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Abstract

In this study, 3D design products of pre-service science teachers were evaluated, and the opinions of the candidates regarding the 3D design process and the design products they created were investigated. This study is a case study of qualitative research designs. The research was carried out with 48 pre-service science teachers studying as sophomores at the education faculty of a university in Turkey. The research was carried out in the course named General Biology Practices II in 7 weeks as three classes per week. As data collection tools in the research, a interview form was used to obtain the opinions of pre-service teachers and rubrics prepared in line with the criteria that should be found in 3D designs and the design process. As a result of the research, it was found that pre-service teachers had a sufficient performance, and created good designs while establishing 3D design products. Candidates gave a positive opinion regarding the 3D design process. In particular, they stated that the implementation process helped the improvement of 3D thinking ability, thereby gaining different perspectives. They also stated that 3D design products created could be used as teaching materials.

Introduction

Rapid developments in science and technology affect each other and create a versatile change. In line with these changes, individuals are expected to exhibit certain behavior and possess some skills. One of these skills, called 21st century skills, is that individuals become literate of information and technology (Partnership for 21st Century Skills, 2020). For this reason, in recent years, technology-supported studies are included in educational environments to raise individuals who can meet the needs of the era and use new technological tools (Cetin, 2020; Heinecke et al., 2001; Parlak, 2017; Wang & Hannafin, 2005).

The use of new technological tools in educational environments is increasing in line with the development of technology. With the development of computer, internet and mobile technologies, many new technological application tools are used in educational environments (Karademir, 2018). One of the education tools that draw attention in recent years is the three dimensional (3D) design tools. These tools, which are seen as the technology of the future, include 3D virtual environments, 3D modelling, virtual laboratories, simulations and virtual objects (Arici, 2013; Kayabasi, 2005; Schecker, 1993; Snir, Smith & Grosslight, 1993; Topuz & Ozdener, 2018). In these virtual tools, students find the opportunity to visualize scientific phenomena by gaining experience with individuals or groups (Rufer-Bach, 2009). Also, these tools offer both teachers and students new ways of different classroom experiences (McGahern, Bosch & Poli, 2015). So much so that while these environments are seen by students as a tool to demonstrate their performance, they are perceived by teachers as a supplementary and facilitating educational tool (Gunersel & Fleming, 2013).

Many studies in the literature show that applications with 3D design tools are used in different educational fields such as chemistry, geology, clothing design, biology and physics, mathematics as well as geometry (Copolo & Hounshell, 1995; Gardner & Olson, 2016; Kostakis, Niaros & Giotitsas, 2015; Lazarowitz & Naim, 2013; Meng, Mok & Jin, 2012; Scheucher et al., 2009; Robertson & Jorgensen, 2015; Wu, Xu & Zou 2005; Yarema et al., 2010). Among these areas, biology subjects are perceived more difficult by students because they contain more abstract concepts (Alparslan, Tekkaya & Geban, 2003; Gul, Ozay-Kose & Konu, 2014; Ozay & Oztas, 2003). Especially in teaching biology subjects, 3D technological tools are used to embody the concepts. Accordingly, studies such as the project of visualizing molecules based on inquiry in 3D protein structure and function analysis (Terrell & Listenberger, 2017), visualization of 3D interactive images of protein structures (Berry & Board, 2014), visualization of molecules with mobile devices (Lam & Siu, 2017), 3D computer simulation-based teaching on cell division (Elangovan & Ismail, 2014), bioinformatics-based training process for understanding the structure of proteins and nucleic acids molecules (Stasinakis & Nicolaou, 2017), examination of human skeletal muscle cells as 3D (Bagley & Galpin, 2015), and the creation of concrete models of basic biological concepts through 3D prints draw attention (Davenport et al., 2014).

3D design applications allow making 3D models, obtaining moving images of the model and viewing the model by rotating it around an axis (Isik, Isik & Guler, 2008). One of the most important features of these applications is that it provides a learning experience by providing reality for situations that are difficult to learn and observe in real life (Bricken & Byrne, 1993; Dalgarno & Lee, 2010; Firat, 2008; Franceschi-Diaz, 2009). In addition, the technological tools used in these applications affect the achievements, interests and motivations of students and constitute learning objects used to support and enrich educational environments (Macromedia, 2004; Wiley, 2002; Turel, 2008). It is important to use learning objects such as computer-aided model, animation and simulation applications in order to enable students to structure their mind more easily around abstract and difficult-to-grasp concepts in order to keep the student active in the learning process (Bulut, 2004; Demirci, 2003; Moyer, 2001; Tasti, Yucel & Yalcinalp, 2015). In this context, it is noteworthy that students create learning objects in their own learning environments, that is, the use of technological tools that they can make their own design products online. One of the commonly used tools is Tinkercad (Oosthuizen & Uys, 2013).

In education environments, Tinkercad design software is used especially in courses such as mathematics and geometry (Ching, Basham & Planfetti, 2005). The Tinkercad software is a web-based program designed to create 3D design products. Since Tinkercad works as a browser, it is a useful tool for making designs over the internet without the need to install on the computer (Griffey, 2014). In addition, this tool provides students the opportunity to create more complex structured objects, starting with the creation of simple objects. In particular, this tool is an innovative practice in terms of contributing to the reasoning of the individual by developing the competencies in the field of education and involving many discipline (Goyanes et al., 2016). With this aspect, it supports STEM education by enabling the combination of technology, design, mathematics and science (Bender, 2017).

One of the educational approaches that support the use of technological tools in educational environments is STEM (science, mathematics, engineering and mathematics) education (Bybee, 2010; Gonzalez & Kuenzi, 2012; Sahin, Ayar & Adiguzel, 2014). Within the scope of STEM education, science, mathematics and technology knowledge are used to find solutions to engineering problems (Daugherty, 2009; Gulhan & Sahin, 2016). Because design, innovation, and problem-solving skills lay the foundation of STEM education (Hernandez et. al., 2014). In this education, in which many disciplines come together in line with a common goal, individuals can learn the information in a holistic and meaningful way by linking their experiences with daily life (Gencer, 2015; Bozkurt-Altan, Yamak & Bulus-Kirikkaya, 2016). In particular, it enables students to design, analyse and interpret data, construct data with experiments, and combine them with everyday life (Wang, 2012). In STEM education, 3D design technologies can be easily used as a tool to provide these skills and behaviours to students (Brown, 2015; Kwon, 2017).

Despite the fact that there are new technological developments day by day, there are limited studies on the usability of 3D design tools that bring different disciplines together in educational activities (Karaduman, 2017). In order to use 3D design technologies more widely in the field of education, it is necessary to reveal the expectations of individuals as well as their effects on individuals (Demir et al., 2016). In particular, determining what type of products pre-service teachers produce in these technologies is important in terms of revealing the usability of these technologies in educational environments. As part of this study, Tinkercad design tool was used, and it provided pre-service teachers the opportunity to use technology, science, mathematics and design together. With these tools, it was aimed to enable the pre-service teachers to become aware of their capabilities in 3D virtual environments, to raise awareness of new technological tools, and to provide application experience in virtual environments. In this study, 3D design products of pre-service science teachers were evaluated, and the opinions of these teachers regarding the 3D design process and the design products they created were investigated. In this regard, answers to the following sub-problems were sought:

- What level are 3D design products created by pre-service teachers?
- What are the pre-service teachers' views on the 3D design process?
- What are the opinions of the pre-service teachers towards 3D design products?

Method

Research Model

This study conducted with pre-service science teachers is a case study of qualitative research designs. Within the scope of the study, it is a holistic single case study design, since only the data of the pre-service teachers for the 3D design process are evaluated. According to Buyukozturk et al. (2012), case study is research where a situation is defined and specified depending on location and time. Case studies are frequently used in assessment studies. It makes descriptive descriptions with qualitative and quantitative data, in particular to obtain in-depth information about a study group or situation (Jensen & Rodgers, 2001). In this design, the aim is to explain the existing situation with causal relationships, to define in detail, to explore undiscovered sections, and to reach an inference

(Yin, 2003). In this study, the designs of the students were evaluated quantitatively and their opinions about the application process were analyzed qualitatively. The situation examined in the research is the process in which pre-service teachers form 3D designs.

Participants

This research was carried out with sophomore pre-service science teachers (age range 19-22) studying at the education faculty of a university in Turkey. A total of 48 science pre-service teachers, 38 females and 10 males, participated in the implementation process. For the first time, pre-service teachers participated in an application related to 3D design. In order to keep the information of the participants, the participants were coded as P_1, P_2, P_3….

Application Process

The research was carried out in the course named General Biology Practices II in 7 weeks as three classes per week. The application process was carried out by the researchers. During the application process, each student has a computer individually and made their designs individually. Pre-service teachers created their designs through the 3D design software Tinkercad (www.tinkercad.com), which Autodesk allows for online and free-to-use. The reason for choosing this tool is that it is an online and easily accessible software. It is also suitable software for candidates to start from simple objects and create more complex structured objects on the design tool.

At the beginning of the application process, researchers introduced the software and made sample applications. In the first four weeks of the application process, they made simple design applications to learn the software. They created more complex designs in the following weeks and worked to do a design task every week. The researchers guided the students in this process. In this process, the first designs made by pre-service teachers were not evaluated, but researchers' feedbacks were given within the scope of rubric criteria. In the last week of the application process, pre-service teachers created their designs for the “DNA isolation” experiment. The reason for choosing “DNA isolation” experiment in the research is that traditional teaching methods are insufficient especially in teaching biology subjects at molecular level. In order for the complex and abstract concepts to become concrete, students must be active in biology teaching (Maras & Akman, 2009).

Pre-service teachers have difficulty comprehending the abstract molecular biology subjects such as the Watson-Crick double helix model and the 3D structure of DNA. In terms of the Watson-Crick double-helix model of DNA, they have difficulty in comprehending the hydrogen bonds formed between bases, the formation of phosphodiester bonds linking bases and the placement of deoxyribose sugar located on the outward-facing face of the strand (Maras & Akman, 2009). For this reason, in this study, pre-service teachers designed the double helix structure of DNA in 3D design tool. The application process for the 3D designs of pre-service teachers is provided in Table 1.

Table 1. The Process of Creating 3D Designs

Weeks	Implementation
Week 1	*Introducing the 3D design environment:* The "Tinkercad" software, in which 3D applications will be made, is introduced, and also, the software features and objects are explained.
Week 2	*Designing a simple glass:* A simple cup design has been made to make simple applications on the software. The researchers made a glass design together with the pre-service teachers by giving them instructions. After this application, they were asked to design their own cups (Figure 1).

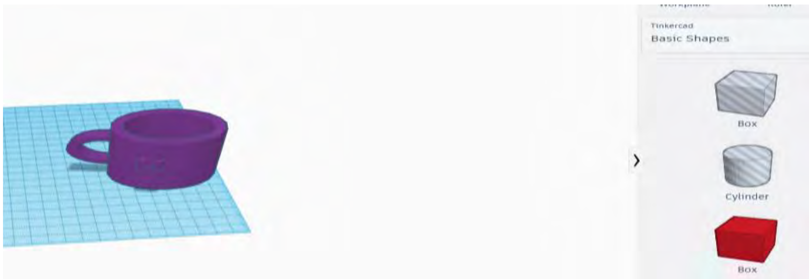

Figure 1. Simple Cup Design

Weeks	Implementation
Week 3	*Designing a bottle opener:* In the 3D design software, a more comprehensive application was made using the features of pre-service teachers, creating different objects by rotating them in the axes (Figure 2).

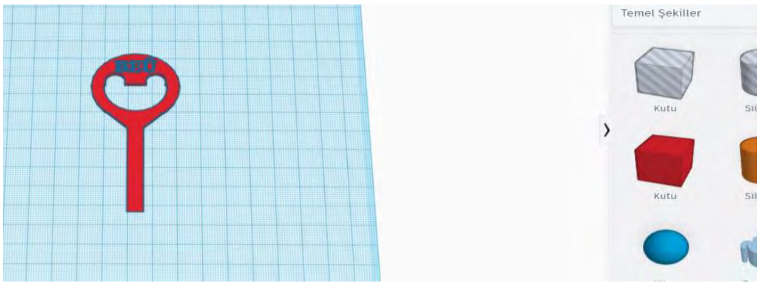

Figure 2. Bottle Opener Design

Weeks	Implementation
Week 4	*Designing a tweety cartoon character:* In the fourth week, the tweety cartoon character design was made by going into details in the 3D design, where the dimensions were determined precisely and the object transformations were considered (Figure 3). Each week, more complex objects were designed compared to previous weeks during the activities.

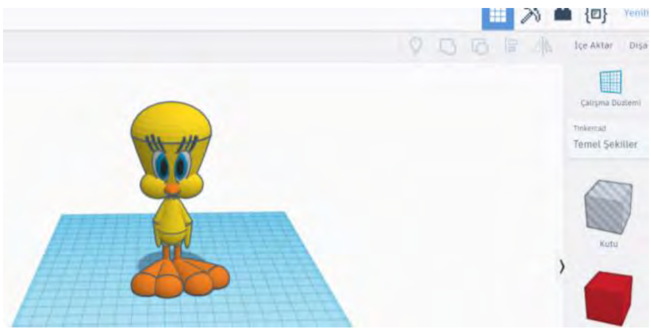

Figure 3. Tweety Cartoon Character Design

Weeks	Implementation
Week 5	*Pre-service teachers' experiment with "DNA isolation":* Pre-service teachers then observed genomic DNA by running it in 1% glucose gel electrophoresis.
Week 6	*Creation of a 3D design by pre-service teachers for the "DNA isolation" experiment:* Pre-service teachers were asked to make a 3D design for the “DNA isolation” experiment.
Week 7	*Evaluation of designs:* The designs created by the pre-service teachers within the scope of the “DNA isolation” experiment were evaluated with the “3D Design Rubric for Biology Lab” prepared by the researchers. *Implementation of the interview form:* Opinions of pre-service teachers regarding the 3D design application process and design products were received with the “Interview Form”.

Data Collection Tools

In order to increase internal validity, triangulation was performed in data collection tools (Denzin, 1978; Streubert & Carpenter, 2011). One of the data collection tools in this research is rubric prepared by researchers, prepared in line with the criteria that should be found in 3D designs. Rubric is a scoring tool that includes measures and criteria for improved performance for scoring any study (Korkmaz, 2004). It can be stated as a rating map with details of how to score part or all of a rubric activity (Karaca, 2006; Stix, 1996). During the preparation process of the rubric, a literature review was conducted and an assessment rubric was developed under six criteria to evaluate 3D designs. The criteria of the developed “3D Design Rubric for Biology Lab”: the “design dimension” of the design creation according to a certain ratio; to be able to use different geometric shapes and to be able to do it in 3D when viewed from different angles was determined as “visuality in design”; adding an innovative feature to the design was regarded as “creativity”; arranging geometric shapes to fit the design was regarded as “adding features to the design”; suitability of the design for the subject was regarded as “design content”, and using the design as a model suitable for the subject was determined as “functionality in design.” During the development of rubrics, the opinions of three experts in this field were taken, it was finalized, and the validity studies were completed. An example criterion of “3D Design Rubric for Biology Lab” is given in Table 2.

Table 2. The Sample Criterion for Rubric

Criteria	Success Levels		
	Weak (2 points)	Medium (5 points)	Good (8 points)
Creativity	There are no innovative features in the design.	The design has some innovative features.	While creating the design, he/she added innovative features with objects on the software.

While the designs made by pre-service teachers are scored, each feature is evaluated within the scope of a certain score. 3D designs were evaluated within the framework of the expected performance of pre-service teachers. In the rubric prepared, the design features were evaluated in three stages: It is rated as “weak” if the desired criterion is missing or incorrect, “medium” if the desired criterion can be improved and “good” if the desired criterion is sufficient.

Another data collection tool in this research is interview form used to obtain pre-service teachers' opinions about the 3D design process and designs. Interview form was preferred to investigate the integration of 3D design applications into the education process, and was prepared in line with the research questions and literature review. Opinions of two field trainers and one assessment expert were taken for the scope validity of the form prepared by the researcher. In the interview form prepared, attention was paid to ensure that the questions are understandable, one-dimensional and do not contain leading questions (Yilmaz & Altinkurt, 2011). It contains a total of seven questions in the interview form where the opinions of pre-service teachers regarding the application process are taken. 40 minutes were given to pre-service teachers to write their opinions on this form. Pre-service teachers wrote their opinions on the form on the basis of volunteering. *A question example in the interview form:* “What is your opinion about integrating 3D design applications into biology subjects?”

Analysis of the Data

One of the data in the study is the scores obtained from the evaluation of 3D designs of pre-service teachers according to the criteria of “3D Design Rubric for Biology Lab.” 3D designs were scored by two researchers based on rubric criteria by making a joint decision. A joint decision was reached by discussing the reasons for the differences in the scoring process. The designs were scored within the framework of the score that both researchers agreed. Scores for each rubric criterion were calculated, and tabulated, with their averages estimated. In addition, the scoring levels as well as the frequencies and percentages of the students who received the relevant score are provided.

Another data in this study is the data obtained from interview form that was subjected to descriptive analysis. The process of descriptive analysis is to bring together similar data within specific contexts and categories, and organize them in an understandable way (Yildirim & Simsek, 2006). There may be more than one opinion of pre-service teachers for each category. In the research, the data analysis process was carried out in three stages. In the first stage, a comprehensive literature review was made and the framework in which the statements were coded was created. In the next stage, the written answers given for the opinions of pre-service teachers on the opinion form were determined in the framework of categories. The categories of the research are the advantages and disadvantages of the application process, the difficulties encountered in the creation of 3D designs, the comparison of two-dimensional drawings and 3D designs, the effect of the 3D design process on the teaching of the subject, the usability of 3D design products as teaching materials, and their use in biology subjects and other undergraduate courses. The coded data is classified according to the relevant category content and the codes of the categories are presented by creating tables. Tables were supported by making direct quotations from the opinions of pre-service teachers.

In the last stage, in order to ensure reliability in descriptive analysis, consistency between coders was calculated during the coding of the data. The answers given by the preservice teachers to the questions in the interview form were examined separately by the two researchers, and the issues with "consensus" and "disagreement" were discussed and necessary arrangements were made. For the reliability calculation of the survey, the reliability formula proposed by Miles and Huberman (1994) was used as 'Reliability = Consensus / (Consensus + Disagreement)'. As a result of the evaluation of two researchers, the Miles-Huberman coder reliability value was calculated as 91.89. This calculated value shows that a sufficient and strong agreement has been achieved (Miles & Huberman, 1994; Yildirim & Simsek, 2006). Therefore, the coding reliability of the research data examined by the two researchers has been increased, and a joint decision has been made by discussing the data they disagreed on.

Results

The findings obtained as a result of the analysis in the research will be presented in line with the sub-problems.

What Level are 3D Design Products Created by Pre-service Teachers?

In line with the first sub-problem of the research, 3D designs of pre-service teachers were scored according to the rubric criteria developed. Frequency and percentage values of the level score ranges they receive according to rubric criteria are given in Table 3 and Table 4.

Table 3. Frequency and Percentage Levels of Evaluation of Designs

Level	Score Range	Frequency	%
Weak	24-49.6	15	31.25
Medium	49.7-75.3	15	31.25
Good	75.4-100	18	37.5

In Table 3, the range of points (24-49.6) was found to be at a weak level, the range of points (49.7-75.3) was found to be at the medium level, the range of points (75.4-100) was found to be at the good level according to the scores of pre-service teachers. According to the 3D design rubric, it was found that 18 (37.5%) of the pre-service teachers were at a good level, and 15 (31.25%) were at the weak and medium levels.

Table 4 shows the level scores according to the criteria of the rubric, where the 3D designs of pre-service teachers are evaluated. The scoring interval for each criterion in the rubric is different, and the scoring interval of the levels is given for each of them separately. As a result of assessing the 3D designs made by preservice teachers with rubrics, it was found that maximum 40 (83.33%) pre-service teachers were at a good level according to the "design dimension" criterion. According to the "visuality in design" criterion, it was found that 29 (60.41%) pre-service teachers were at a good level and 11 (22.92%) pre-service teachers were at a medium level. According to the "creativity" criterion, it was found that maximum 25 (52.08%) pre-service teachers were at a weak level, and 18 (37.5%) were at a medium level.

Table 4. Frequency Levels and Percentages of the Designs

Criteria	Level	Score Range	Frequency	%
Design Size	Weak	3-6.3	6	12.5
	Medium	6.4-10.6	2	4.17
	Good	10.7-15	40	83.33
Visualization in Design	Weak	4-8.7	8	16.67
	Medium	8.8-14.4	11	22.92
	Good	14.5-20	29	60.41
Creativity	Weak	4-7.3	25	52.08
	Medium	7.4-11.6	18	37.5
	Good	11.7-16	5	10.42
Adding Attributes to the Design	Weak	4-7.3	17	35.42
	Medium	7.4-11.6	18	37.5
	Good	11.7-16	13	27.08
Design Content	Weak	6-10.7	23	47.92
	Medium	10.8-16.4	15	31.25
	Good	16.5-22	10	20.83
Functionality in Design	Weak	3-5	18	37.5
	Medium	6-8	22	45.83
	Good	9-11	8	16.67

According to the criterion of "adding feature to design", it was determined that maximum 18 (37.5%) pre-service teachers were at the intermediate level and 17 (35.42%) pre-service teachers were at the low level. According to the "content of design" criterion, it was found that 23 (47.92%) pre-service teachers were at a weak level, and 15 (31.25%) pre-service teachers were at medium level. According to the criterion of "functionality in design", it was determined that 22 (45.83%) pre-service teachers were at the medium level, and 18 (37.5%) pre-service teachers were at a low level. According to these results, it was found that pre-service teachers were at a good level in terms of design size and visualization in design; they were at the medium level in terms of the criteria of adding features to design and functionality in design, and at a weak level in terms of the criteria of creativity and design content. Some examples of 3D designs made by pre-service teachers about DNA are given in Figure 4.

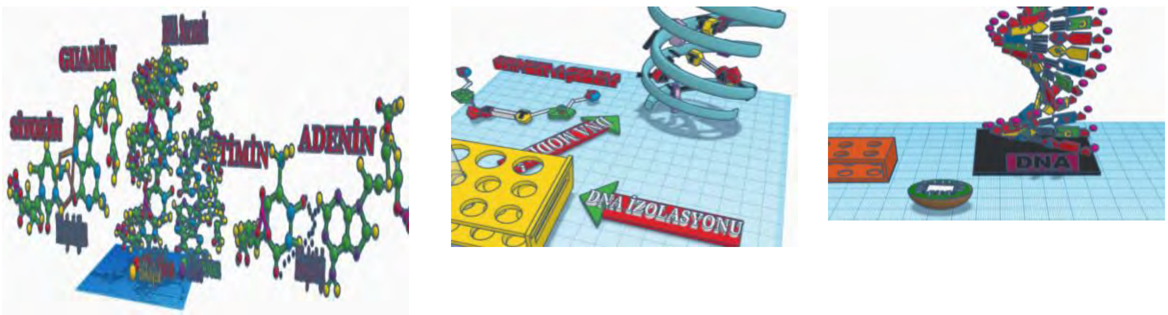

Figure 4. DNA Model Design Examples of Pre-service Teachers

What are the Pre-service Teachers' Views on the 3D Design Process?

For the second sub-problem of the research, opinions received from pre-service teachers on the application process were examined at the end of the 3D design process. In this context, questions were asked about the advantages and disadvantages of the application process, the difficulties encountered in the creation of 3D designs, comparing the two-dimensional drawings with the 3D designs, and investigating the effect of the 3D design process on teaching the subject. Regarding the advantages of the application process, opinions received from pre-service teachers are given in Table 5.

Table 5. Views on the Advantages of the Application Process

Code	Frequency
A process that contributes to the knowledge of the field of teaching	17
Developing 3D thinking	11
Providing a different perspective	10
Analysing the subject in more detail	9
A different application	6
Permanence in experiments and subjects	6
Improving creativity	5
Repeating experiments and subjects	5
Detailed research of the subject	4
Thinking like a teacher and preparing materials	3
Differentiating the experiments	3
Making a 3D design	3
Development of visual thinking	2
Learning to design	2
Creating models	2
Positive attitude towards computers and technology	2
Improving imagination	2
Making abstract thoughts concrete	1

According to Table 5, pre-service teachers stated that this is a process (17) that most contributes to the knowledge of the field of teaching within the scope of the advantages category of 3D design process. However, they are of the opinion that the implementation process improves 3D thinking (11), provides different perspectives (10), and gives the opportunity to examine the subject in more detail (9). Regarding the advantages of the 3D design process, the pre-service teachers' views are as follows; (P_{12}): *"Among the advantages of this process, we have learned new and different software. We use our imagination while modelling abstract subjects. Therefore, we are learning the subject in more detail."* and (P_{23}): *"While creating the designs, I realized that I learned the subject in more detail. Because I need to know all the details to create the DNA model so that I can make the calculation. I think I can say that it is an application that makes one improve in every respect. I feel fortunate that I learned this software".* (P_{14}) expressed that the design process affects permanence with the following words "*As an advantage, the designs* *remained more in mind because they were a 3D visual, so it was permanent".* However, P_6 pre-service teacher explained that it was fun and different with the words *"I think that these applications contribute to my teaching knowledge. I learned a different and fun application"*. It can be said that since the pre-service teachers made more detailed research on the subject in order to design in the design process, it has a positive impact on the permanence and learning of the subject. It can be thought that the application process has directed pre-service teachers to think in many ways and provided different perspectives. The opinions of the pre-service teachers regarding the disadvantages of the application process are given in Table 6.

Table 6. Views on the Disadvantages of the Implementation Process

Code	Frequency
Time consuming application	14
No disadvantage	12
Assessment of designs	5
A challenging process	5
An exhausting process	4
Computer use is difficult	2
Not suitable for every subject	1

According to Table 6, among the disadvantages of the application process, the application being regarded as time-consuming was found as the biggest disadvantage (14). In addition, some of the pre-service teachers stated that it did not have a disadvantage (12). Regarding the disadvantages of the 3D design process, the pre-service teachers' views are as follows; (P_1): *"As a disadvantage, it is a time consuming and challenging process.",* (P_{22}): *"It took time because the design process was challenging."* and (P_{41}): *"I think there is no disadvantage. It is an application that should be learned"*. The common opinion was that it is an exhausting and challenging application, because pre-service teachers devote a lot of time to the application process. But some of the pre-service teachers also argued that it did not have a negative feature. The opinions of the pre-service teachers regarding the difficulties encountered in the creation of 3D designs are given in Table 7.

Table 7. The Opinions regarding the Difficulties Encountered

Code	Frequency
While proportioning the objects to each other in the design software	17
While creating shapes in the design software	13
Generating new ideas	9
The lack of shapes on the software	7
Difficulty in thinking in three dimensions	5
In the first design applications	5
I did not struggle	5
The entire design process	3
Due to designing on the computer	2

In Table 7, it was found that pre-service teachers experienced the most difficulty in proportioning objects with each other (17) in terms of the difficulties they encountered in the 3D design process. The pre-service teachers also stated that they had difficulty in creating shapes in the design software (13), generating new ideas (9), they struggled due to the lack of shapes on the software (7). Regarding the difficulties encountered during the implementation process, the opinions of the pre-service teachers are as follows; (P_{15}): *"I had a hard time figuring out how to do it while preparing the design. I also had difficulty adjusting the size of the objects.",* (P_{33}): *"While I was doing the application, there were not as many shapes as I could in order to make the designs that I dreamed of. It took a lot of time for me to make these shapes. So my designs were different than I imagined."* and (P_{29}): *"It was especially difficult in the design process when comparing the objects on the screen with each other. Initially, I had problems thinking of objects in 3D and combining them in proportion"*. Pre-service teachers stated that they mostly faced difficulties arising from the software during the design process. It can be said that the features of the Tinkercad software used as a training tool affect the pre-service teachers at the beginning of the application process. The opinions of pre-service teachers for comparing two-dimensional drawings with 3D designs are given in Table 8.

Table 8. Opinions on Comparing Two-dimensional Drawings and 3D Designs

Category	Code	Frequency
Two-dimensional drawings (8)	Because I do not like to use applications on a computer	3
	Information is more permanent with drawings	3
	Easier	2
	Drawings are more descriptive	1
3D design application (30)	provides detailed investigation of the subject	15
	More effective as the subject has been thoroughly researched	11
	More effective because it increases permanence	9
	Permanent because more time is spent	7
	More effective because it increases creativity	6
	More effective because there are concrete studies	6
	More effective as it appeals to visual intelligence	4
	More effective as it performs meaningful learning	3
	A noteworthy application	3
	More effective as it allows 3D thinking	3
	An informative process	2
	It encourages material preparation	1
Both two-dimensional design and 3D design applications (7)	Both are effective in the learning process	7

In Table 8, as a result of comparisons of the effectiveness of 3D designs and two-dimensional drawings by pre-service teachers, they stated that the applications of 3D designs were the most effective (30). There are fewer pre-service teachers who state that two-dimensional drawings (8) are effective and also that both applications (7) are effective. They stated that the application of 3D design is more effective as it provides detailed investigation of the subject (15), comprehensive research of the subject (11), and increased permanence (9). Regarding the effectiveness of 3D design applications, the opinions of pre-service teachers are as follows; (P_4): *"I think it was more effective when we used a 3D design software. We think multi-dimensionally, our creativity improves and we do more research on the subject of the lesson."*, (P_{19}): *"Because two-dimensional designs are more abstract and 3D designs are more concrete, so it is more memorable. Because concrete objects are more permanent than abstract objects."* and (P_{42}): *"We conduct more research while making 3D designs. We have to investigate every detail of the subject. So, it remains more in mind".*

Those who stated that the two-dimensional drawings were more effective, stated that they did not like to use applications on the computer (3) and that the drawings were more permanent (3). The opinions of pre-service teachers regarding the two-dimensional drawings are as follows; (P_7): *"Drawing was easier than working on the software, making two-dimensional more permanent and effective."* and (P_{27}); *"I don't like working on a computer. Because I do not know the computer very much, maybe that is the reason".* There are also pre-service teachers who state that both two-dimensional drawings and 3D design applications are effective in the learning environment. However, most of the pre-service teachers stated that 3D design applications are more effective in the learning process, since they allow detailed and in-depth research of the subject. The opinions of the pre-service teachers regarding the impact of the 3D design process on instructiveness of the subject are given in Table 9.

Table 9. Opinions on the Impact of 3D Design Process

Code	Frequency
Design products made the subject more detailed	15
They increased the permanence of the subject	11
Visually effective	8
They provide repetition of the topic	7
They make abstract subjects more concrete	7
It has no effect	3

When Table 9 is examined, it is seen that pre-service teachers have a positive assessment of the impact of 3D design process on instructiveness of the subject. Preservice teachers stated that it detailed the subject in the design process (15), increased the permanence of the subject (11) and was visually effective (8). The opinions of pre-service teachers regarding the effect of 3D design products on instructiveness of the subject are as follows; (P_{13}); *"It certainly positively affected the subject's instructiveness. While doing the 3D design, we unwittingly research the subject and reinforce it with visuals, thereby positively affecting the permanence of the subjects."* and (P_{34}): *"It was an instructive design process. I delved in researching to draw DNA, so when I was researching for design, I investigated and studied the subject in detail without being aware of it. Because I need to master the subject to do the design, so I did a thorough research".* One of the pre-service teachers, who stated that 3D design products have no effect on instructiveness of the subject (3), said as follows; (P_6): *"Experiments are sufficient in teaching the subject. Such practices are unnecessary".* The pre-service teachers stated that the 3D design process was positive in terms of learning the subject, since they had to investigate all the details of the subject in order to create 3D designs and examined them in detail.

What are the Opinions of the Pre-service Teachers towards 3D Design Products?

For the third sub-problem of the research, the opinions received from pre-service teachers on their designs were examined at the end of the 3D design process. In this context, questions were asked to investigate the usability of 3D design products as teaching materials, and to investigate their usability in biology subjects and other undergraduate courses. Opinions of pre-service teachers regarding the usability of 3D design products as teaching materials are given in Table 10.

Table 10. Opinions on the Usability of 3D Products

Codes	Frequency
Usable	26
Some designs are usable	9
Can be used as a visual material	7
I am undecided	2
Well-envisioned designs can be used	2
I would not use them	2

In Table 10, the majority of pre-service teachers stated that their 3D designs can be used as teaching materials (26). However, some pre-service teachers stated that some designs are usable (9) and can be used as a visual material (7). The opinions of the pre-service teachers regarding the usability of 3D designs as teaching materials are as follows: (P_{18}):*"I will use it when I am going to be a teacher. Using them as a visual material can be very useful. However, it is important to consider the suitability of the material at the class level in the process of its use...",* (P_{21}): *"I will definitely use it. I would use it as a material as it offers concrete examples on the subject.", and* (P_2): *"When I will become a teacher, I would use the designs I make during the application process. Especially designs made by some of my friends can be used as a 3D model. Because they created the structure of DNA on the design by considering all the ratios."*

They stated that 3D designs created by pre-service teachers during the application process can be used as models and they would use it as a teaching material especially when they become teachers in the future. Opinions of pre-service teachers regarding the usability of 3D design products in biology are given in Table 11.

Table 11. Opinions on the Usability of 3D Products in Biology

Codes	Frequency
On all biology topics	19
On some biology topics	11
On many biology topics	8
For biology subjects suitable for design and visuality	8
Not applicable for other topics	2

When Table 11 is analyzed, the majority of pre-service teachers stated that 3D design products are also applicable in other biology subjects (19). In addition, pre-service teachers stated that they are applicable to some biology subjects (11), many biology subjects (8), and biology subjects suitable for design and visuality (8). Regarding the applicability of the 3D design process on other biology subjects, pre-service teachers stated the following: (P_{16}): *"A design can be created in every subject. I think it is necessary to think creatively and use the software professionally in order to be able to create effective and sufficient designs.",* (P_{23}): "*I think it can be applied in any subject. At the beginning of the process when we talked about 3D designs, I said 'Are we going to do DNA? Well, how do we do it? I thought about the 3D model of DNA in my mind. But now I design very easily in every subject, there is no such thing as impossible."*, and (P_5): *"I think it can be used in subjects with high visuals. Especially the subjects that the students cannot think concretely are very suitable for this purpose. So, it can be used in many subjects."*

It is instructionally important to visualize units that are abstract or too small to be visible in micro-level study areas of living organisms, like Biology, with designs. Therefore, the pre-service teachers stated that 3D design products can be used in many biology subjects, especially in terms of visualization. Opinions of pre-service teachers regarding the usability of 3D design products in other undergraduate courses are provided in Table 12.

Table 12. Opinions on the Usability of 3D Products in Other Courses

Codes	Frequency
Chemistry	29
Biology	22
Organic Chemistry	13
Physics	10
Classes with Visual Content	9
All courses	7
Geometry	5
Science	4
Not applicable in other courses	3
Laboratory lessons	1
Applied lessons	1

According to Table 12, the majority of pre-service teachers stated that 3D design products can be used in chemistry (29), biology (22), organic chemistry (13), physics (10), courses with visual content (9), all courses (7) and geometry (5). The opinions of the pre-service teachers regarding the usability of 3D design products in other undergraduate courses are as follows: (P_{36}): *"It can be used in courses such as chemistry, biology, physics, and geometry. But most often, it can be used more in chemistry classes. Especially, the subject can be reflected by making structures such as molecules and atoms with 3D designs.",* (P_{14}): *"Organic chemistry; because it definitely has an effect on the representation of molecules and atoms. It is even more effective than displaying difficult problems and molecules on paper.", and* (P_{35}): *"It can be used in lessons with visual content. It is appropriate to use as it enables more permanent and effective teaching."*

3D design products can be used effectively in making complex and abstract subjects more concrete, and especially in subjects that should supplement the teaching process with visual elements.

Conclusion, Discussion and Recommendations

In this study, the 3D design products created by pre-service science teachers for the "DNA isolation" experiment within the scope of the course General Biology Practices II were evaluated, and the opinions of the pre-service teachers about the 3D design process and the design products they created were examined. The first sub-problem of the research is to evaluate the 3D design products that the pre-service teachers created for the "DNA isolation" experiment. Accordingly, when the 3D design products of pre-service teachers are evaluated according to the rubric prepared by the researchers, they were found to perform at a good level. It was found that the design objects are at a good level in proportion and compatibility with each other, especially when pre-service teachers were creating their designs on the design software. Another result of evaluating the designs of pre-service teachers is that their ability to add different features to created designs and create functional designs is at a medium level. However, it was observed that pre-service teachers could not add innovative features in their designs to reflect especially important parts of the subject. These results show that, although pre-service teachers cannot adequately emphasize important parts of the subject in their 3D designs, they were found to be able to do 3D designs at a sufficient level. The reason for this may be that they create a design for the first time within the scope of a biology subject specified. Evaluating the 3D design products of pre-service teachers can enable them to become aware of their sufficient or inadequate skills and abilities. Especially, making such applications in new technological tools can be important in terms of revealing the competencies of pre-service teachers in applications. Similar to our study, Ludwig, Nagel and Lewis (2017) stated that in their study, they helped students discover their talents by using new technologies. In their study, they showed that different skills and knowledge of students can be revealed with new technological tools. They also observed that students planned their future according to their abilities within the scope of the study.

In the second sub-problem of the research, pre-service teachers expressed a positive opinion regarding the 3D design process. Pre-service teachers stated that the 3D thinking ability of the process improved, and they gained a different perspective. In addition, they emphasized that it provides a lasting effect on learning since it provides a more detailed and comprehensive research of the subject. Another result that supports this is that 3D design applications are more effective in learning than two-dimensional drawings. Similarly, Karaduman (2017) used new and non-experienced technologies such as 3D design tools for students and stated that using concrete 3D models instead of using two-dimensional teaching methods in information transfer strengthens the learning experiences of students. Vijapur, Kawalkar and Nambiar (2014) stated in their study on the cell that students visualize the cell as a two-dimensional structure instead of a 3D structure, thereby showing a strong resistance to change this two-dimensional structure.

Using simulations, models, videos and animations in laboratory experiments helps students understand and reinforce concepts (Escalada & Zollman, 1997). Models, simulations, or animations prepared in the computer environment may be good educational program choices in terms of learners (Lowe, 2003). Especially since they perform experiential learning by making 3D educational objects and interdisciplinary learning, they are used in teaching mathematical shapes, atoms, molecules, cells and similar concepts (Papp, Tornai & Zichar, 2016; Smith & Tilman, 2015). Many studies in the literature show that 3D design tools affect students positively in education. In his study with 47 elementary students, Kwon (2017) found that 3D design environments positively affect students' achievements, motivations and interests. Similarly, Bozkurt and Sarikoc (2008) compared a virtual laboratory application created with simulations prepared with an experiment with real laboratory materials, and the virtual laboratory group was very successful compared to the traditional laboratory group. Maras and Akman (2009) found that computer-assisted teaching method has a positive effect on the academic achievement of students in the study of the topic of the activities of enzymes for levels of apprehension by students. In addition, in their study with elementary school students, Sung, Shih and Chang (2015) stated that 3D design applications increase students' mathematical achievements, and they think that they positively influence the attitudes of low and middle level students towards mathematics.

Studies show that 3D design tools are used as educational objects in educational environments (Ferk et al., 2003; Gu̇nersel & Fleming, 2013; McGahern, Bosch & Poli, 2015; Sensoy & Yildirim, 2016). Elangovan and Ismail (2014) applied a 3D computer simulation based teaching method on cell division with biology students, and stated that they have an impact on students' academic achievement and the permanence of learning at the end of their studies. In a study conducted by Sensoy and Yildirim (2016) at the level of middle school, it was determined that the use of 3D visual material was effective for improving the level of academic achievements of students.

The pre-service teachers stated that the features of the software used in the application process were insufficient and stated that they had difficulty in creating the designs. Although technical issues such as proportioning objects on the design software with each other and creating new shapes are also difficult, they stated that they will use these design tools in their future professional lives. They emphasized that such applications can be used in biology, chemistry, organic chemistry, and physics. In fact, they stated that they can be used in teaching chemistry subjects such as atom, molecule, and organic chemistry. Most of the research in the literature supports this view. Using 3-dimensional simulations in education as tools to help understand the chemistry of biomolecular events were emphasized in subjects such as researching its effect on students' knowledge on genetics using a web-based simulation developed for biology students, showing the representations of two-dimensional macro-molecular structure in 3D, illustration of the representations of different molecular structures used in chemistry instruction, and the importance of visualizing molecules in science education (Cooper & Oliver-Hoyo, 2017; Ferk et al., 2003; Gelbart, Brill & Yarden, 2009; Gu̇nersel & Fleming, 2013; José, & Williamson, 2005).

Regarding the third sub-problem of the research, pre-service teachers stated that 3D design products they created could be used as teaching materials. They stated that they can be used especially when designing a model in teaching environments. They stated that such applications can be used not only in the scope of DNA but also in other biology subjects. As a reason for this, they stated that visualization of abstract or invisibly small units with designs in areas of examination at the micro-level such as biology can be educationally important. They stated that these design products can be used effectively in making abstract and complicated subjects more concrete, and in the subjects that should supplement the teaching process with visual elements.

Studies have shown that technological tools and models used as learning objects affect students' learning positively (Adiguzel, Gurbulak & Saricayir, 2011; Cankaya, & Girgin, 2018; Pekdag, 2010). In the study of Gunes and Celikler (2010) to make abstract and complex concepts concrete, they investigated the effect of model building and computer-assisted instruction on students' success in teaching “cell division.” As a result of their research, it was found that it is effective in learning abstract and complex biology topics. In their study, Johannes et al. (2016) taught the basic concepts of molecular biology using 3D molecule models developed by scientists and as a result of their study, they achieved a remarkable success in teaching conceptual knowledge. Traditional teaching methods are inadequate, especially in the teaching of molecular biology topics. In order for the complex and abstract concepts to become concrete, students must be active in biology teaching (Maras & Akman, 2009).

Virtual environments help making abstract concepts concrete, enabling information to be formed effectively in students' minds (Aktamis & Arici, 2013; Arici, 2013; Demir & Armagan, 2018; Gul & Sahin, 2017). In their study Demir, Demir, Caka, Tugtekin, Islamoglu and Kuzu (2016) emphasized that 3D tools concretize the abstract information students have learned in the field of education. In particular, the use of these tools becomes important in the teaching of subjects where students have difficulties in learning and there is no opportunity to observe (Korakakis et al., 2009). In virtual environments, students can structure information in their minds when interacting with objects and events by looking at them from multiple perspectives by zooming in and out of 3D objects (Huang, Rauch & Liaw, 2010).

3D virtual technologies support students to design their own technologies, improve their imagination and creativity, and combine STEM from different disciplines to support experiential learning (Peels, 2017). It is a powerful educational tool that supports STEM education by combining 3D design technologies of engineering, technology, and science applications (Novak & Wisdom, 2018). In addition, these technologies can be useful in providing to and developing 21st century skills in students (Cano, 2015; Karaduman, 2017; Trust & Maloy, 2017). For this reason, in the last years, educational environments that provide this skill to students are being prepared and applications are made (Nemorin & Selwyn, 2017).

The most important limitation of the 3D designs of pre-service teachers within the scope of the study is that they have a certain time restriction within the scope of “DNA isolation” experiment. The data in the research consist of the designs made at the end of the application process and the interviews received from pre-service teachers. At this point, data covering the 3D design process can be collected. In addition, applications can be made in the study group with different ages and characteristics. In order to realize meaningful learning in educational environments, it is important to use educational tools that provide students with an opportunity to use innovative, up-to-date and different disciplines at the same time, providing a practical experimental learning environment for students. In this study, it is aimed to integrate 3D design technologies into educational environments. In line with the findings obtained, it is important to reveal the difficulties encountered in the process of integrating these technologies into educational environments and to reveal the necessary information in order to shed light on future studies. In addition, 3D design tools can be used as an aid to produce materials for activities for the process of applying STEM activities in educational settings. In addition, experimental or mixed research can be carried out to investigate the impact of applications made with 3D design tools on students in educational environments.

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