Journal of Turkish Science Education, 2022, *19*(3), 887-910.
DOI no: 10.36681/tused.2022.155

The Effects of Activities Designed with Three-Dimensional Printing Technology on Science Education

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**This study has been derived from the first author's master's thesis. Quantitative part of the research was presented orally in the VIth International Eurasian Educational Research Congress, June 19-22, 2019, Ankara University, Ankara, Turkey, and qualitative part of the research was presented orally in the 28th International Conference on Educational Sciences, April 25-28, 2019, Ankara, Turkey.*

ABSTRACT
The aim of this study is to investigate the effectiveness of the activities designed with 3D printing technology on the teaching of the sixth-grade systems in our body unit and to determine the views of students on this technology. In this study, a mixed research design in which quantitative and qualitative research methods are used together was preferred. A total of 60 sixth grade students participated in the study. The study was carried out for 6 weeks and within the scope of a science lesson. During the study, lessons in the experimental group were processed using the activities developed with 3D printing technology in addition to the current curriculum while lessons in the control group were processed using the 2018 Science Curriculum. Data were then analyzed using the SPSS statistics program and descriptive analysis. The findings of the study revealed that there was a significant difference between the post-test mean scores for academic achievement in the experimental and control groups. It can be said that the activities developed with the 3D printing technology used in the teaching of the subjects in the experimental group after the application increased the academic achievement compared to the teaching in the control group where the current program was used. The results obtained from the qualitative findings of the research also support these quantitative results. It is recommended to use more 3D printing technology in science education.

RESEARCH ARTICLE

ARTICLE INFORMATION
Received:
01.10.2021
Accepted:
14.02.2022

KEYWORDS:
Academic achievement, science teaching, sixth-grade students, 3D printing technology.

To cite this article: Avinal, M. & Aydın, A. (2022). The effects of activities designed with three-dimensional printing technology on science education. *Journal of Turkish Science Education*, *19*(3), 887-910.

Introduction

Many methods and techniques are used in science education. In order for students to benefit most effectively in science lessons, learning environments should appeal to many sense organs and mental functions. In other words, students cannot benefit from science education at a sufficient level just by reading or seeing (watching) (Dewaters & Powers, 2006). The primary goals of the lesson include understanding the basic concepts by students, transferring the learned information to daily life, and replacing the wrongly shaped concepts with scientific truths in the minds of the students.

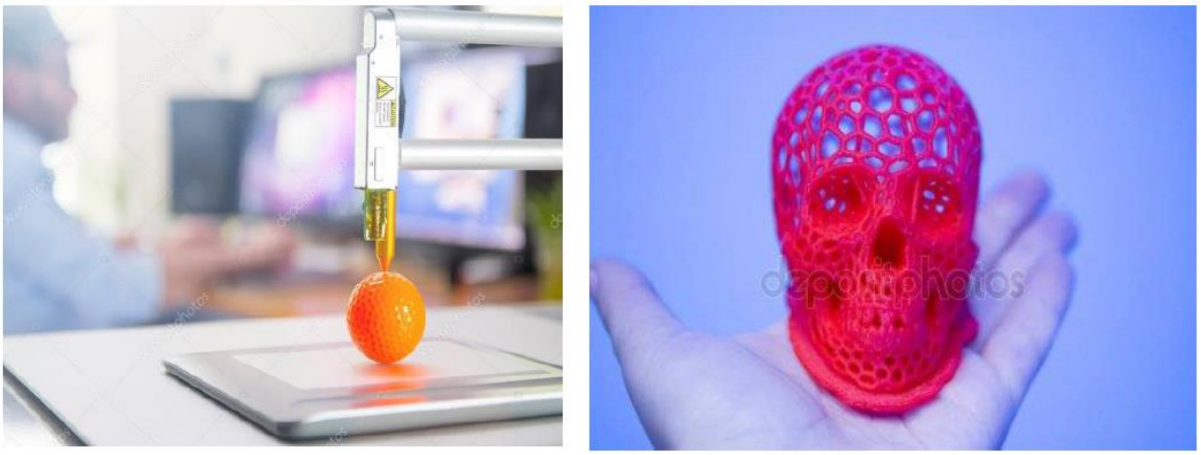
In today's world when technological innovations are integrated into education very quickly, many studies are carried out to determine the educational potential of different technologies. One of

these technologies is 3D printing technology. 3D printers are used in the production of many educational materials, tools and it also has a wide range in the industrial sector. The production of letter envelopes, bottle cap production, vehicle engine production, decorative article production, and the ability to produce everything astronauts need in space can be shown as examples (Hagel et al., 2015). Especially in areas where models and modeling are in the center, 3D printers are widely preferred compared to other solutions. This preference stems from the fact that they offer people the opportunity to activate their imagination and turn it into a product.

The production of motor vehicle parts, the creation of architectural products, the production of surgical materials, the production of prostheses, the convenience of the fashion and clothing industry, the development of materials used in the food industry, toy making, and the production of robotic materials are among these productions (Akpek, 2018). Models produced with 3D printing technology are shown in Figure 1.

Figure 1

A ball and Skull Model Prepared in a 3D Printer



Note: URL-1, 2019

In some reports that direct the studies in the literature and enable the determination of current trends, it is emphasized that 3D printing and printing technologies will become widespread in the upcoming years and that the studies carried out in this field will increase day by day (Johnson et al., 2013; Yıldırım et al., 2018). 3D printing technology is being used in four main pedagogical environments within the education system in which 3D printing is being used: (1) schools; (2) universities; (3) libraries; and (4) special education settings (Arvanitidi et al., 2019; Ford & Minshall, 2019).

The 3D printing technology with prototype design can provide the basis for improving understanding of science and mathematics (Bull et al., 2014). The printing technology is used to support STEM education in schools. The international literature cites 3D applications at universities that have to do with the creation of 3D printer systems, scientific models, and test models. It is also used during project-based learning, in the introduction to 3D printing technology development curricula by integrating it into existing lessons or by creating new lessons. In particular, 3D printing technology can be used to create test models for experiments. This also includes test specimens for learning the mechanical properties of materials (Ford & Minshall, 2019). In the international literature, it seems that the use of 3D printing technology in school libraries, universities, vocational colleges, public libraries, medical libraries, and libraries, in general, is positive. 3D printing technology is used in special education environments for those with visual, motor, and cognitive disorders, kinetic and cognitive impairments, along with combinations of the previous ones. The use of 3D printing technology involves the creation of customized devices and training aids that provide greater

participation of these students in STEM objects. The use of the 3D printer in special educational environments is not without its challenges as described in various studies. Students' interest in finalizing designs with a 3D printer seems to be diminishing due to the challenge of using the software. In addition, three-dimensional design capability is difficult for students with high support needs. Several professional therapists who worked with students in some research while delighted with the potential of 3D printing technology were worried about the effort needed to learn how to use the software (Buehler et al., 2014; Ford & Minshall, 2019; Kane & Bigham, 2014).

There are six main ways in which 3D printing technology is being used: (1) to teach students about 3D printing; (2) to teach educators about 3D printing technology; (3) as a support technology during teaching; (4) to produce artifacts that aid learning; (5) to create assistive technologies; and (6) to support outreach activities (Arvanitidi et al., 2019; Ford & Minshall, 2019).

However, the costs of the technology in question are high, the employment of qualified teachers who can use and transfer this technology is not sufficient, only having pedagogical content knowledge and professional knowledge are not sufficient, as well as not having software, coding, robotics knowledge and advanced computer literacy are disadvantages for this technology (Corlu & Aydin, 2016). However, these disadvantages have largely been eliminated and continue to be eliminated day by day, largely as a result of state support and own efforts of private schools (Daugherty, 2009).

3D printers are tools that free the imagination of people and provide the opportunity to produce anything that they imagine through software knowledge (Erdogan et al., 2013). Students can design and develop materials and print them in 3D in order to have more detailed and permanent information while working on a subject. Nowadays, 3D printing technology is actively used in science education in many countries of the world, and software education is taught to students starting from a very young age.

In today's world where technology is developing rapidly, information also shows a constant change. 3D printing technology is one of the technologies that make our lives easier and is becoming more and more widespread today (Kuzu-Demir et al., 2016). With the effective use of this technology in the educational environment, different experiences can be experienced in many different fields. For example, thanks to 3D printing technology, which have many application examples such as printing organ models in science lessons, especially in biology, it is easier to explain difficult concepts to students, attract their attention and ensure their participation in the lesson more effectively, and in-class interaction can be easier. In this way, it is possible for students to be prepared for their careers and to gain valuable skills for the future (Kökhan & Özcan, 2018).

A limited number of studies have been conducted on 3D printing technology in the field of education. In these studies; middle school students (Gürel-Taşkıran, 2019; Küçüksolak, 2019), prospective teachers (Güleryüz et al., 2019; 2020; Karagöz & Şahin-Çakır, 2020), high school students (Küçüksolak , 2019), preschool children (Yüksel, 2015) were studied. When the studies made with 3D printing technology in science education are examined in the literature; determination of science teacher candidates' opinions about 3D printers (Karagöz & Şahin-Çakır, 2020), 3D printing technology in education and some examples of 3D printer technology materials applied in chemistry education (Topçuoğlu et al, 2021), the effects of 3D printer and robotic coding applications on 21st-century learning skills, STEM awareness and STEM teacher self-efficiency of preservice teachers (Güleryüz, 2020), pre-service science teachers' learning and implementation experiences with 3D Technologies (Doğan & Uluay, 2020), an overview of the 3D solid model studies such as design and usage needs of physics, chemistry, and biology teachers (Aslan et al., 2021) were found. It is thought that this research, in which both the academic achievements of the students and their views about the activities made using 3D printing technology, will contribute to the literature.

The Aim of the Study

In this study, activities designed with 3D printing technology were used and it was aimed to examine the change in students' academic achievement on science and their views about this teaching process. Within the scope of this study, the following research questions were investigated:

1. Is there a significant difference between the post-test academic achievement scores of the experimental and control groups students after the application?
2. Is there a significant difference between the pre-test and post-test academic achievement scores of the control group students before and after the application?
3. Is there a significant difference between the pre-test and post-test academic achievement scores of the experimental group students before and after the application?
4. What are the views of the students in the experimental group about the application?

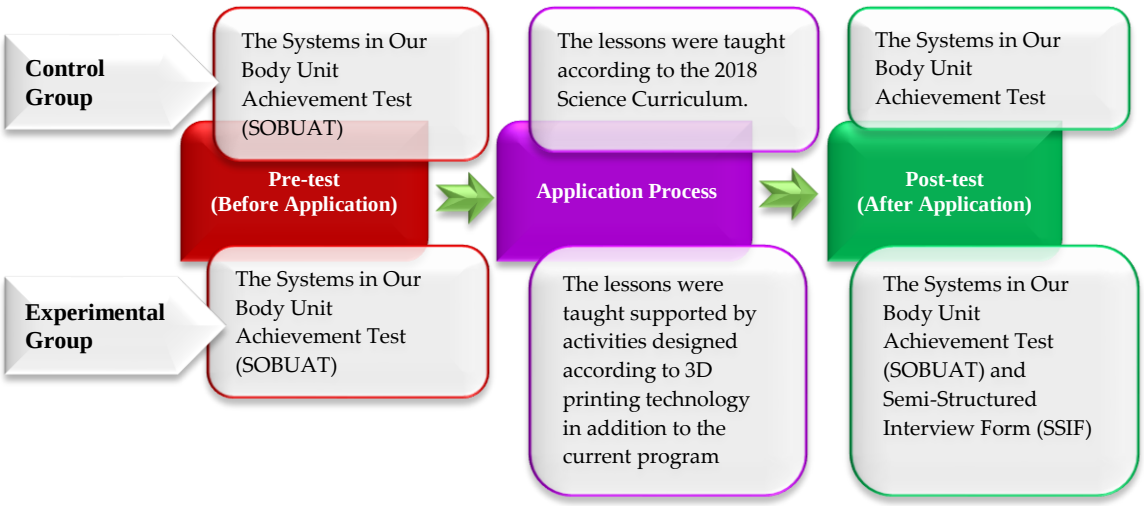
Method

Research Design

In this study, a mixed research design in which quantitative and qualitative research methods are used together was preferred. Onwuegbuzie & Leech (2004) stated in their study that the purpose of the mixed research design is to broaden a person's understanding of the event rather than validating or supporting an idea in many cases. In this research design, quantitative data are collected as the first step and then qualitative data are collected to detail and explain these collected quantitative data as the second step (Cresswell, 2008). In the study, a quasi-experimental model with a pre-test post-test control group was used to examine the effect of 3D printing technology-supported activities used in teaching the 6th grade the Systems in Our Body Unit (SOBU) on students' academic achievement on science lessons. Also, the case study method was used to collect students' views. The case study is an in-depth description and examination of this limited system with detailed information (Creswell, 2008) obtained using multiple information sources (Merriam & Grenier, 2019). In other words, case study is defined as a longitudinal approach that explains the current situation or examines and analyzes the communication between the factors affecting change and development in depth and shows the development in the process (Best & Kahn, 2017). In research, quantitative data were collected with the Systems in Our Body Unit Achievement Test (SOBUAT) and qualitative data were collected with the Semi-Structured Interview Form (SSIF). The experimental model of the research is given in Figure 2.

Figure 2

The Experimental Design Used in the Stud



Study Group

The research was conducted with sixth-grade students studying at a public secondary school located in Kastamonu Province, Turkey in the first semester of the 2018-2019 academic years. According to the pre-test results of the SOBUAT, 60 students in 6-A and 6-B branches with close academic achievement status constituted the study group. From these branches, 6-A (N=30) was randomly determined as the control group and 6-B (N=30) as the experimental group. Of the students that make up the study group, 32 are female and 28 are male. 46.7% of the students in the control group are female while 53.3% of them are male, and in the experimental group, 60% of them are female while 40% of them are male.

Data Collection Tools

Systems in Our Body Unit Achievement Test (SOBUAT)

A multiple-choice achievement test consisting of 22 questions and four answer options was developed by the researchers in order to determine the effect of the lessons supported by the activities developed with 3D printing technology on the students' academic achievement. Initially, a question pool consisting of 40 items was created. In the creation of these questions, the learning outcomes of SOBU were examined and an achievement test was created by considering these outcomes. In this unit, it is aimed that students gain knowledge and skills related to the structures and organs of support and movement, digestive, circulatory, respiratory, and excretory systems (MoNE, 2018).

The data obtained as a result of the preliminary applications were examined with the SPSS program, and after determining the item difficulty and item discrimination values, the items in question were presented to expert views once more and took their final form. Both content validity and face validity of the achievement test developed in this way were ensured (McMillan & Schumacher, 2006). In order to perform the reliability study of the achievement test, it was applied to 200 seventh-grade students, who were studying in secondary schools in Kastamonu Province, Turkey, and were not included in the study group, and the Cronbach's Alpha value was found as 0.83; thus, the SOBUAT consisting of 22 questions was decided to use as the final test.

Semi-Structured Interview Form (SSIF)

In this study, SSIF was used to determine the views of students on the activities designed with 3D printing technology. SSIF is one of the frequently preferred data collection tools in qualitative studies (Çepni, 2014). This form, which provides a lot of convenience and flexibility to the researcher, is more useful than other interview forms. Because the researcher may want to intervene in the process from time to time and direct the study accordingly (Yıldırım & Şimşek, 2018). SSIF was conducted in order to support the quantitative data collected and to identify views of the students on 3D printing technology and developed activities. The students participating in the interviews were determined on a voluntary basis and it was accepted that they were sincere in their answers. While selecting the students, their achievement test post-test mean scores were taken into account and this form was applied to a total of 9 students, three of whom had low-medium-upper score averages. 10 questions were initially prepared but in line with the suggestions of experts and teachers, necessary arrangements were made in terms of time and comprehensibility of the questions, and it was decided to be reduced to six questions.

Application Process

In this study, the application process (teaching of the lessons) is discussed under two different headings. Firstly, the teaching of the students in the control group was discussed in general, and then the teaching of the students in the experimental group was discussed for six weeks.

Teaching in the Control Group

In quantitative studies and especially in studies where quasi-experimental designs (pre-test, post-test with control group) are preferred, two different student groups with similar traits are first determined to examine the effectiveness of the teaching methods or approaches, and one of them is defined as the control and the other as the experimental group (Çokluk et al., 2014). The control group is usually the group in which standard procedures are performed and no differences are made. In these groups, subjects are taught in a standard manner depending on the curriculum. In this study, the process was similarly continued. In the branch designated as the control group for six weeks, the systems in our unit subjects were taught by the course teacher to the students within the framework of certain plans following the 2018 Science Curriculum. Unit subjects were taught to the students by using the textbook as the source with interactive activities and experiments when necessary. However, no other intervention was made as in the experimental group. The lessons in the control group were taught by the teacher.

Teaching in the Experimental Group

In the experimental group, as in the control group, the subjects of the SOBU were taught by the researchers in the framework of certain plans following the 2018 Science Curriculum. However, unlike the control group, activities developed with 3D printing technology were used for each learning outcome while teaching the subjects, and the activities carried out each week are shown below:

First Week Teaching in the Experimental Group

Before starting to teach the subjects in the first lessons of the first week, necessary information about 3D printing technology, information on how to produce the materials and activities, and extensive information about the applications to be carried out for six weeks were provided by the researchers. Moreover, the subjects of the SOBU were mentioned and the importance of using models

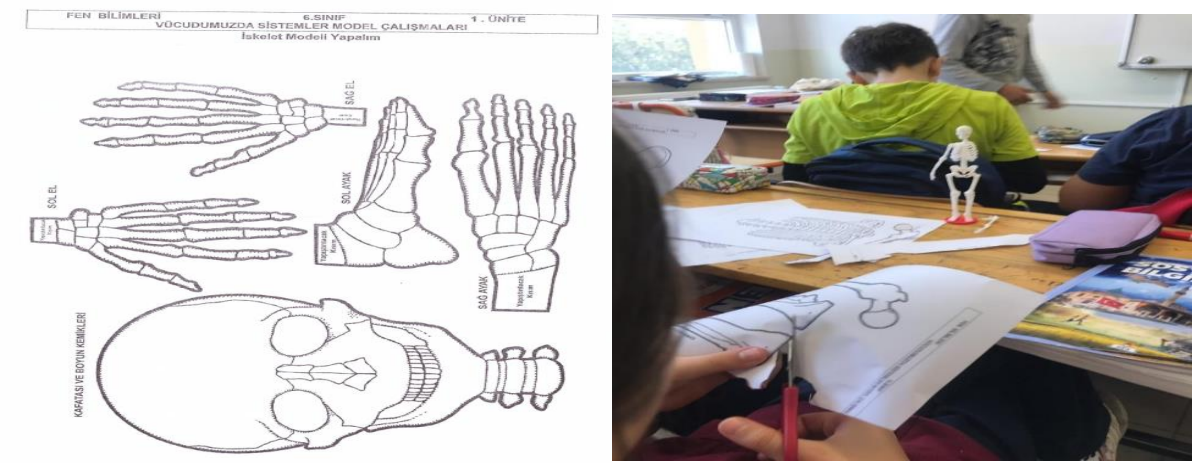
in teaching these subjects was emphasized. It was mentioned that before these models were produced with 3D printing technology, students were asked to make their own designs on each subject and then those designs would be turned into a concrete model with 3D printing technology and activities would be continued as a group. In the next lesson, students were occasionally divided into groups of three or five according to the subjects and their activities were planned accordingly.

Second Week Teaching in the Experimental Group

The subject that was taught to the students in the second week was *"support and movement system"*. In this subject, the concepts of cartilage, bone and bone types, joint and joint types, muscles and muscle types were taught to the students. While these subjects were taught according to the curriculum, activities were planned as shown in Figure 3 by using 3D printing technology for support purposes. The groups were formed and worksheets related to the subject were given to each group while teaching these subjects.

Figure 3

Skeleton Model Building Worksheet



As shown in Figure 3, the students made their own designs by cutting the shapes on these worksheets. Later, these designs were transformed into a concrete model shown in Figure 4 using 3D printing technology.

Figure 4

Hand, Skeleton, and Bone Models Developed with 3D Printing Technology

As seen in Figure 4, the designs of the students were turned into a concrete model with the help of 3D printing technology and they continued to learn the relevant unit subjects through these models.

Third Week Teaching in the Experimental Group

The subject that was taught to the students in the third week was the *"digestive system"*. The content of this subject is as follows; the structures and organs that form the digestive system, physical (mechanical) and chemical digestion, enzymes, liver, pancreas, the digestive functions of the liver and pancreas. In teaching these subjects, students participated in activities in groups. As in the previous activity, students were given a worksheet on these subjects (Figure 5) and they were asked to make their own designs. The students in the groups first created their own designs by cutting and gluing the pictures on the worksheet provided, and then they continued to learn their subjects by seeing the concrete models of their designs with the help of 3D printing technology (Figure 6).

Figure 5

Digestive System Organs Worksheet

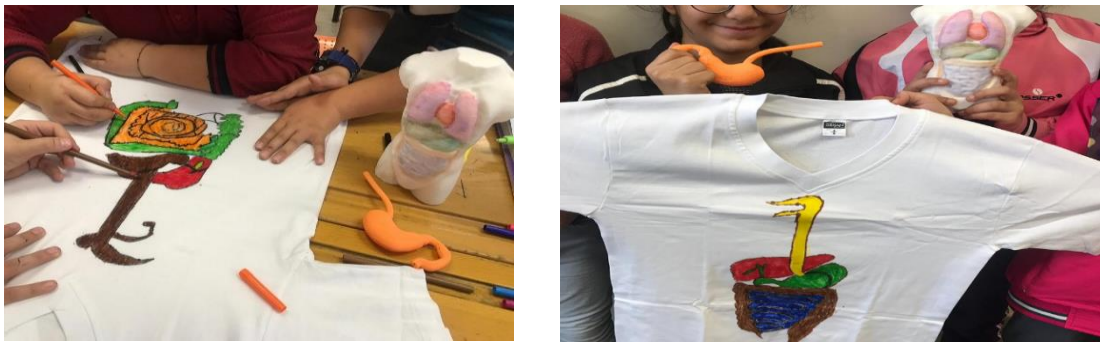
Figure 6

Models Developed with 3D Printing Technology

Furthermore, during the learning of the subjects of this week, the students made a t-shirt painting activity as shown in Figure 7, using the design they prepared themselves.

Figure 7

T-shirt Painting Activity

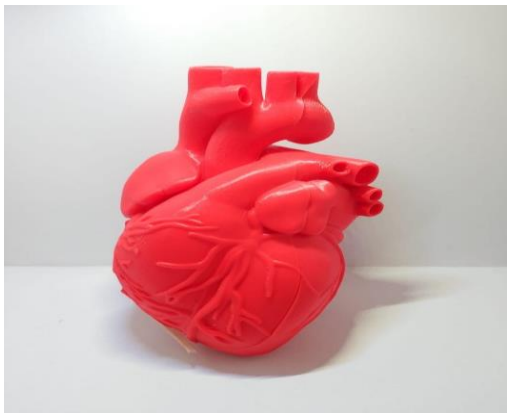


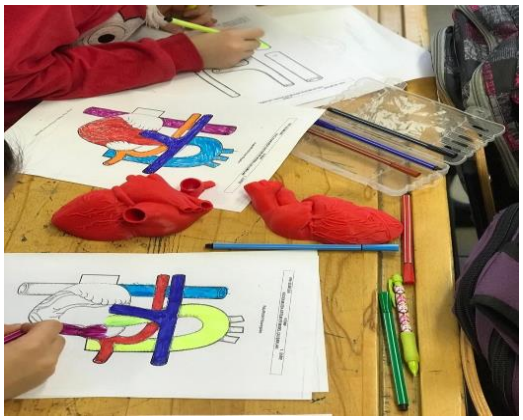
Fourth Week Teaching in the Experimental Group

The subject of the fourth week was the *"circulatory system"*. The content of this subject is as follows: the structures and organs that form the circulatory system, the structure and function of the heart, blood vessels, systemic circulation and microcirculation, blood groups, blood donation, and the circulatory system. In teaching these subjects, as in the previous weeks, worksheets were distributed to the students in groups and they were allowed to make their own designs by using the pictures on this sheet (Figure 8).

Figure 8

A Model Developed with Circulatory System Organs Worksheet and 3D Printing Technology





As shown in Figure 8, these designs prepared by the students were turned into a concrete model with 3D printing technology and the relevant unit subjects were explained using this model.

Fifth Week Teaching in the Experimental Group

The subject of the fifth week was *"respiratory system"*. The content of this subject is as follows: the structures and organs that form the respiratory system and the lungs. In teaching these subjects, the students were divided into groups, and the worksheet shown in Figure 9 was distributed to them by the researchers. The students made their own designs using this worksheet, and later this design was turned into a concrete model with 3D printing technology (Figure 10).

Figure 9

Respiratory System Worksheet

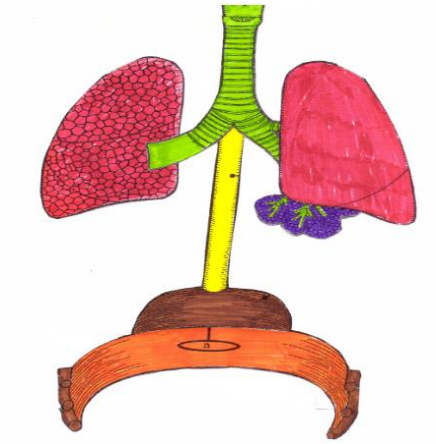
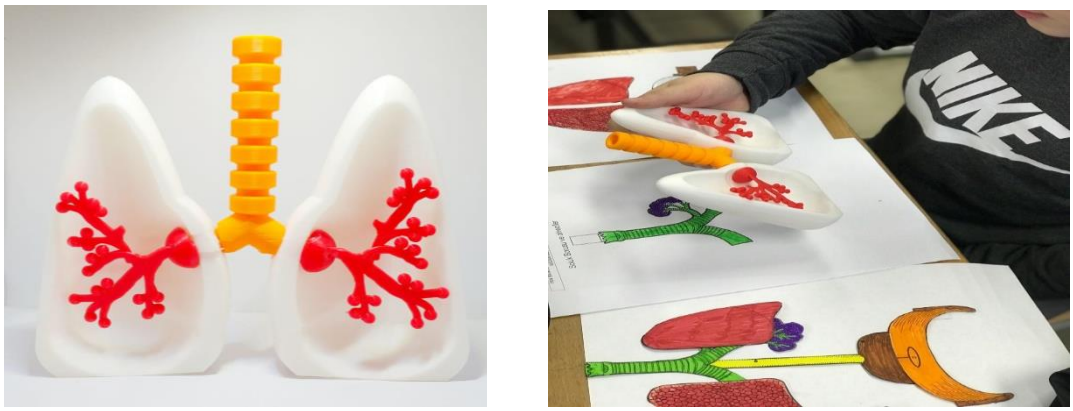


Figure 10

Models Developed with 3D Printing Technology



This model, shown in Figure 10, was used while teaching the relevant subjects of that week.

Sixth Week Teaching in the Experimental Group

The subject of the sixth week was *"excretory system"*. The content of this subject is as follows; excretion, kidneys, skin, lungs, and large intestine. In teaching these subjects, the worksheet shown in Figure 11 was provided to the students who were divided into groups and they were asked to make their own designs on those subjects by using the pictures on the sheet. The designs that students made using the worksheet were turned into concrete models shown in Figure 12 with the help of 3D printing technology. The students learned the relevant subjects by using these models.

Figure 11

Excretory System Worksheet

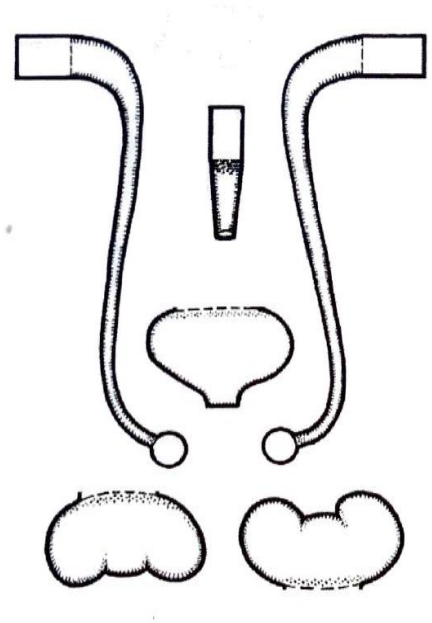


Figure 12

Models Developed with 3D Printing Technology

Analysis of the Data

Analysis of the Data Obtained from SOBUAT

The data obtained by quantitative data collection tools in the study were analyzed with the SPSS statistics program. The obtained data was examined whether they had a normal distribution before deciding which tests to use. In this study, a normality test was performed to determine whether the data obtained from SOBUAT were suitable for normal distribution, and the test results of the Shapiro-Wilk test (Shapiro & Wilk, 1965) were evaluated since the sample size was smaller than 35, and the data obtained are shown in Table 1.

Table 1

The Normality Test Results of the Data Obtained from SOBUAT

SOBUAT	*Group*	*N*	*p*
Pre-test	Experimental	30	.217
	Control	30	.154
Post-test	Experimental	30	.423
	Control	30	.102

Note: p> .05

In Table 1, according to both pre-test and post-test data for the achievement test, it was determined that the data showed a normal distribution due to *p*> .05 and parametric tests were used in the next steps. Before starting the research, it was examined whether there is a significant difference between the pre-test academic achievement scores of the experimental and control group students before the application and the data obtained are shown in Table 2.

Table 2

T-test Results of Experimental and Control Groups in SOBUAT Before the Application

Group	*N*	$\bar{X}$	*SS*	*SD*	*t*	*p*
Experimental	30	52.27	9.53	58	.56	.580
Control	30	50.93	9.67			

Note: p> .05

According to Table 2, there was no significant difference between the pre-test mean scores for academic achievement in the experimental and control groups (t = .56; *p*> .05). Before the application, it was observed that the preliminary knowledge of the students on the systems of our body unit in the experimental and control groups were close to each other and the difference was not statistically significant.

Analysis of the Data Obtained from (SSIF)

The data obtained from the SSIF were subjected to descriptive analysis and coded separately by two people, one of whom was the researcher. In descriptive analysis, the data obtained are classified, summarized and interpreted according to predetermined themes. A cause-effect relationship is established between the findings of the research and comparisons are made between the cases when necessary (Yıldırım & Şimşek, 2018). Each question in the SSIF was considered as a theme. As a result of the coding, similarities and differences were revealed and the obtained interview data became more meaningful. The proportion of agreement was calculated to determine the reliability between coders. In the calculation of this value, the following formula of agreement proportion of Miles & Huberman (1994) was used:

$$Percentage\ of\ Consistency\ (P) = \frac{Na\ (Consensus)}{Na\ (Consensus) + Nd\ (Dissensus)}\ X\ 100$$

As stated in the literature, intra-and/or intercoder agreement should be the 85% and above (Miles et al., 2020). According to the formula above, the agreement between the coders was found as 89%. The result indicates that it is reliable to evaluate the questionnaire using different coders.

Ethical Statement of the Study

As authors of the research, we declare that the study has no unethical problem and we observed research and publication ethics. Ethical principles and rules were followed during the planning, data collection, analysis and reporting of the research. Before starting the study, the necessary permission was obtained from the Kastamonu Provincial Directorate of National Education for the school to be researched, with the letter dated 22.10.2018 and numbered E.19959921.

Findings

In this section, the quantitative and qualitative data obtained from experimental and control groups were analyzed.

Findings Related to the Quantitative Data

Findings Concerning the First Research Question of the Study

The first research question of study was expressed as "is there a significant difference between the post-test academic achievement scores of the experimental and control groups students after the application?". The independent sample t-test was used to analyse the data obtained from experimental and control groups for this research question. Descriptive statistics of the data are shown in Table 3.

Table 3

Post-test Results of Experimental and Control Groups in SOBUAT

Group	*N*	$\bar{X}$	*SS*	*SD*	*t*	*p*
Experimental	30	67.01	14.70	58	2.96	.000
Control	30	55.96	23.72			

Note: p< .05

According to Table 3, there was a significant difference between the post-test mean scores for academic achievement in the experimental and control groups (t=2.96; *p*< .05). It can be said that the activities developed with the 3D printing technology used in the teaching of the subjects in the experimental group after the application increased the academic achievement compared to the teaching in the control group where the current program was used.

Findings Concerning the Second Research Question of the Study

The second research question of study was expressed as "is there a significant difference between the pre-test and post-test academic achievement scores of the control group students before and after the application?". The dependent sample t-test was used to analyze the data obtained from the control group for this research question. Descriptive statistics of the data are shown in Table 4.

Table 4

Pre-test Post-test Results of Control Group in SOBUAT

SOBUAT	*N*	$\bar{X}$	*SS*	*SD*	*t*	*p*
Pre-test	30	50.93	9.67	58	2.23	.003
Post-test	30	55.96	23.72			

Note: p< .05

According to Table 4, there was a significant difference between the mean scores of the achievement test before and after the application in the control group (t=2.23; *p*< .05). It was observed that the current curriculum applied in the control group also contributed positively to academic achievement.

Findings Concerning the Third Research Question of the Study

The third research question of study was expressed as "is there a significant difference between the pre-test and post-test academic achievement scores of the experimental group students before and after the application?". The dependent sample t-test was used to analyze the data obtained

from the experimental group for this research question. Descriptive statistics of the data are shown in Table 5.

Table 5

Pre-test post-test results of the experimental group in SOBUAT

SOBUAT	*N*	$\bar{X}$	*SS*	*SD*	*t*	*p*
Pre-test	30	52.27	9.53	58	2.21	.004
Post-test	30	67.01	14.70			

Note: p< .05

According to Table 5, there was a significant difference between the mean scores of the achievement test obtained before and after the application in the experimental group, which was supported with activities developed with 3D printing technology (t=2.21; *p*< .05). According to this result, it was observed that the activities developed with the 3D printing technology used in the teaching of the SOBU made a positive contribution to the academic achievement of the students.

Findings Related to the Qualitative Data

Findings Concerning the Fourth Research Question of the Study

The fourth research question of study was expressed as "what are the views of the students in the experimental group about the application?". In order to find an answer to the fourth research question, the answers given to the SSIF by the students as well as the codes of these answers are shown in Tables 6-11.

It was asked to the students in the first question that *"have you been satisfied with the lessons taught with the activities designed with 3D printing technology?"*. The theme and codes of the students' answers to this question are shown in Table 6.

Table 6

Student Views on Teaching with the Designed Activities

Theme	*Code*	*Student*	*f*
Satisfaction with activities designed with 3D printing technology	*Very satisfied*	L1, L2, L3, M1, M2, M3, U1, U2, U3	9
	So much fun	M3, U1, U2	3
	Very good to be colorful	L1, U1	2
	Helps with focusing	L1, U2	2
	Lifelike	U1, U3	2

Note: U: Upper achievement student, M: Middle achievement student, L: Lower achievement student

According to Table 6, all of the students participating in the SSIF said *"I was very satisfied"*. 2 students with both low achievement and upper achievement scores said, *"it was very good to be colorful"*. This situation shows that in general, the students participating in the interview are very satisfied with the lessons taught with the activities developed with 3D printing technology.

It was asked to the students in the second question that *"are there any activities that you like and feel different from the activities that you did while learning the subjects? if yes, what are they?"*. The theme and codes of the students' answers to this question are shown in Table 7.

Table 7

Student Views on Activities Designed and Liked

Theme	*Code*	*Student*	*f*
Activities designed with 3D printing technology and liked by the students	*T-shirt painting*	L1, L3, M3, U1, U2	5
	Building a skeleton	L2	1
	Building a heart, lungs, and intestines	M2	1
	Hand model	U3	1

According to Table 7, 5 students participating in the interview stated that they liked *"t-shirt painting"*, 1 student *"skeleton building"*, 1 student *"heart, lung and intestine building"* and one student *"hand model"*. This situation shows that students are more interested in activities in which they actively participate and use their psychomotor manual skills.

It was asked to the students in the third question that *"were there any activities that disliked among the activities that you did while learning the subjects or that seemed boring to you? if yes, what are they?"*. The theme and codes of the students' answers to this question are shown in Table 8.

Table 8

Student Views on the Disliked Activities among the Designed Activities

Theme	*Code*	*Student*	*f*
Activities designed with 3D printing technology and disliked by the students	*No boring activity, all of them were good*	L1, L2, L3, M1, M2, M3, U1, U2	8
	The white skeleton model is weak and small	U3	1
	Not boring as I imagined, drew and painted	U2	1

According to Table 8, the majority of the students (8 students) who participated in the interview stated that *"there was no boring activity, all of them were good"*. This situation shows that the students are not bored with the activities performed while learning the relevant unit subjects and there are almost no activities that are disliked.

It was asked to the students in the fourth question *"have you learned something new during the lessons taught with activities designed with 3D printing technology?"*. The theme and codes of the students' answers to this question are shown in Table 9.

Table 9

Student Views on the Use of the Designed Activities in the Lessons

Theme	*Code*	*Student*	*f*
The contribution of activities designed with 3D printing technology to learning new information	*Learning new knowledge*	L1, L2, L3, M1, M2, M3, U2, U3	8
	A better understanding of the structure of the larynx and respiratory system (mouth and nose junction, alveoli, bronchi)	L1, L2, L3, U1, U3	5
	A better understanding of the shapes of the organs	L2, L3, U1, U2, U3	5
	Learning that systems are simpler	L2, M1, U3	3
	Not being able to imagine the heart model, understanding it better	L3, M1, U1	3
	Learning the features of the digestive system better	M3, U2	2

According to Table 9, most of the students (8 students) stated that *"I learned new information"*. 3 students stated that *"I could not imagine the heart model in my mind, I understood better"*. This situation shows that the students have the opportunity to understand the relevant unit subjects better and in-depth as a result of the activities.

It was asked to the students in the fifth question that *"What are the problems that you encountered while studying with activities designed with 3D printing technology?"*. The theme and codes of the students' answers to this question are shown in Table 10.

Table 10

Student Views on the Problems Encountered while Using the Designed Activities in Lessons

Theme	*Code*	*Student*	*f*
Problems encountered in lessons taught with activities designed with 3D printing technology	*No problem*	L1, L2, L3, U1, U3	5
	Some problems but understood better thanks to the activities	L2, L3, M3	3
	Poor quality of some items / materials used inside the printers	M2	1
	Difficulty in understanding some systems before the activity	M3	1
	The heart model is colorless and differently colored vessels	U2	1

According to Table 10, more than half of the students used the expression *"no problem"* regarding the use of the activities developed with 3D printing technology in their lessons. This indicates that the students did not encounter any problems during the activities and that the activities were well designed.

It was asked to the students in the sixth question that *"do learning environments related to activities designed with 3D printing technology have any superiority over current learning environments?"*. The theme and codes of the students' answers to this question are shown in Table 11.

Table 11

Student Views on Comparing the Designed Activities with the Current Learning Environment

Theme	*Code*	*Student*	*f*
The superiority of the activities designed with 3D printing technology over the current learning environment	*Causing to be more interested in the lesson*	L3, M1, M2, M3, H1, H2, H3	7
	Better understanding of organs that are hard to perceive	L1, L3, M1, H2	4
	A better visualization	L3, M1, H2	3
	Not taking time	M3, H1	2
	Having new ideas	H1, H3	2
	Better due to application	L2	1
	Color makes it easier to understand	L1	1

According to Table 11, the majority of the students (7 students) stated that *"it made me more interested"*. Moreover, there is 1 student who stated that *"it was better for me to understand because it was colored"* and *"it was better because we performed"*. This situation shows that the use of activities by the students developed with 3D printing technology in their lessons is more effective than in current learning environments. Sample expressions from the answers given by the students to the semi-structured interview questions are shown in Table 12.

Table 12

Sample Expressions from the Answers Given by the Students to the Interview Questions

Student	*Sample expression*
L1	*"Actually, I did not like science before. Because I was getting low grades. Then I started solving tests. In 20-question tests, I sometimes got 2, 3, or 5, 6 mistakes. But when I did these activities, I understood better, but I still got a low grade. Then I started to love science. I started participating in lessons".*
M1	*"I was very happy when I was doing activities in science with teamwork, that is, with my friends. Because I had a good time with my friends and these activities contributed to my in-class performances. I also liked Merve teacher. I had a good time with her".*
U2	*"Only the heart was not colored. The veins could have been more colored, but still, all the activities were impressive without any problems".*

Discussion

The 3D printing technology has been found to affect on academic achievement and 6th-grade students' views on the activities designed with 3D printing technology as well as on their knowledge about support and movement system, digestive system, circulatory system, respiratory system, excretory system of the SOBU. When the achievement test results of the SOBU were examined, it was found that there were no statistically significant differences between the mean scores of the academic achievement pre-test of the experimental and control groups and the students in the experimental group and the control group had similar mean scores before the application. Thus, this is accepted as a desired and expected situation in the literature.

After the application, it was determined that there was a statistically significant difference between the academic achievement post-test scores in favor of the experimental group. Accordingly, the 3D printing technology-based instruction in the experimental group increased the academic achievement of the students. This can be interpreted to a great extent as the fact that the 3D printing

technology-based instruction enables students to gain active participation in the lesson, conduct group activities, make comments, discuss and produce projects and develop their conceptual understanding. When the related literature was reviewed, Burkaz (2012) examined the use of 3D models in science and technology teaching in a constructivist learning environment and found that the achievement test results of the students in the experimental group differed significantly. The study of Çoklar & Çekirge (2020), it was aimed to examine the effect of using physical materials in addition to 3D digital materials on academic achievement, attitude, and motivation by focusing on 3D printers. The research was conducted with a total of thirty-five 7th grade students. As a result of the research, it was found that the academic achievement was higher in the group where physical materials were shown to the students in the next week in addition to digital materials. In their study, Çopur & Türkdoğan (2021) investigated the effect of the worksheet designed in harmony with the 3D printer pen on the learning of the subject of solid objects. There were 12, tenth grade, students in the study. As a result, it was found that the use of worksheets compatible with 3D printing pens in education was positively effective. It is seen that the worksheets and the materials created with the 3D printing pen enable the students to discover and understand the subject.

In the control group, there was a significant difference between the academic achievement pre-test and post-test score in favor of the post-test. Accordingly, the current curriculum in the control group increased the academic achievement of the students. In the experimental group, there was a significant difference between the academic achievement pre-test and post-test score in favor of the post-test as in the control group. In both groups, it was found that the learning occurred at the end of the application for both groups, but the academic achievement of the experimental group was higher than the academic achievement of the control group. The average academic achievement scores of the students in the experimental group, in which teaching supported by activities designed with 3D printing technology, increased by approximately 15.00 points compared to the pre-test while the average academic achievement scores of the control group students, who were taught according to the curriculum, increased by approximately 5.00 points compared to the pre-test.

It was also stated in this study that the use of 3D models is very useful in concretizing and realizing the ideas of the students. It was observed that this result and the results of similar studies conducted in the literature (Çapar, 2006; Çoklar & Çekirge, 2020; Çopur & Türkdoğan, 2021; Eryiğit, 2010; Paul et al., 2014; Telli, 2009) support the results obtained from this study. In these studies, in the literature, it was observed that the academic achievements of the students in the experimental group differed significantly in favor of the experimental group students compared to the academic achievements of the students in the control group.

As a result of the themes and coding, it was observed that the students were very satisfied with the lessons taught with the activities designed with 3D printing technology, their expectations increased positively, they did not get bored, did not get distracted during the activities, and they showed great desire and effort to participate in the activities. Furthermore, the students stated that they could more easily understand the micro-level shapes and structures that they could not imagine with the help of materials produced by 3D printers and that these materials were effective in learning the subjects. It was determined that the students did not encounter many negative situations and problems due to the high level of focus in the lessons, which were taught using models obtained from 3D printers, and following the process closely. Jo et al. (2016) interviewed four students and stated that 3D printers make it easier for students to remember and understand, and bring liveliness and fun to the classroom. They further mentioned that this printing technology directly visualizes the image in minds of the students, improves their attention, increases memorability, and provides concentration throughout the lesson. However, they stated that this technology may have limitations in terms of cost, design difficulty, production, and durability. In another study conducted by Saorin et al. (2017), 15 high school students were interviewed. As a result of these interviews, 3D printing technology enabled students to work better and increased their interest in sculpture architecture and achievement rates. In similar studies in the literature, Doğan & Uluay (2020) stated in their study that the pre-service teachers stated that they did not have any difficulties while they were using the

Tinkercad and said that the software was applicable in science classes. They also determined that they would use the program in their classes in their future professional lives. Çopur & Türkdoğan (2021) stated in their study that the worksheets and the materials created with the 3D printing pen enable the students to discover and understand the subject. In another study in the literature, Karagöz & Şahin-Çakır (2020) aimed to get the views of science teacher candidates about 3D printers. They stated in their study, science teacher candidates stated that 3D printers are costly, the infrastructure and technological inadequacy in schools, there are few educated people to use this technology.

In recent years, an important area of use of 3D printing technology has become education. Today, 3D printing applications can be found in many different fields, from micro systems such as cells and microorganisms to macro systems such as the earth and space, from concepts and phenomena that are impossible or difficult to observe with the human eye, to teaching multi-component structures such as human anatomy, DNA helix or atomic model (Bardakcı et al., 2018; Emre et al., 2015; Karaduman, 2017; Lipson & Kurman, 2013a; 2013b; Özgüven, 2015; Petrick & Simpson, 2013). The interaction between the educator and the student will increase even more with the increase in the widespread use of this technology thanks to the decreasing investment costs and it will be easier for students to gain creativity and innovative thinking skills by transforming what they envision into tangible objects (Kökhan & Özcan, 2018). When the studies (Aslan et al., 2021; Çoklar & Çekirge, 2020; Çopur & Türkdoğan, 2021; Doğan & Uluay, 2020; Karagöz & Şahin-Çakır, 2020; Topçuoğlu et al., 2021) in the literature in recent years are examined, it has been determined that 3D printing technology is increasingly used in education. It is stated in the literature that the use of 3D printers in educational environments may have positive effects. In this context, it is thought that 3D printers can be effective in students to develop concrete learning experiences, creative thinking skills and to learn while having fun (Eisenberg, 2013; Yıldırım et al., 2018).

Conclusions and Implications

Especially in group work, about the use of the activities developed with 3D printing technology by the experimental group students in every subject of the unit from the first week; harmony, communication, cooperation, responsibility, event design, etc. The subjects were observed and evaluated by the researchers. The students in the experimental group were quite irregular and uninterested in the practices in the first weeks, but in the second and third weeks of the practice, the students started to participate in the activities and adapted to working as a team was observed. As students get busy with activities and become acquainted with 3D printing technology, their attendance and love of the lesson have increased. These results are an indication that students' interest in the lesson, working in harmony, knowing their responsibilities, evaluating the process and increasing their skills. The reason for this may be that the 3D printing technology is remarkable by the experimental group students.

By making use of the academic achievement post-test scores of the experimental group students, 3 students were selected from among the students with low average achievement, medium achievement average, and high achievement average, and semi-structured interviews were conducted with 9 students in total on a voluntary basis. According to the results obtained, the students are very satisfied with the activities designed with 3D printing technology and their expectations have increased positively, they take an active part in the activities, they produce as a result of a certain effort and they assimilate these activities in a remarkable way, they are not bored during the activities designed with the help of 3D printers, they are not distracted much, and they try to provide a great desire and participation in the activities, they feel that they understand the shapes and structures at the micro-level or that they cannot visualize more easily with the help of materials produced with 3D printers and that these materials are effective in learning the subjects. In the lessons taught on the basis of 3D printing technology, the students do not encounter many negative situations and problems due to the high level of focus and close follow-up of the process, 3D printers affect students in many ways, improve their curiosity and motivation positively, help them to be interested and

actively participate in the lesson, and provide them with a great advantage compared to the current teaching method. The results obtained from the qualitative findings of the research also support these quantitative results.

As observed in this study, the 3D printing technology-based instructions increased the academic achievement of students in the experimental group and made a positive contribution to their views on the 3D printing technology and its applications. Therefore, it is important to use defensible technologies such as 3D printing technology that consists of visualization and concretization of knowledge.

Suggestions

In this study, the 3D printing technology-based instruction was observed to have a positive effect on students' academic achievements and their views on the activities designed with 3D printing technology in the unit of systems in our body unit. As the number of research increases, an idea can be formed concerning the common impact of this technology. The effects of 3D printing technology-based instruction can be investigated at different grade levels, such as pre-school and primary school.

More different and up-to-date lesson activities can be developed using 3D printing technology. The number of teachers who have received training on material production using 3D printing technology in schools can be increased. Information and materials regarding the use of 3D printers can be included in the Education Information Network (EBA). A printing room can be established in schools where 3D printers can be used.

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