAC helps gain different perspectives*, f = 2 (1.9%) disagreed, f = 7 (6.5%) were undecided, f = 41 (38%) agreed, and f = 56 (51.9%) strongly agreed. Similarly, f = 1 (0.9%) of students strongly disagreed with the statement, *3D design programs and 3D printers in SAC motivate me more in the lesson*, f = 4 (3.7%) disagreed, f = 21 (19.4%) were undecided, f = 36 (33.3%) agreed, and f = 46 (42.6%) strongly agreed. In addition, f = 1 (0.9%) of students strongly disagreed with the item, *the products produced using 3D printers motivate me towards creating projects*, f = 1 (0.9%) disagreed, f = 9 (8.3%) were undecided, f = 51 (47.2%) agreed, and f = 46 (42.6%) strongly agreed.

Table 8

Problems Encountered in Using 3D Design Programs and 3D Printers

Items: Problems Encountered in Using	SD		D		U		A		SA	
	f	%	f	%	f	%	f	%	f	%
I cannot sufficiently use the 3D printers in SAC, as getting printouts from them takes a long time.	13	12	25	23.1	37	34.3	21	19.4	12	11.1
I experience problems in finding filament in my desired colors and properties for the 3D printers in SAC.	6	5.6	22	20.4	33	30.6	28	25.9	19	17.6
I experience problems while printing out products developed in 3D design programs.	23	21.3	37	34.3	28	25.9	18	16.7	2	1.9
Carrying 3D printers is difficult for me.	11	10.2	31	28.7	34	31.5	23	21.3	9	8.3
I experience difficulty when adjusting the print settings in slicing programs before getting printouts from the 3D printers.	20	15.5	35	32.4	30	27.8	20	15.5	3	2.8
I experience problems in getting printouts because of the small number of 3D printers in SAC.	16	14.8	32	29.6	28	25.9	16	14.8	16	14.8

SD: Strongly Disagree, **D**: Disagree, **U**: Undecided, **A**: Agree, **SA**: Strongly Agree

Table 8 presents the frequencies and percentages of student responses to the questionnaire questions in regard to understanding the disadvantages/problems in using 3D design programs and 3D printers. As per results, f = 13 (12%) of students strongly disagreed with the item on long printing time, f = 25 (23.1%) disagreed, f = 37 (34.3%) were undecided, f = 21 (19.4%) agreed, and f = 12 (11.1%) strongly agreed. To the item on whether students could find filament in desired colors and properties, f = 6 (5.6%) of students stated that they strongly disagreed, f = 22 (20.4%) disagreed, f = 33 (30.6%) were undecided, f = 28 (25.9%) agreed, and f = 19 (17.6%) strongly agreed. Further, to the item on whether students experienced problems when getting printouts from the printer, f = 23 (21.3%) of students stated they strongly disagreed, f = 37 (34.3%) disagreed, f = 28 (25.9%) were undecided, f = 18 (16.7%) agreed, and f = 2 (1.9%) strongly disagreed. Moreover, f = 11 (10.2%) of students strongly disagreed with the item, *carrying 3D printers is difficult for me*, f = 31 (28.7) disagreed, and f = 34 (31.5%) were undecided, whereas f = 23 (21.3%) agreed and f = 9 (8.3%) strongly agreed. To the item directed to students to understand whether they face difficulties when adjusting the print settings in the slicing programs before printing, f = 20 (15.5%) of students mentioned they strongly disagreed, f = 35 (32.4%) disagree, and f = 30 (27.8%) were undecided, but f = 20 (15.5%) agreed and f = 3 (2.8%) strongly agreed. Besides, f = 16 (14.8%) of students strongly disagreed with the on whether the number of 3D printers used in the institution is adequate, f = 32 (29.6%) disagreed, and f = 28 (25.9%) were undecided, whereas f = 16 (14.8%) agreed and f = 16 (14.8%) strongly agreed.

Tablo 9

Emotions Students Feel When Using 3D Design Programs and 3D Printers.

Items: Emotional Status at Using of 3D Printers	SD		D		U		A		SA	
	f	%	f	%	f	%	f	%	f	%
I refrain from using printers in lessons because of the expensiveness of 3D printers.	42	38.9	37	34.3	19	17.6	6	5.6	4	3.7
I enjoy printing out the products I design in 3D design programs from the 3D printers.	1	0.9	1	0.9	4	3.7	24	22.2	78	72.2
Printing out the unique products I design using 3D design programs from printers excites me.	0	0	2	1.9	5	4.6	26	24.1	75	69.4
I prefer using 3D printers in the courses in SAC.	0	0	3	2.8	21	19.4	27	25	57	52.8
I feel comfortable when using 3D design programs and 3D printers in SAC.	1	0.9	8	7.4	16	14.8	43	39.8	40	37
I consider myself competent in using 3D design programs and 3D printers in SAC.	3	2.8	12	11.1	38	35.2	34	31.5	21	19.4
Materials printed using 3D printers increase my interest in the subject.	0	0	3	2.8	4	3.7	38	35.2	63	58.3

SD: Strongly Disagree, **D**: Disagree, **U**: Undecided, **A**: Agree, **SA**: Strongly Agree

Responses regarding the items created to understand students' feelings when using the 3D design programs and 3D printers are given in the table above. Of these students, f = 42 (38.9%) strongly disagreed with the item, *I refrain from using printers in lessons because of the expensiveness of 3D printers*, f = 37 (34.3%) disagreed, f = 19 (17.6%) were undecided, while f = 6 (5.6%) agreed and f = 4 (3.7%) strongly agreed. Also, f =1 (0.9%) of students strongly disagreed with statement, *I enjoy printing out the products I design in 3D design programs from the 3D printers*, f = 1 0.9%) disagreed, and f = 4 (3.7%) were undecided, whereas f = 24 (22.2%) agreed and f = 78 (72.2%) strongly agreed. While f = 2 (1.9%) students disagreed with the statement, *printing out the unique products I design using 3D design programs from printers excites me*, and f = 5 (4.6%) were undecided, f = 26 (24.1%) agreed and f = 75 (69.4%) strongly agreed. And, f =3 (2.7%) of students disagreed with the item, *I prefer using 3D printers in the courses in SAC*, f = 21 (19.4%) were undecided, f = 27 (25%) agreed, and f = 57 (52.8%) strongly agreed. Of these students, f = 1 (0.9%) strongly disagreed with the item, *I feel comfortable when using 3D design programs and 3D printers in SAC*, f = 8 (7.4%) disagreed, f = 16 (14.8%) were undecided, f = 43 (39.8%) agreed, and f = 40 (37%) strongly agreed. Further, f = 3 (2.8%) strongly disagreed with the item, *I consider myself competent in using 3D design programs and 3D printers in SAC*, f = 12 (11.1%) disagreed, and f = 38 (35.2%) were undecided, but f = 34 (31.5%) agreed and f = 21 (19.4%) strongly agreed. In addition, f = 3 (2.8%) of students disagreed with the item, *materials printed using 3D printers increase my interest in the subject*, f = 4 (3.7%) were undecided, f = 38 (35.2%) agreed, and f = 63 (58.3%) strongly agreed.

Table 10

Situations Where Students Get Support While Using 3D Design Programs and 3D Printers.

Items: Need for Support at Using of 3D Printers	SD		D		U		A		SA	
	f	%	f	%	f	%	f	%	f	%
The SAC Administration supports us to use 3D printers.	2	1.9	2	1.9	10	9.3	32	29.6	62	57.4
Our teachers support us to use 3D printers.	1	0.9	0	0	3	2.8	27	25	77	71.3
My family supports me to use 3D printers.	3	2.8	5	4.6	15	13.9	32	29.6	53	49.1
Working with 3D design programs and 3D printers in SAC makes me willing to produce projects.	2	1.9	5	4.6	4	3.7	40	37	57	52.8
Working with 3D design programs and printers may help me select professions like printing technologies/engineering.	5	4.6	10	9.3	24	22.2	39	36.1	30	27.8
When I experience problems regarding the 3D printers in SAC, I get support from my other friends.	3	2.8	9	8.3	26	24.1	45	41.7	25	23.1

SD: Strongly Disagree, **D**: Disagree, **U**: Undecided, **A**: Agree, **SA**: Strongly Agree

Responses that students provided to the items created to understand their states of getting support when using the 3D design programs and 3D printers are given in the table above. Of these students, f = 2 (1.9%) of students strongly disagreed with the item, *the SAC Administration supports us to use 3D printers*, f = 2 (1.9%) disagreed, f = 10 (9.3%) were undecided, f = 32 (29.6%) agreed, f = 62 (57.4%) strongly agreed. Likewise, f =1 (0.9%) of students strongly disagreed

with the item, *our teachers support us to use 3D printers*, and f = 3 (2.8%) were undecided, whereas f = 27 (25%) agreed and f = 77 (71.3%) strongly agreed. With respect to the item, *my family supports me to use 3D printers,* f = 3 stated that they strongly disagreed, f = 5 (4.6%) disagreed, and f = 15 (13.9%) were undecided, whereas f = 32 (29.6%) agreed and f = 53 (49.1%) strongly agreed. Concerning the item, *working with 3D design programs and 3D printers in SAC makes me willing to produce projects*, f = 2 (1.9%) of students stated that they strongly disagreed, f = 5 (4.6%) disagreed, and f = 4 (3.7%) were undecided, while f = 40 (37%) agreed and f = 57 (52.8%) strongly agreed. Further, regarding the item, *working with 3D design programs and printers may help me select professions like printing technologies/engineering*, f = 5 (4.6%) mentioned that they strongly disagreed, f = 10 (9.3%) disagreed, and f = 24 (22.2%) were undecided; however, f = 39 (36.1%) agreed and f = 30 (27.8%) strongly agreed. Lastly, regarding the item, *when I experience problems regarding the 3D printers in SAC, I get support from my other friends*, f = 3 (2.8%) stated that they strongly disagreed, f = 9 (8.3%) disagreed, and f = 36 (24.1%) were undecided, whereas f = 45 (41.2%) agreed and f = 25 (23.1%) strongly agreed.

Two open-ended questions were added to the questionnaire devised to collect the quantitative data from the students and in this section, they responded to the open-ended questions like "If you want to add more, please write." When the responses were examined, 65% of students suggested increasing the number of printers, 45% suggested renewing the computers, 70% suggested spending more time with the printers and getting more printouts, and so forth.

Qualitative Findings

The qualitative were collected both from students and teachers. The data were analyzed under six themes, namely courses in which 3D Design programs and printers are used, their utilization purposes, their benefits to students, problems experienced in the process, emotions felt when using 3D design programs and printers, and suggestions regarding the design programs and printers. However, the qualitative findings relating to teachers were analyzed under six themes, namely utilization purposes, advantages and disadvantages, problems experienced in the process, the effects of the 3D design programs and printers on students, feelings of teachers, plus views and suggestions.

Findings Relating to the Research Question: What Are the Views of Students Studying at the Science and Art Center on Using 3D Design Programs and 3D Printers?

The following table is presented in the light of the qualitative research findings.

Table 11

Codes, Categories, and Views Relating to the Theme of the Courses in Which 3D Design Programs and Printers are Used

Code	Category	f	Views
Technology design	**Disciplines**	**10**	*"As we have to produce a prototype like technology design that we usually do in our projects, we mostly utilize printers in this area."*
Computer		**2**	**FA[P]:** *"We mostly use them in the technology design course, but we also use them in computer and science courses."*
Science		**3**	**AO[B]:** *"I think it is mostly used in technology design and science courses."*

Concerning this theme, during the interviews students were asked "In which courses are 3D design programs and 3D printers mostly used in SAC?" Considering the views of students regarding this question, all students stated that the 3D design programs and printers were mostly used in technology design courses. As seen in the table, they have stated that 3D printers and design programs were also used in science and information technology courses.

Table 12

Codes, Categories, and Views Relating to the Theme of Utilization Purposes of 3D Design Programs and Printers

Code	Category	f	Views
Getting printouts in projects	For Utilization in Projects	**7**	**ÜO[Ö]:** *"I think they are mostly used in design-oriented areas in projects. We had used them to place the sensors under the ground in our project."* *(Questionnaire – Anonymous) "I use the 3D design programs, especially the TinkerCad, in my projects and this helped me win places in STRCTS competitions in Turkey. I won fourth place in the STRCTS Research Project competitions in Turkey by integrating the 3D design into Turkish."*

Hobby	For Personal Purposes	**3**	**FA^{P}:** *"Generally, I make things like home or hobby products that I should obtain quickly without getting out of home or ordering something and waiting until it arrives and similar things using my home printer."*
Relaxation		**1**	
Individual Needs – Things		**4**	
Getting Private Design Printout		**2**	
Study Material	For Learning Purposes	**1**	**AO^{B}:** *"For example, they say let's create a 3D ecosystem, something tangible, but I can design the thing I want to build first in a 3D environment. Therefore, this will be an advantage for me but we have to put it on paper later but I can do this homework first in the 3D program."*
Education		**4**	
Concretizing the Abstract		**5**	**ÜO^{Ö}:** *"Finally, they can touch and feel the design they have made."*

According to the table regarding the utilization purposes of 3D design programs and printers, the ITR and STD period students stated that they mostly obtain the printouts of apparatuses, products, or designs they are going to use in their projects in their science and information technologies courses. Considering the theme of utilization purposes, half of the students stated that they utilized the 3D printers and design programs for the projects. As regards this theme, codes such as Hobby, Individual Needs – Things, Design Printout, Study Material, Education, Relaxation, and Concretizing the Abstract were extracted and these codes were analyzed under the categories of project purposes, personal purposes, and learning purposes.

Findings Regarding the Theme of Programs Used in Science and Art Center

Table 13

Findings Regarding the Theme of Programs Used in 3D Design Programs and Printers

Code	Category	f	Views
TinkerCad	Design Programs	**10**	**AO^{B}:** *"I saw the TinkerCad. I mean we only saw TinkerCad as 3D design but I also tried the Fusion 360 by myself but I put it away for being a bit difficult.*
Fusion 360		**2**	**UÜ^{P}:** *"For a start, we used the TinkerCad and then we used the Fusion 360."*
Cura		**3**	**UÜ^{P}:** *"There are programs like Cura that we use to adjust the designs to the printer to slice."*

The table related to the question "Which programs do you use for 3D design programs and printers in the Science and Art Center?" is given above. In relation to the theme of programs used in SAC, codes such as TinkerCad, Fusion 360, and Cura were created. The codes were placed under the design programs and slicing program category. All students mentioned that they used the TinkerCad program as a design program. Some students also had seen a higher-level program called Fusion 360. Of project and ITR students, **FA^{P}**, **AO^{B}**, and **ÜO^{Ö}** stated that they also had seen a program called Cura, which allows doing several adjustments to print their 3D design products in the printer. Student remarks regarding the theme are given as examples in the table.

Findings Regarding the Theme of the Effect of 3D Design Programs and 3D Printers on Students

Table 14

Code, Categories, and Views Regarding the Effect of 3D Design Programs and Printers on Students

Code	Category	f	Views
Increase in Course Achievement		**6**	**MA^{B}** *"As I create designs, my desire for achievement also heightens and my achievement increases. I can use some of the designs. For example, it increases my achievement in the technology design course."* **FA^{P}** *"I had helped my classmates understand better by printing it in a 3D form from a 3D printer and showing it to them in the class as if it were an experimental and practical lesson."*
Increase in Project Achievement		**3**	**FA^{P}** *"If there is an advantage of having a 3D printer during the prototype making process, the project will work steadily and look more appealing and visually more glamorous compared to other projects from an external perspective, and this is one of the factors that fetches our project and prototype to the fore."*
	Cognitive		
Enable Remembering		**2**	**UY^{B}** *"Yes, because for example when our part is missing, our success is low but when we have more part, our success is higher."* **FA^{P}** *"Having an advantage of owing something like a 3D printer that can turn what you find challenging to learn like issues we can understand abstractly but cannot fully understand into visible and tangible 3D forms helps you understand your lesson even better and help you understand in an even more memorable way."*
Provide Motivation		**3**	**FA^{P}** *"It pushes me towards a feeling as if I have produced a product and succeeded. This makes me more successful in my subsequent works by motivating me evermore and perhaps helps me achieve what I desire by working more determinedly."*
	Affective		
Increase in Interest towards the course		**3**	**UÜ^{P}** *"But when I was getting its printout, I became more interested."*
Provide on Self-Confidence		**1**	**RL^{B}** *"When I create a design, my self-confidence increases and feel stronger."*
Have Fun – Have a Good Time		**1**	

Considering their views relating to the theme of course achievement under the cognitive and affective categories, students used statements like "my achievement increases", "enables remembering", "my motivation increases", "my interest increases towards the course", and "my self-confidence increases." Students expressed that 3D design programs and printers particularly increase their technology design course achievements. Samples relating to students' views are given in the table.

Findings Regarding How Using 3D Design Programs and 3D Printers Make Students Feel

Table 15

Codes, Categories, and Views Regarding the Theme of How Using 3D Design Programs and 3D Printers Make Students Feel.

Code	Category	f	Views
Enjoyable	**Positive Emotions**	**1**	**UÜP** *"I like doing such things. They are fun and enjoyable."*
Fun		**5**	
Give Happiness		**5**	**MAB** *"It makes me happy and I enjoy and I actually like it very much and I closely watch when one of my friends is getting a printout."*
Pleasant- nice		**4**	
Exciting		**4**	
Arouse Curious		**4**	**RLB** *"I am glad. Also, I think it will influence my career choice in the future."*
Satisfactory		**2**	
Appealing		**1**	
Positive Feelings		**3**	**YUB** *"What is good about it is that it is fun. Opposite to all bad things, I become happy. I mean, I feel positive things."*
Feeling Concerned	**Negative Emotions**	**4**	**UYB** *"We apply glue on it to sit on the floor. If it does not sit on the floor, the design may collapse. There is a concern of whether it will collapse or not."*
Impatience		**1**	

The following code emerged per students' views concerning the theme of how using 3D design programs and 3D printers made students feel under cognitive and affective categories: enjoyable, fun, give happiness, nice, pleasant, exciting, arouse curiosity, satisfactory, appealing, and positive feelings, feeling concerned, and impatience.

Findings Regarding the Advantages and Disadvantages of 3D Design Programs and 3D Printers

Table 16

Codes, Categories, and Views Regarding the Advantages and Disadvantages of 3D Design Programs and 3D Printers

Code	Category	f	Views
Nozzle Clogging	**Mechanical Problems**	**1**	**UÜP** *"Problems occur in mechanical terms. Software problems do not often occur. What I just said are generally problems such as the slipping of the belts, throwing gear or the filament's not melting completely, nozzle clogging, I mean the clogging of the part which melts the filament and ensures that it sticks on the tray."* **UÜP** *"It requires knowledge. I mean it requires technical knowledge."* **FAP** *"There is a material process. Bringing or using its materials is probably the biggest problems I have ever faced because of the development of the sector.* **UÜP** *"There is no design fee. The production cost of the printer is the only fee at start, which is a bit pricy and has no any other big issue."*
Slipping of the Belt		**1**	
Throwing Gear		**1**	
Filament Not Melting		**1**	
Long Printing Time		**3**	
Requiring Technical Knowledge		**1**	
Printer Prices		**1**	
Difficulty of Find Extra Parts		**1**	
Disallowing Detailed Drawing	**Program Deficiencies**	**2**	
Program Learning Duration		**1**	

Two categories of mechanical programs and program deficiencies emerged under the theme of disadvantageous circumstances experienced by students concerning the 3D printers and 3D design programs. Codes relating to these

categories were Nozzle Clogging, Slipping of the Belt, Throwing Gear, Filament Not Melting, Long Printing Time, Requiring Technical Knowledge, Printer Prices, Difficulty of Finding Parts, and Disallowing Detailed Drawing.

Table 17

Codes, Categories, and Views Regarding the Advantages of 3D Design Programs and 3D Printers

Code	Category	f	Views
The Programs Are Free	**Positive Views**	**1**	**UÜP** *"I mean, first and foremost, the 3D design programs enable our solution-oriented thinking. There is a problem before us and how can I apply a solution, and this is what they help us do first."*
Easy to Use Programs		**2**	
Solution-Oriented Thinking		**1**	
Functionality		**4**	

As seen in the table, codes such as "programs are free", "easy to use programs", "solution-oriented thinking", and "functionality" emerged from student statements in the "positive views" category relating to the theme of the advantages of 3D design programs and 3D printers.

Findings Regarding Views and Thoughts of Students on 3D Design Programs and 3D Printers

Table 18

Codes, Categories, and Views Regarding the Theme of Students' Views and Thoughts on 3D Design Programs and 3D Printers

Code	Category	f	Views
Training should be provided in every school	**Suggestions**	**1**	**RLB** *"I mean we are the selected students in our regular schools, but I want the unselected students to see it as well because it is a good application."*
Internet should speed up		**2**	
Every student should receive training		**1**	**AOB** *"It would be better if making animation in TinkerCad is easy because making animation is difficult."*
Animations should be added to the programs		**1**	

Codes like "training should be provided in every school", "internet should speed up", "every student should receive training", and "animations should be added to the programs" were obtained from student statements under the "suggestions" category relating to the theme of students' views and thoughts on 3D design programs and 3D printers.

Findings Regarding the Theme of the Utilization Purposes of 3D Design Programs and 3D Printers

Table 19

Codes, Categories, and Views Regarding the Theme of Teachers' Purposes of Utilizing 3D Design Programs and 3D Printers

Code	Category	f	Views
Getting printouts in projects	**Project**	**3**	**ZZT** *"We use them for drawing in 3D design programs and getting their printouts. I mean, in short, we use them after designing parts that kids will use in their projects to turn them into products."* **RZT** *"They develop solutions for the project problems. When developing these suggestive solutions, we need special products and the kids can design these special products in three-dimensional programs, get the printouts of their designed products from the printer, and use them in their projects."*
Producing hard to-reach material		**1**	**EA[F]** *"The last thing we did was a spectroscopy experiment and there was a material that we were couldn't find. We made it using 3D, without which we would not have been able to make it or we had to tackle with carpenters."*
Preparing for the future	**Personal Development**	**1**	**RZ[T]** *"Fields of occupations relating to industry 4.0 and 3D printing engineering will take shape. I think preparing our children to the future will make a contribution."* **ZZ[T]** *"We support them by explaining the 3D design programs and they make their designs using their imagination and get their printouts from the 3D printer."*
Designing one's own products		**2**	

Per students' views relating to the theme of utilization purposes of 3D design programs and 3D printers shown in the table, codes such as "getting printouts in projects", "printing hard-to-reach materials", "preparing for the future", and "designing one's own products" emerged in the "project" and "personal development" categories.

Findings Regarding Teacher Views on Advantages and Disadvantages of 3D Design Programs and 3D Printers

Table 20

Codes, Categories, and Views Relating to Advantages and Disadvantages of 3D Design Programs and 3D Printers

Code	Category	f	Views
Concretizing the abstract	**Benefits**	**2**	**RZ[T]** *"The TinkerCad program has such an advantage where you can create virtual classrooms. As a teacher, I see the children's designs, and we can also work jointly on that design together with children."* **EA[F]** *"I mean when necessary, we go together with them to their technology design teachers. There are things that we may not know, which we consult with them and I have to say that we do interdisciplinary work together."*
Raising production awareness		**1**	
Saving time		**1**	
Producing hard-to-reach materials		**1**	
Cloud-based working		**1**	
Virtual classroom opportunities		**1**	
Interdisciplinary work		**2**	

As a result of the interviews conducted with teachers, codes such as "concretizing the abstract", "raising the production awareness", "saving time", "producing hard-to-reach materials", "cloud-based working", "virtual classroom opportunities", and "interdisciplinary work" were extracted in the category of "benefit" relating to the theme of advantages of 3D design programs and 3D printers.

Table 21

Codes, Categories, and Views Relating to The Disadvantages of 3D Design Programs and 3D Printers

Code	Category	f	Views
Slow printing	**Limitations**	**2**	**RZ^{T}** *"Sometimes we experience problems of adhesion on the tray or we can experience problems like filament breakage that occurs when fixing the filaments from the back. We can say that these are disadvantages we experience when using the 3D printer."*
Limited printing dimension		**1**	
Single color printing		**1**	
Tray adjustment		**2**	**ZZ^{T}** *"Changing the filament requires specific technical knowledge and preparation. Therefore, we cannot leave students, especially the support group, on their own. When the filament needs to be changed, we help them by providing guidance."*
Slicing issues		**1**	
Time-consuming learning		**1**	
Printer price (expensive)		**1**	**EA^{F}** *"As I said at first, from to time, we may experience problems with respect to the slicing programs in student dimension.*
Few printers		**2**	
Filament clogging		**1**	**RZ^{T}** *"The SAC groups are not very crowded. We can provide more opportunities for printer utilization if printers are procured for every single student."*
Mechanical issues		**1**	**EA^{F}** *"There are problems with what we have at hand like removing it, changing its part, and greasing that part, but if you ask the pros or cons, the pros of course."*
			ZZ^{T} *"Technical adjustments such as fixing the printing floor glitches and the printing tray of 3D printers are important. When these adjustments are not done properly, the printing does not provide good results."*
Internet infrastructure		**1**	**EA^{F}** *"The problem we experience is the low internet speed. A solution should be found as soon as possible."*

As a result of the interviews conducted with teachers, the codes "slow printing", "limited printing dimension", "single color printing", "inability to remove from the tray", slicing issues", "time-consuming learning", "expensive printer prices", "filament clogging", "mechanical issues" and "internet infrastructure" were extracted in the category of "limitations" relating to the theme, disadvantages of 3D design programs and 3D printers.

Findings Regarding Teacher Views on 3D Design and 3D Printing Programs Taught in SAC

Table 22

Codes, Categories, and Views Related to the Theme of 3D Design and 3D Printing Programs Taught in SAC.

Code	Category	f	Views
TinkerCad	**Design**	**3**	**ZZ^{T}** *"We use TinkerCad because it is the easiest, fastest to learn, and the most easily accessible program."*
Fusion 360		**3**	
Cura	**Slicing**	**2**	**RZ^{T}** *"We use the TinkerCad for designing and after TinkerCad we use the Fusion 360."*

Under the theme of 3D design and 3D printing programs taught in SAC and the categories of "design" and "slicing", the programs called "TinkerCad", "Fusion 360", and "Cura" were reportedly used.

Teacher Views on the Effects of 3D Design and 3D Printing Programs Taught in SAC on Students

Table 23

Codes, Categories, and Views Related to the Effects of 3D Design and 3D Printing Programs Taught in SAC on Students

Code	Category	f	Views
Increases achievement	**Instructional**	**2**	**RZ[T]** *"I definitely think that they increase their achievement. When they were doing projects in other branches, for example, when they were working on a theme in the Turkish course, they started using 3D printers. I mean the 3D design and printer entailed such an awareness that after learning this system, the kids actually can integrate what they have learned to other courses as well."*
Facilitates project production		**2**	
Excites		**3**	
Increases their self-efficacy		**2**	
Increases self-confident		**2**	**ZZ[T]** *"They gain a sense of self-efficacy by saying that I can think of a given problem, solve it, design it, and print its product. This of course makes us delighted."*
Increases motivations		**3**	
Thinks differently		**1**	**RZ[T]** *"Students can experience feelings like now I can design and produce this product on my own and handle the software part by myself; they are not difficult as shown on TVs and social media, and I can do it."*

In the "instructional" category of the theme relating to the effects of 3D design and 3D printing programs taught in SAC on students, the codes "increases achievement", "facilitates project production", "excites", "increases their self-efficacy", "increases their self-confidence", "increases motivation", and "thinks differently" were obtained.

Findings Regarding Teacher Views on How 3D Design and 3D Printing Programs Taught in SAC Make Teachers Feel

Table 24

Codes, Categories, and Views Relating to the Theme on How 3D Design and 3D Printing Programs Taught in SAC Make Teachers Feel

Code	Category	f	Views
Satisfaction	**Positive Feelings**	**3**	**EA[F]** *"When things are going well, I would say so glad I have you."*
Motivation		**2**	
Happiness		**3**	**RZ[T]** *"They give a feeling of excitement and together with this excitement a sense of learning increasingly continues in me because it makes you happy when you see kids learn and can do something on their own. At the same time, it motivates me; I mean are we are in mutual communication with students. As they learn something from me, they get more motivated and want to work more and as I see the excitement in them, I want to learn more and more. Therefore, it encourages me to research new technologies."*
Excitement		**3**	
Increased desire for learning		**1**	**ZZ[T]** *"Of course, it makes us delighted when they experience the production chain and show this motivation. After getting a 3D printout, they express and share with us and their friends feel like I can do it, I can design it, and I can succeed. As such, this is a state which increases our motivation as well."*

Codes such as "motivation", "happiness", "excitement", and "increased desire for learning" were obtained in the category of "positive feelings" of the theme related to what 3D design and 3D printing programs taught in SAC make teachers feel.

Discussion and Conclusion

This study was conducted to explore teacher and student views on using 3D design programs and 3D printers. In general, students and teachers stated that 3D design programs and printers are used per their intended purposes, the design programs and printers are highly functional in solving daily life problems, they facilitate many tasks in daily life, and despite having some disadvantages, students and teachers were satisfied with using the printers and learning design programs, as reflected in both the qualitative and quantitative data.

Primarily, students' views on 3D design programs and printers used in SAC were addressed in the study. In the questionnaire administered to the students, attempts were made to understand in which course or courses they mostly used the 3D printers and design programs and for what types of purposes. As per the resultant quantitative finding, students mostly used the design programs and printers in the technology design course and the reason behind it was that they received the 3D design and printer education in this course. In addition, they stated that they also used the printers in information technologies and science courses. The fact that students utilized the printers to print the parts or prototypes of projects they fulfilled in these courses was qualitatively supported by interviews conducted with them. In a study conducted on the effect of designs created by children using the TinkerCad 3D design program on their development process, students stated that they applied their acquired skills in mathematics, geometry, visual arts, and basic science courses (Yüksel, Çetin, & Berikan, 2019). The resultant qualitative and quantitative findings were similar to those in this research. Students utilize the theoretical and practical education they receive in technology and design courses in fulfilling their project ideas in different courses. They expressed that they utilize the design programs and printers, as they provide an opportunity to create prototypes and produce their missing parts in projects like STRCTS and Technofest (https://www.tubitak.gov.tr/en, https://www.teknofest.org/en/). For instance, two students stated that they obtained 3D printouts for a project idea they had developed for the Turkish course and their project became more comprehensible, whereby they won the national award. In a study titled "Preservice Teachers' Views on Using 3D Printers in STEM Applications" by Güleryüz et al. (2019), the preservice teachers defined the 3D printers as a technology of the 21st century skills, which facilitates learning, concretize knowledge, and provides material support in the learning process. Students noted that they used the design programs and printers to print products and print their private designs for hobby purposes and they also used them for instructional purposes to produce learning materials in courses. As students' current semester level in the SAC increases, their utilization purposes also differ. Students who have produced their own printers can design and print a product that they need at home. This result shows that printers are very important tools in terms of raising students' production awareness. The design process could be a significant factor career choices of students, who design products they need both in project development and their daily life, in coming years. In this context, one teacher stated that they also teach printers for future careers and try to raise students' awareness in this regard. The results obtained in the light of the qualitative and quantitative data also support teacher opinions. An interviewed teacher described that printers have become "our saviors" in courses and projects. Likewise, the technology design teachers stated that students often use printers in projects both in their courses as well as in other courses. Particularly, the ITR, STD, and Project students used the design programs and printers for project purposes. From the qualitative data collected one can understand that printers are generally used for their intended purposes, they concretize the abstract and that holding what they have in mind on their hands excites them as well as increases their interest and motivation towards courses and projects. Nemorin and Selwn (2017) also expressed that design processes sometimes can turn into interesting activities for students who are unmotivated and uninterested at the beginning.

In interviews conducted with students and teachers, the contributions of 3D design programs and printers to students were also explored. Per quantitative data collected from students, one could argue that students see the design programs and printers as sources of their motivation. A vast majority of students stated that they improved their creativity, found an opportunity to do joint activities with their friends, entered into the production process with their designs, found an opportunity to work online, gained different perspectives, and became more active in courses in which they used printers. In addition, the products students produce using design programs and printers motivate them towards project production. As a result, the findings suggest that they may contribute to students' development both cognitively and affectively. The results from interviews conducted with students and teachers also support these results. Some students built their own 3D printers and used these printers in schools where they studied and produced

concrete instructional materials related to some subjects they mentioned. For example, one student stated that they encountered challenges when learning the structures of molecules and compounds in the chemistry course but handled these challenges through printers. Supporting this remark of students, Scalfani and Vaid (2014) concluded that 3D printing is a perfect method to manufacture the 3D models of molecules and extended solids. In the interviews conducted, teachers maintained that students' achievements increase, they take on more active roles in project production processes, approach events and facts from different angles, meanwhile, students taking the design course have a higher motivation towards the course, and that their self-confidence and sense of self-efficacy also increase. As appears from all these results, when students use 3D printers and design programs, they contribute to students both cognitively and affectively. Students' integrating what they learn into other courses, their desires to learn new and higher-level design programs according to circumstances could be the indicators of students' self-efficacy and self-confidence development. Students' utilization of design programs in their assignments or projects increases their sense of achievement. The reason for this is that students' designing and printing out concretely their imaginative thoughts and that each of these concrete printouts are materials which could be used in solving many problems may increase both their achievements and their senses of self-confidence. In addition, this could be considered a factor that increases students' self-efficacy levels and motivations. In this regard, Verner and Merksamer (2015) stated that assignments that enable building concrete models and using them in real teaching practices motivate students and improve their information about digital technologies.

The study also included findings regarding the views of students and teachers on the advantages and disadvantages of 3D design programs and 3D printers. Per quantitative data collected from students, 31% of students stated that they were unable to use the printers a lot due to long printing time, whereas 37% were undecided in this regard. Considering the responses, 35% of students did not experience such challenges. The study showed that students experienced problems in finding filament, a material used for 3D printers, and some experienced problems while getting printouts and experienced challenges in the slicing process, which is the last stage of preparation for printing. In addition, one of the issues that students found most problematic was waiting for their turns to print for a long time because of the insufficient number of printers according to the quantitative data. Similar remarks emerged in interviews conducted with students and teachers in this regard. The qualitative findings showed that the problems students experienced were mechanical issues and program deficiencies. Students experienced many problems with the mechanical part of the printers and received support both from their teachers and peers in order to solve them. Nozzle clogging, slipping of the belt, throwing gear, filament-related issues, expensiveness of printers, long printing time, and so forth were among the issues that students mentioned. Teachers also referred to similar issues under the limitations category regarding the disadvantages of printers mentioned by students. In addition to slow printing, tray adjustment, and the insufficient number of printers, teachers reported problems such as limited printing dimension, single-color printing, expensiveness of printers, internet infrastructure issues, mechanical issues, and learning takes time. Per these remarks, the qualitative data support the quantitative data. To conclude, students and teachers experienced problems in using printers and these circumstances had some disadvantages in using printers in education and project processes. However, because of being a technology and having moving parts, the emergence of such problems in printers may sound normal. In order to solve the problems they experience when working with design programs, students in support and ITR period get support from their teachers. Some students did not receive such support during distance education. One could argue that the utilization of printers requires technical knowledge, acquired over time by practice. As such, Nermorin and Selwn (2017) stated that even making a design printable with a basic 3D printer requires significant technical efforts and skills. Demir et al. (2016) noted that individuals expected to have the necessary skills to utilize 3D printer technologies effectively do not yet have the required qualifications to use the software and equipment that comprise the components of 3D printing technologies and that costs are also high. SAC students receive practical education regarding 3D design programs and printers for more than two years, develop projects, and produce the necessary parts in most projects they develop, whereby they attain qualifications related to printing technologies. In this regard, Leinoen et al. (2020) stated that the technical skills of students related to 3D design processes can be developed through assignments and in-depth studies given by their teachers and ensure that students learn about these skills. Students given an opportunity to use technology may be able to develop their technical skills about modeling by using the design programs. Şen et al. (2020) stated that students who use the TinkerCad program and printers gain experience in technology utilization and that students' utilization of information and communication technologies through 3D STEM activities improves their technical skills and engineering design processes.

Students' and teachers' views about the advantages of 3D design programs and printers were amassed under the positive views and benefit categories. The students stated that the design programs are free of charge and that the

TinkerCad program has advantages such as being easy to learn, functionality, and developing different perspectives. Teachers talked about advantages such as facilitating interdisciplinary work, concretizing the abstract circumstances, raising production awareness, producing difficult materials, offering cloud-based working, working in virtual classrooms, and saving time. Considering the quantitative data, a vast majority of students reported that printers and design programs had them acquire different perspectives, they experienced a sense of involvement in the production process, they could concretize abstract issues and contents, online programs provided facilitation, they were motivated, and their creativity developed. All these results show that the quantitative data are supported by the views obtained qualitatively. In a study conducted to unravel the contributive effects of 3D-CAD applications on the creative design of students and examine the differences in 3D-CAD effects on students, Chang et al. (2016) reported that activities conducted with 3D-CAD programs improved students' creative performance. There are also studies in the literature where students have not been able to be deeply involved in the process (Leinonen et al., 2020). As appears from the findings and the literature, 3D technologies have various advantages besides having benefits in students' development.

This research also sought to determine students' and teachers' affective feelings when working with 3D design technologies. What students and teachers felt in this regard was congruent. According to the questionnaire data collected from students, a vast majority of them stated that they were happy, excited, and felt comfortable when working with 3D printers and design programs and did not hesitate to use them, wanted to use them in other courses, and their interest increased and felt themselves adequate. Students stated in the interviews that they were fun, satisfactory, pleasant and nice, exciting, intriguing, delightful, interesting, and gave positive feelings, but some students also mentioned that sometimes they felt concerned and got impatient. It is observed that students experience very different emotions when working with 3D technologies. It appears that most of these emotions are positive, but from time to time they also go through negative emotions such as feeling anxious, worrying, and losing patience. As such, students experience more negative emotions in the printing phase of their designs. Reasons such as the long printing phase and the design not sticking to the printer's tray in the first stage, possible mechanical failure in later stages, and loss of electricity may be factors causing anxiety and impatience in students. Teachers also expressed similar feelings in the interviews. Moreover, teachers noted that positive emotions such as happiness, excitement, motivation, and increased interest in learning developed. Leinonen et al. (2020) stated that students get involved in project processes related to 3D design with the designs they create in digital production activities and practical art lessons using 3D modeling and printing technologies and meanwhile, they feel joyful, happy, and strong. The results obtained in this study are similar to the results of the study by Leinonen et al.

Considering the findings related to the views of teachers and students on the utilization of 3D design programs and printers, in the category of suggestions, students offered opinions and suggestions that the internet speed should increase, 3D technology training should be given in every school, every student should receive training, and animation feature should be added to the programs. In addition, in the opinions and suggestions section inquired at the end of the questionnaire, students had opinions and demands like there should be more printers and computers in more institutions, and there should be printers that print faster. In addition, in the questionnaire, students running projects mentioned about the conveniences they experienced when using printers and design programs in the project processes. According to the results obtained from the resultant findings, 3D technologies play a significant role in developing students' knowledge and skills. It is also understood that students use these technologies quite a lot when creating projects or designing the products of their projects, and this motivates them in the project production process. It also appears that students can print their own course materials to learn abstract subjects if they are given sufficient education and offered an opportunity to practice with these technologies.

Recommendations

In this study, which examined the views of students and teachers about 3D design programs and the use of printers, the following suggestions were presented based on their results.

Recommendations for Applicants

Schools like science and art centers or other schools with learning environments such as application ateliers and design skills ateliers that provide training and teach these technologies to students in cooperation with qualified instructors can be a significant factor in involving students in the production process. 3D technologies facilitate the implementation of the project ideas put forth by students. Therefore, this situation encourages students to present ideas and generate solutions to problems and involves them in the production process. It appears that students

produce products for hobby purposes, produce some parts or models they need in daily life and produce concrete materials in abstract lessons using the experiences they have gained.

In the light of all these results, considering that 3D technologies positively affect students' course achievement, planning lessons with an interdisciplinary focus and using 3D technologies effectively will benefit students.

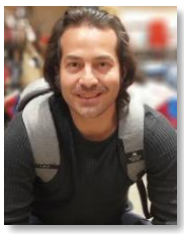
The educators wanting to utilize the 3D printer technologies in their institutions could first determine the purposes upon which they are going to use the printers. These technologies could be included in ateliers and classrooms considering the price and performance balance. They could prepare basic educational programs for their students on issues such as design principles, solid modeling, and 3D drawing by selecting 3D design programs according to students' levels. They could guide students to fulfill their own learning by having them practice printer technologies over time.

Recommendations for the Further Research

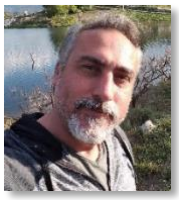
In the light of the results obtained from the research, the following suggestions are presented.

The views of students and teachers in this study could be examined in a qualitative study. Likewise, a quantitative study could be conducted on the effect of 3D design programs and printers on course achievement. This study, conducted on gifted students and SAC, could be conducted in other formal educational institutions.

Biodata of the Authors



Cüneyt Akyol is a science teacher of gifted students. He is a PhD student at Mersin University, Faculty of Education, Curriculum and Instruction Department, Turkey. At the Science and Art Center, he guides gifted children to find solutions to their daily lifeproblems. His research interests include STEM/STEAM education and science education issues. He also works on the integration of robots, 3D technology and sensors into Education. Affilation: Nigde Aksemseddin Science and Art Center, Science Department, Nigde, Turkey. **E-mail**: cakyol51@gmail.com **ORCID**: 0000-0002-8576-6421, **Web Site**: www.cuneytakyol.com



Dr. **Mutlu Uygur** works as a classroom teacher. He graduated from Mersin University, Faculty of Education, Department of Curriculum and Instruction, and received his doctorate. He has studies and academic publications in areas such as the use of technology in education, STEM, quality assurance in higher education, science teaching and teacher training. Affilation: 24 Kasım Primary School, Mersin, Turkey. **E-mail**: mutluygur@gmail.com, **ORCID**: 0000-0002-7756-2576

Prof. Dr. **Tugba Yanpar-Yelken**, works at Mersin University, Educational Sciences Department. She conducts research on program development and technology integration in Education. Affilation: Mersin University, faculty of Education, Department of Educational Sciences, Mersin, Turkey. **E-mail:** tyanpar@gmail.com, tyanpar@mersin.edu.tr, **ORCID**: 0000-0002-0800-4802

References

Akgündüz, D., & Ertepınar, H. (2015). İstanbul Aydın Üniversitesi [Istanbul Aydin University]. Retrieved 0n 20.12.2020 from: https://www.aydin.edu.tr/trtr/akademik/fakulteler/egitim/Documents/STEM%20E%C4%9Fitimi%20T%C3%BCrkiye%20Raporu.pdf

Buhler, A., Gonzalez, S., Bennett, D., & Winick, E. (2015). *3D Printing for Middle School Outreach: A Collaboration between the Science Library and the Society of Women Engineers.* 2015 ASEE Annual Conference and Exposition Proceedings, 26.14.1-26.14.7. https://doi.org/10.18260/p.23353

Büyüköztürk, Ş., Kılıç Çakmak, E., Akgün, Ö. E., Karadeniz, Ş., & Demirel, F. (2016). *Bilimsel Araştırma Yöntemleri [Scientific Research Methods]*. Ankara: Pegem Akademi.

Çepni, S. (2014). *Araştırma ve proje çalışmalarına giriş [An introduction to research and project activities]*. Trabzon: Celepler Matbaacılık

Çetin, E., Berikan, B., & Yüksel, A. O. (2019). 3B tasarim öğrenme deneyiminin süreç değerlendirmesi ve eğitsel çiktilarinin keşfedilmesi [Formative evaluation of 3D design learning experience and discovering the educational outcomes]. *Eğitim Teknolojisi Kuram ve Uygulama*, 9(1), 21-49.

Chang, Y. S., Chien, Y. H., Lin, H. C., Chen, M. Y., & Hsieh, H. H. (2016). Effects of 3D CAD applications on the design creativity of students with different representational abilities. *Computers in Human Behavior*, 65, 107-113.

Chien, Y. H. (2017). Developing a pre-engineering curriculum for 3D printing skills for high school technology education. *Eurasia Journal of Mathematics, Science and Technology Education, 13*(7), 2941-2958.

Chmiliar, l. (2010). *Multiple-case designs*. In A. J. Mills, G. Eurepas & E. Wiebe (Eds.), Encyclopedia of case study research (pp 582-583). USA: SAGE Publications.

Choi, H., & Kim, J. (2018). Implications for activating 3D printer use for education in elementary and secondary schools. *International Journal on Advanced Science, Engineering and Information Technology*, 8(4-2), 1546.

Cingöz, İ. D., & Kavuncu, S. (2019). Craniosynostosis surgery and three- dimensional printing technology. *Journal of eMedical Innovation and Technology*, 1(1), 1-4.

Creswell, J. W. (2007). *Qualitative inquiry & research design: Choosing among five approaches* (2nd ed.). USA: SAGE Publications.

Creswell, J. W. (2009). *Research design: Qualitative, quantitative and mixed methods approaches*. Third Edition, SAGE Publications, Inc.

Creswell, J. W., & Plano Clark, V. L. (2011). *Designing and conducting mixed methods research (2nd ed.)*. Thousand Oaks, CA: Sage.

Demir, K., Kuzu Demir, E. B., Çaka, C., Tuğtekin, U., İslamoğlu, H., & Kuzu, A. (2016). Üç boyutlu yazdırma teknolojilerinin eğitim alanında kullanımı: Türkiyedeki uygulamalar [Using 3D printing technologies in education: Practices in Turkey]. *Ege Eğitim Dergisi*, 2(17), 481-503.

Dickson, B., Weber, J., Kotsopoulos, D., Boyd, T., Jiwani, S., & Roach, B. (2020). The role of productive failure in 3D printing in a middle school setting. *International Journal of Technology and Design Education,* 1-14. https://doi.org/10.1007/s10798-020-09568-z

Doğan, A., & Uluay, G. (2020). Fen Bilgisi Öğretmen Adaylarının 3D Teknolojilerini Öğrenme ve Uygulama Deneyimleri: TinkerCad Örneği. *Trakya Eğitim Dergisi*, 10(3), 980-994. https://doi.org/10.24315/tred.674462

Elo, S., & Kyngäs, H. (2008). The qualitative content analysis process. *Journal of advanced nursing, 62*(1), 107-115.

Fukuyama, M. (2018). *Society 5.0: Aiming for a New Human-Centered Society*. https://www.jef.or.jp/journal/pdf/220th_Special_Article_02.pdf

Güleryüz, H., Dilber, R., & Erdoğan, İ. (2019). STEM uygulamlarında öğretmen adaylarının 3D yzıcı kullanımı hakkındaki görüşleri [Preservice teachers' views on using 3D printers in STEM applications[. *Ağrı İbrahim Çeçen Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, 5(2), 1-8.

Huberman, M., & Miles, M. B. (2002). *The qualitative researcher's companion*. Sage.

Karaduman, H. (2018). Soyuttan somuta sanaldan gerçeğe:öğretmen adaylarının bakış açısı ile üç boyutlu yazıcılar [From abstract to concrete and from virtual to reality: 3D printers from preservice teachers' perspectives]. *Abant İzzet Baysal Üniversitesi Eğitim Fakültesi Dergisi*, 18(1), 273-303.

Kızmazoğlu, C., Altınağ, R. S., Durak, F. O., Coşkun, E., Hüsemoğlu, R. B., İsmail, K. A., et al. (2019). 3D printing assisted upper thoracic vertebra (T1-6) fractures instrumentation. *Journal of Medical Innovation and Technology,* 1(2), 40-44.

Lauri S. & Kynga¨s H. (2005). *Developing Nursing Theories (Finnish: Hoitotieteen Teorian Kehitta¨minen).* Werner So¨derstro¨m, Dark Oy, Vantaa

Leinonen, T., Virnes, M., Hietala, I., & Brinck, J. (2020). 3D Printing in the Wild: Adopting Digital Fabrication in Elementary School Education. *International Journal of Art & Design Education, 39*(3), 600-615.

Ministry of National Education, MEB. (2006). *İlköğretim teknoloji ve tasarım dersi öğretim programı ve kılavuzu [Primary education technology and design course curriculum and guide].*

Merriam, S. B. (1998). *Qualitative research and case study applications in education*. San Francisco: Jossey-Bass Publishers.

Merriam, S. B. (2013). *Nitel araştırma: Desen ve uygulama için bir rehber [Qualitative research: A guide for design and application*] (3. Baskıdan Çeviri, Çeviri Editörü: S. Turan). Ankara: Nobel Yayın Dağıtım

Nemorin, S., & Selwyn, N. (2017). Making the best of it? Exploring the realities of 3D printing in school. *Research Papers in Education, 32*(5), 578-595.

Özsoy, K. (2019). Üç boyutlu yazıcı teknolojisinin eğitimde kullanılabilirliği: Senirkent MYO örneği [Usability of three-dimensional printing technology in education: The case of Senirkent MYO] *Düzce Üniversitesi Bilim ve Teknoloji Dergisi,* 7(2), 111-123.

Scalfani, V. F., & Vaid, T. P. (2014). 3D printed molecules and extended solid models for teaching symmetry and point groups. *Journal of Chemical Education,* 91(8), 1174-1180.

Şen, C., Ay, Z. S., & Kiray, S. A. (2020). A design-oriented STEM activity for students' using and improving their engineering skills: the balance model with 3D printer. *Science Activities, 57*(2), 88-101.

TEDMEM. (2020). Toplum 5.0 insan merkezli toplum [Society 5.0 human-centered society]. Retrieved on 20, 12, 2020 from: https://tedmem.org/download/toplum-5-0-insan-merkezli-toplum?wpdmdl=3362&refresh=5ff35c7ac79461609784442

Verner, I., & Merksamer, A. (2015). Digital design and 3D printing in technology teacher education. *Procedia Cirp, 36*, 182-186.

Yamamoto, T., Hosoda, Y., Satou, M., Ishiko, Y., & Sawadaishi, H. (2018). Proposal for manufacturing learning using a 3D printer in primary education. *日本産業技術教育学会誌 第巻 第号*, 60(4), 201-208.

Yavuz, S., Büyükekşi, C., & Çolakoğlu, Ö. M. (2020). Organik Kimya Dersinde 3 Boyutlu Uygulamaların Öğrencilerin Uzamsal Yeteneklerine Etkis [Effect of 3D Applications in Organic Chemistry Lesson on Students' Spatial Ability]. *Online Fen Eğitimi Dergisi*, *5*(1), 1-8.

Yıldırım, A., & Şimşek, H. (2013). *Sosyal bilimlerde nitel araştırma yöntemle*ri. Ankara: Seçkin Yayıncılık

Yıldırım, A., & Şimşek, H. (2011). S*osyal bilimlerde nitel araştırmaya giriş [An introduction to qualitative research in social sciences] (*8th ed.). Ankara: Seçkin Yayıncılık

Yıldırım, G., Yıldırım, S., & Çelik, E. (2018). Yeni bir bakış 3 boyutlu yazıcılar öğretimsel kullanımı: bir içerik analizi [A new insight – 3D printers and their instructional use: A content analysis]. *Bayburt Eğitim Fakültesi Dergisi*, 13(25), 163-184.

Yıldırım, G., Yıldırım, S., & Çelik, E. (2018). Yeni Bir Bakış—3 Boyutlu Yazıcılar ve Öğretimsel Kullanımı: Bir İçerik Analizi [A new insight – 3D printers and their instructional use: A content analysis]. 13(25), 21.

Yüksel, A. O., Çetin, E., & Berikan, B. (2019). 3D tasarım öğrenme deneyiminin süreç değerlendirmesi ve eğitsel çıktılarının keşfedilmesi [Formative assessment of 3D design learning experience and discovering the educational outcomes]. *Eğitim Teknolojisi Kuram ve Uygulama*, 9(1), 21-49.

Appendix 1

Views about Using 3D Printers as an Educational Tools Questionnaire (English)

Strongly Disagree 1, Disagree 2, Undecided 3, Agree 4, Strongly Agree 5

Views about Using 3D Printers as an Educational Tools Questionnaire					
Items	1	2	3	4	5
Dimension 1. Aim of Usage					
The 3D design programs and printers we use in SAC help me generate different solutions to the problems I face in daily life.					
Activities conducted with 3D design programs and printers we use in SAC increase a sense of curiosity.					
I think the 3D printers are used per their intended purpose.					
I have the opportunity to examine and investigate the outputs I have obtained using 3D programs and printers as tangible and 3D objects.					
Dimension 2. Preparations for Usage					
I would like to take additional courses to feel more prepared for the 3D design programs and printers we use in SAC.					
I come to the course by getting preparation before working with 3D design programs and printers.					
Preparations made before using 3D printers in SAC take most of my time.					
When I have free time, I watch videos about the utilization of 3D design programs and 3D printers.					
Dimension 3. Contributions of the Outcomes					
The 3D design programs' working online helps me to work in collaboration with my friends.					
I take on more active roles in lessons by using 3D design programs and 3D printers in SAC.					
The 3D design programs and 3D printers in SAC develop my creativity.					
I think the 3D design programs and 3D printers in SAC make abstract subjects or content concrete.					
Most 3D design programs' working online (internet connection) provide me facilitations in many issues.					
Using 3D design programs and 3D printers in SAC helps me enter into the production process.					
Using 3D design programs and 3D printers in SAC helps gain different perspectives.					
3D design programs and 3D printers in SAC motivate me more in the lesson.					
The products produced using 3D printers motivate me towards creating projects.					
Dimension 4. Problems Encountered at Using					
I cannot sufficiently use the 3D printers in SAC, as getting printouts from them takes a long time.					
I experience problems in finding filament in my desired colors and properties for the 3D printers in SAC.					
I experience problems while printing out products developed in 3D design programs.					
Carrying 3D printers is difficult for me.					
I experience difficulty when adjusting the print settings in slicing programs before getting printouts from the 3D printers.					
I experience problems in getting printouts because of the small number of 3D printers in SAC.					
Dimension 5 . Emotional Status at Using of 3D Printers					
I refrain from using printers in lessons because of the expensiveness of 3D printers.					
I enjoy printing out the products I design in 3D design programs from the 3D printers.					
Printing out the unique products I design using 3D design programs from printers excites me.					
I prefer using 3D printers in the courses in SAC.					
I feel comfortable when using 3D design programs and 3D printers in SAC.					
I consider myself competent in using 3D design programs and 3D printers in SAC.					
Materials printed using 3D printers increase my interest in the subject.					
Dimension 6. Need for Support at Using of 3D Printers					
The SAC Administration supports us to use 3D printers.					
Our teachers support us to use 3D printers.					
My family supports me to use 3D printers.					
Working with 3D design programs and 3D printers in SAC makes me willing to produce projects.					
Working with 3D design programs and printers may help me select professions like printing technologies/engineering.					
When I experience problems regarding the 3D printers in SAC, I get support from my other friends.					

Thanks

Appendix 2

Views about Using 3D Printers as an Educational Tools Questionnaire (Turkish version)

Hiç Katılmıyorum 1, Katılmıyorum 2, Kararsızım 3, Katılıyorum 4, Kesinlikle Katılıyorum 5

3D Yazıcıların Eğitimsel Bir Araç Olark Kullanımına Yönelik Görüşler Anketi					
Maddeler	1	2	3	4	5
Bölüm 1. Kullanim Amacı					
BİLSEM' de kullandığımız 3D tasarım programları ve yazıcılar, karşılaştığım günlük yaşam problemlerine karşı farklı çözümler üretmemde yardımcıdır.					
BİLSEM' de kullandığımız 3D tasarım programları ve yazıcılar ile yapılan etkinlikler merak duygumu artırır.					
BİLSEM' de 3D yazıcıların amacına göre kullanıldığını düşünüyorum					
3D tasarım programları ve yazıcılar kullanarak elde ettiğim çıktıları somut ve 3 boyutlu nesneler olarak inceleme ve araştırma imkânı bulurum					
Bölüm 2. Kullanım Hazırlıkları					
BİLSEM' de kullandığımız 3D tasarım programları ve yazıcılar konusunda kendimi daha hazır hissetmek için ek dersler almak isterim.					
3D tasarım programları ve yazıcılar ile çalışmadan önce derse hazırlanarak geliyorum.					
BİLSEM' de 3D yazıcı kullanımı öncesi yapılan hazırlıklar çok vaktimi almaktadır.					
Boş zamanlarımda vakit buldukça 3D tasarım programları ve 3D yazıcı kullanımı hakkında videolar izlerim.					
Bölüm 3. Sonuçların Katkısı					
3D tasarım programlarının çevrim içi olarak çalışıyor olması arkadaşlarım ile ortak çalışma yapma imkânı sağlar.					
BİLSEM' de 3D tasarım programları ve 3D yazıcı kullanarak derslerde daha aktif rol alırım.					
BİLSEM' de 3D tasarım programları ve 3D yazıcılar yaratıcılığımı geliştirir.					
BİLSEM' de 3D tasarım programları ve 3D yazıcıların soyut olan konu veya içerikleri somut hale getirdiğini düşünüyorum.					
3D tasarım programlarının çoğunun online (internet bağlantısı) çalışıyor olması bana birçok konuda kolaylık sağlar.					
BİLSEM' de 3D tasarım programları ve 3D yazıcı kullanımı benim üretim sürecine dahil olmamı sağlar.					
BİLSEM' de 3D tasarım programları ve 3D yazıcı kullanımı bana farklı bakış açıları kazandırır.					
BİLSEM' de 3D Tasarım programları ve 3D yazıcılar derse daha çok motive olmamı sağlar.					
3D yazıcılar kullanılarak üretilen ürünler beni proje üretme konusunda motive eder.					
Bölüm 4. Kullanımda Karşılaşılan Sorunlar					
BİLSEM' de 3D yazıcılardan baskı almak uzun sürdüğü için 3D yazıcıları yeteri kadar kullanamıyorum.					
BİLSEM' de 3D yazıcılar için istediğim renkte ve özellikte flament bulmakta sorunlar yaşıyorum.					
3D tasarım programlarında ortaya çıkan ürünleri yazıcıdan baskı alırken sorunlar yaşıyorum.					
3D yazıcıları taşımanın zor olması beni zorlayan durumlardandır.					
3D yazıcıdan baskı almadan önce dilimleme programlarında baskı ayarı yaparken zorluk yaşıyorum.					
BİLSEM' de 3D yazıcı sayısının az olması nedeni ile baskı almada sorunlar yaşıyorum.					
Bölüm 5. 3D Yazıcı Kullanımında Duygusal Durum					
3D Yazıcılar pahalı olduğu için derslerde yazıcıyı kullanmaktan Çekiniyorum.					
3D tasarım programlarında tasarladığım ürünleri 3D yazıcılardan baskı alırken eğleniyorum					
3D tasarım programları ile özgün ürünler tasarladığımda yazıcıdan baskı almak beni heyecanlandırır.					
BİLSEM' de derslerimde 3D yazıcı kullanmayı tercih ederim					
BİLSEM' de 3D tasarım programları ve 3D yazıcı kullanırken kendimi rahat hissederim.					
BİLSEM' de 3D tasarım programları ve 3D yazıcılar konusunda kendimi yeterli görüyorum.					
3D yazıcı ile basılmış materyaller benim konuya olan ilgimi artırır.					
Bölüm 6. 3D Yazıcı Kullanımında Destek İhtiyacı					
31. BİLSEM Yönetimi bizi 3D yazıcı kullanmamız konusunda destekler.					
32. Öğretmenlerimiz 3D yazıcı kullanmak konusunda bizlere destek veriyor.					
33. Ailem 3D yazıcı kullanmam konusunda beni destekler.					
34. BİLSEM' de 3D tasarım programları ve 3D yazıcılar ile çalışmalar yapmak beni proje üretme konusunda istekli hale getiriyor					
35. 3D tasarım programları ve yazıcılar ile çalışmam baskı teknolojileri/mühendislik gibi meslekleri seçmem için destek olabilir.					
36. BİLSEM' de 3D yazıcılar ile ilgili sorunlar yaşadığımda diğer arkadaşlarımdan destek alıyorum.					

Teşekkürler

Appendix 3

Interview Form for Teachers (Turkish Version)

Görüşme Formu-Öğretmen
Demografik Sorular
Lisans derecesi ile mezun olduğunuz bölüm nedir? Ya da branşınız nedir?
Mesleğinizde kaçıncı yılı çalışıyorsunuz?
BİLSEM' de kaç yıldır görev yapıyorsunuz?
3D tasarım ve 3D yazıcılar ile ilgili katıldığınız hizmet içi eğitim kurslar nelerdir?
Görüşme Soruları
1- Bilim ve sanat merkezlerinde (BİLSEM) 3D tasarım programlarını ve 3D yazıcıları hangi amaçla kullanmaktasınız?
2- BİLSEM 'de verilen derslerde 3D tasarım programlarını ve 3D yazıcıları kullanmak ne gibi avantajlar ve sınırlıklara neden olmaktadır
3- BİLSEM 'de 3D tasarım programlarını ve 3D yazıcıları 3D Tasarım programlarını kullanma konusunda öğrenciler ile veya teknik konularda sorunlar yaşıyor musunuz? bu sorunları çözmek için neler yapıyorsunuz?
4- 3D tasarım programları ve 3D Yazıcıların bilsem destek, BYF, ÖYG ve Proje öğrencilerinin başarı ve motivasyonlarına etkisi hakkında neler düşünüyorsunuz?
5- 3D tasarım programları ve 3D yazıcıları kullanılarak işlenen bir dersin, BİLSEM destek, BYF, ÖYG ve Proje öğrencileri üzerinde ne gibi etkileri bulunmaktadır? (başarı, öz-yeterlik, motivasyon vb.)
6- Derslerde 3D tasarım programları 3D yazıcı kullanmak size neler hissettiriyor?
7- 3D tasarım programları ve 3D yazıcıların BİLSEM Derslerinde kullanımına ilişkin eklemek istediğiniz görüş ve düşünceleriniz varsa açıklayabilir misiniz?

Appendix 4

Questions Asked in Interviews with Teachers (English)

Interview Form- Teacher
Demographic Questions
What department did you graduate from?
What year are you working in your profession?
How many years have you been working at SAC?
What are the in-service training courses you attend about 3D design and 3D printers?
Interview Questions
1- For what purpose do you use 3D design programs and 3D printers in science and art centers (SAC)?
2-What are the advantages and limitations of using 3D design programs and 3D printers in the courses given at SAC?
3- Do you have problems with students or technical issues in using 3D design programs and 3D printers at SAC? What are you doing to solve these problems?
4- What do you think about the effects of 3D design programs and 3D Printers on the success and motivation of support, ITR, STD and Project students?
5- What kind of effects does a course taught using 3D design programs and 3D printers have on BİLSEM support, ITR, STD and Proje students? (Achievement, self-efficacy, motivation, etc.)
6- How does it make you feel to use 3D design programs and 3D printers in lessons?
7- If you have any opinions and thoughts about the use of 3D design programs and 3D printers in SAC Courses, could you explain them?

Thanks

Appendix 5

Questions Asked in Interviews with Students (Turkish Version)

Görüşme Formu-Öğrenci
Demografik Sorular
En son devam ettiğin program nedir?
Devam ettiğin okul türü nedir?
BİLSEM' de kaç yıldır öğrenim görüyorsun?
Görüşme Soruları
1- Bilim ve Sanat Merkezlerinde (BİLSEM) 3D tasarım programları ve 3D yazıcılar daha çok hangi derslerde kullanılıyor?
2- BİLSEM' de 3D tasarım programlarını ve 3D yazıcıları hangi amaçla kullanmaktasınız?
3- BİLSEM 'de derslerde 3D tasarım programları ve 3D yazıcılar kullanılması ile ilgili neler düşünüyorsunuz? Neden bu şekilde düşünüyorsunuz?
4- BİLSEM' de kullanılan 3D tasarım programları ve 3D yazıcıların ders başarınıza etkisi konusunda neler düşünüyorsunuz?
5- BİLSEM' de derslerde 3D tasarım programları ve 3D yazıcı kullanmak size neler hissettiriyor?
6- 3D tasarım programları ve 3D yazıcıların kullanımına ilişkin eklemek istediğiniz görüş ve düşünceleriniz varsa açıklayabilir misiniz?

Teşekkürler

Appendix 6

Questions Asked in Interviews with Students (English)

Interview Form-Student
Demographic Questions
What is the last program you attended?
What type of school do you attend?
How many years have you been studying at SAC?
Interview Questions
1- In which courses are 3D design programs and 3D printers mostly used in Science and Art Centers (SAC)?
2- For what purpose do you use 3D design programs and 3D printers at SAC?
3- What do you think about the use of 3D design programs and 3D printers in the lessons at SAC? Why do you think this way?
4- What do you think about the effect of 3D design programs and 3D printers used in SAC on your course success?
5- How does it make you feel to use 3D design programs and 3D printers in lessons at SAC?
6- If you have any comments or thoughts about the use of 3D design programs and 3D printers, can you explain them?

Thanks