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STEM ACTIVITIES MADE WITH 3D PRINTER; THE EFFECT ON AWARENESS OF TEACHER CANDIDATES REGARDING ITS USE IN SCIENCE LESSONS

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ABSTRACT

The inclusion of integrated structures and interdisciplinary relations in education and inclusion in course curricula in the world has become even more important with the prominence of STEM education in the world. STEM means the inclusion of project-based applications in education within an integrated structure with science, technology, mathematics and engineering activities.

Motivation/Background: It is noted that the majority of STEM research in our country is focused on science education. The aim of this study is to investigate the effect of 3D printing STEM activities on teacher candidates ' awareness of their use in science course.

Method: 37 science teacher candidates participated in the 7-week study. Qualitative research method was used in this study. Qualitative data was taken from the field notes and semi-structured interview.

Results: Thanks to 3D STEM activities, teacher candidates achieved to create a realistic product by using their knowledge in different disciplines such as science, mathematics, technology, and engineering and 21st century skills.

Conclusions: According to the results of the research, the usage of 3D printer in a science course creates awareness in teacher candidates in terms of three-dimensional thinking and learning experience.

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Keywords: Stem Activities, 3d Printer, Science, Awareness

1. INTRODUCTION

It has been emphasized that knowledge should not only remain just theory, but also should be applied in life. Applying knowledge in life will allow individuals to produce various solutions for the problems they face. STEM approach, using science, mathematics and technological tools, provides new solutions for problem status and creates a learning environment for raising generations with 21st century skills Carroll (2014), Simeon et al. (2020). STEM education aims to enable students to solve real-world problems, learn knowledge in a more holistic and organized way, and integrate interdisciplinary knowledge Aydın et al. (2017), Beane (1995), Burrows et al. (1989), Capraro and Slough (2008), Childress (1996), Jacobs (1989), Sweller (1989). STEM is shaped by experiences of teachers and students and it enables to teach specific knowledge and skills with the integration of STEM disciplines (Corlu, Turkey & Aydin, 2017).

The contributions of STEM activities to the learning environment and student are as follows: critical thinking, creativity, problem solving, productivity and responsibility.

- STEM activities provide a natural learning environment.
- It provides 21st century skills.
- By introducing new products, it contributes to the ecosystem.
- It allows students to be aware of inventions and better understand the relationship between events.
- It enables design thinking and innovation.
- It develops students ' self-confidence and self-sufficiency through collaboration and independent study.
- It increases learning motivation.
- It allows them to come up with pratical solutions to the problems they face.
- It encourages students to flexible thinking Akgündüz et al. (2015), Güleryüz (2020).

It is predicted that 3D printing technologies used for various purposes will be among the most preferred technologies on an individual scale in the future Gartner (2015), Johnson et al. (2014). It is believed that 3D printers will also make significant contributions to science education. 3D printing is seen as an effective way to integrate STEM disciplines into science education. 3D printing will provide students with interesting education experience that improve their problem solving, creativity and critical thinking skills in science classes Cano (2015).

Today, many studies have been carried out to determine the educational potential of different technologies. One of these technologies is 3D printing technology. 3D printers seem to be very effective tools for providing production of a physical model through laminated materials. Besides with the development of technology, its widespread use in daily life will benefit its use in educational environment. It is believed that the use of 3D printers in education increases students ' motivation to learn. As part of the research, it is aimed to determine the current state of 3D printers' usage for educational purposes Güleryüz (2020).

3D printers can produce a specified object with the desired properties. This leads to significant transformations in both professional and individual production activities. 3D printers have the potential to cause significant changes in areas related to design and production, as well as in all other areas where objects play a role. 3D printers have a strategic importance in 21st century education system. It is seen as an important tool in increasing creativity in technical and mechanical courses Campbell et al. (2011). By effectively using 3D printing technology as a material in the educational and training environment, it provides students with different experiences in different fields. 3D printer used in education is a technology that increases students' self-confidence and imagination, providing new learning opportunities Güleryüz et al. (2019). In 2011, The Economist referred to three-dimensional printing technology as "world-changing manufacturing technology" Ratto and Ree (2012) and predicted that this technology would lead to a revolutionary change in the near future, such as steam engine, nuclear energy, microchips and the Internet Campbell et al. (2011). Three-dimensional printing is seen as a technology that can change the way of production, consumption and life in the world Prince (2014).

Usage areas of three-dimensional printers;

- Science Education
- Robotics
- Aerospace
- Shoe Design
- Accessory
- Civil engineering

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- Geographic Information Systems
- Jewelry
- Sculpture
- Automotive industry
- Industrial and architectural designs
- Construction
- Dentistry and medical sector
- Scientific studies in different fields

In the future, if printers start to be used at homes, their usage areas might diversify Güleryüz (2020).

Creating realistic products through 3D printers can enhance students' imagination. With three-dimensional printers, students can embody the abstract information they dream of or learn in the course. Thus, it is thought that creating realistic products thanks to STEM activities increase students 'motivation to produce, and provide a unique experience for students Brown (2015).

Examining the relevant literature, it is understood that in-depth studies of the use of 3D printers in STEM activities are necessary. When considering 3D STEM activities enhancing three-dimensional thinking, better imagination, problem solving, decision making and 21st century skills, it is necessary to study the impact of the use of STEM activities in science course on teacher candidates ' level of knowledge and awareness of three-dimensional design. It is also believed that this study will contribute to the literature.

Importance and Justification of Research

This research aims to provide students with skills of collaboration, creativity and problem solving by focusing on integrating teacher candidates' STEM knowledge and design-driven education. It is important because it has the potential to contribute to the awareness of teacher candidates for the use of 3D STEM activities in science course. These issues are currently being promoted in the Ministry of Education.

Ministry of National Education, General Directorate of Innovation and Educational Technologies shared views about STEM education and 3D designing within the scope of the 2023 education vision;

"…. Today, STEM education, which allows students to integrate their knowledge in Science, Technology, Mathematics and Engineering courses, is integrated into education system of many countries…. "

"… The content will be developed for improving digital skills and integration of electronic design, 3D designs, and programming into learning processes at elementary, secondary and high school levels for the next three years …." YEĞİTEK (2019).

Purpose of Research

As part of STEM activities, science teacher candidates were trained in the use of 3D printer. Teacher candidates carried out 3D design-driven activities. The aim of this study is to examine the impact of 3D activities on three-dimensional design skills of teacher candidates and to reveal their awareness of using them in science course.

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For these purposes, answers to the following sub-problems are sought:

1) Do 3D activities have an impact on teacher candidates' awareness of using three-dimensional design skills in science courses?
2) What are the opinions of teacher candidates about 3D printing STEM activities?

Research Problem

Do 3D activities have an impact on teacher candidates' awareness of using three-dimensional design skills in science courses?

2. MATERIALS AND METHODS

Qualitative research method was used in this study. Qualitative research involves collecting and analyzing non-numerical data to understand concepts, opinions, or experiences. The content analysis method was used for the analysis of qualitative data. Content analysis is a systematic, repeatable technique in which some words of a text are summarized with smaller content categories with certain rules-based encodings Büyüköztürk et al. (2013).

Sampling

37 science teacher candidates studying at a State University participated in the study voluntarily.

Application

In this study, STEM education program covering 3D printing activities, which made learning simple and fun for science teacher candidates, were implemented. This program lasted 2 hours a week for 7 weeks (total of 28 hours). Within the scope of STEM education, 3D Builder and Zaxe (destop) PLA for 3D printer programs were taught in 3D printing activities. A brief summary of the application on STEM activities with 3D printing is given below and the work schedule is shown in Table 1.

A Brief Summary of The Application:

- Teacher candidates ' readiness levels for STEM education was measured. Information about activities related to STEM education was given.
- For the next two weeks, teacher candidates were asked to draw on the shape they would make before designing in the 3D Builder Program because the teacher candidates were asked to think in a two-dimensional framework. Then, they were asked to design the two-dimensional shapes in the 3D builder program. They were taught Zaxe (Destop) PLA program.
- After two weeks of training, four activities related to the 3D printing were carried out after a certain competence and knowledge about the 3D printing and its programs had been achieved.
- Prints of these designs were taken from the 3D printer.

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Figure 1 Additive Manufacturing Process Campbell et al. (2011)

Figure 1.

Table 1 Event Schedule

Week	Subject
Week 1	What Does STEM Education Mean?
Week 2	Teaching of 3D Builder
Week 3	Teaching of Zaxe (Desktop) PLA
Week 4	3D Activity; Making Key Holder
Week 5	3D Activity; Making Simple Machines-1
Week 6	3D Activity; Making Simple Machines-2
Week 7	3D Activity; Making Simple Machines-3

3D-printed objects with their activity label are shown below.

Activity 1: Making Key Holder

Activity 2: Making Simple Machines-1

Activity 3: Making Simple Machines-2

Activity 4: Making Simple Machines -3

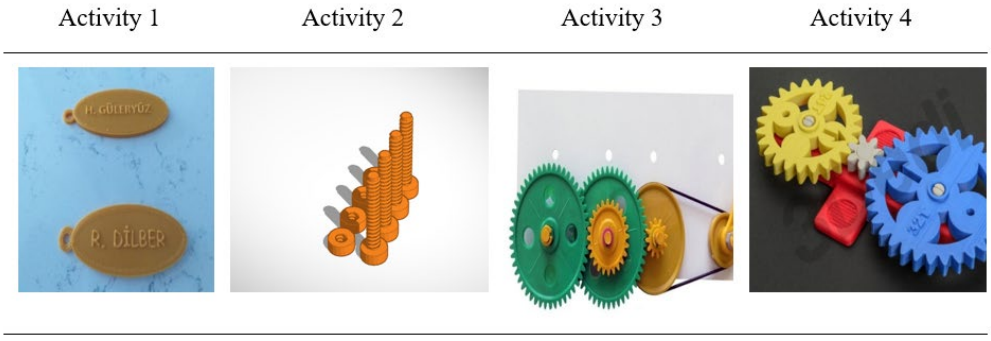

Figure 2 3D activities

Data Collection Tools

For qualitative data, field notes and semi-structured interview forms were used. The researcher helped participants whenever they needed during activities. Throughout the study, the researcher took field notes related to the activities. Field notes recorded by the researcher were given to teacher candidates at the end of the

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course, confirming the accuracy of the notes. Field notes were used in the analysis of qualitative data and the interpretation of events.

Interview Questions

1) What do you know about STEM?
2) What are the benefits of using 3D printer in science course in terms of teaching?
3) How did you experience a change in your learning life after 3D activities?
4) What are the limitations of 3D printing in education?
5) What are the advantages of 3D printer training in science course?

Analysis Of the Data

After completing the activities, the semi-structured interview form prepared with expert opinions was given to the teacher candidates. It was declared that this form would not be used for academic evaluation, but would only be used in the study. Students were also asked not to write their names. In this way, an environment was provided for teacher candidates to express their ideas in a more comfortable and neutral way.

It was tried to obtain data on the awareness of teacher candidates related to the use of 3D activities in science course by analyzing qualitative data. Opinions of teacher candidates were taken into account in the activities carried out.

The data obtained was first organized by the researcher and then presented to the evaluation of two experts. As a result of evaluation, the necessary changes were made. Categories were created by the researcher. Expert opinions were taken for the categories and the categories were finalized.

3. RESULTS AND DISCUSSIONS

Answers of teacher candidates to the interview questions are given in tables below.

Table 2 shows the answers of science teacher candidates to the question of "what does STEM mean for you?".

Table 2 What do you know about STEM?

	f	%
An interdisciplinary approach	29	78.3
Product-oriented rather than theory-oriented	21	56.7
One of 21st century skills	14	37.8
Fun classes	9	24.3
High-order thinking skills	3	8.1

Examining Table 2, an interdisciplinary approach stood at % 78.2, representing the highest rate, product-oriented rather than theory-oriented stood at % 56.7, and high-order thinking skills stood at %8.1, representing the lowest rate.

STEM is an acronym for the fields of science, technology, engineering and math. STEM education mainly includes science and mathematics disciplines and covers the fields of engineering and technology. STEM education is very important in terms

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of converting theoretical knowledge into a realistic product, and aims to make students more aware of production. Students must have sufficient knowledge to be productive in many areas.

Some answers of science teacher candidates to the question of "What does STEM mean for you" are given below:

TC (Teacher Candidate)5:" ... thanks to STEM activities, we got rid of rote learning... now we work product-oriented ... "TC21:" ... I enjoy studying science courses together with STEM activities...the lessons are very fun...".

Table 3 depicts the answers of science teacher candidates to the question of "What are the benefits of using 3D printer in science course in terms of teaching?".

Table 3 What Are the Benefits of Using 3D Printer in Science Course in Terms of Teaching?

	f	%
Converting knowledge into practice	29	78.3
Knowledge visualization	24	64.8
Enabling self-production	21	56.7
Paving the way for learning	15	40.5
Enabling three-dimensional thinking	9	24.3

Examining Table 3, converting knowledge into practice stood at %78.3, representing the highest rate, knowledge visualization stood at %64.8, Enabling three-dimensional thinking stood at %24.3, representing the lowest rate.

3D printing technology also helps teacher candidates enhance their imagination. Thanks to 3D printers, teacher candidates can easily create realistic products. Thus, it is a unique experience for students. Teacher candidates can identify the problems they face and produce solutions using design programs. Then, by using 3D printers, they can convert solutions into practice, allowing them to be solution-oriented and more creative. The use of three-dimensional printers in classrooms also makes it easier for teacher candidates to understand objects that are difficult to visualize. Thus, the lessons in the curriculum are more instructive and catchier. 3D STEM activities provide students with the opportunity to convert knowledge into practice and to produce the necessary material through 3D printers. The statements of teacher candidates support this.

Some of participants' answers to the question of "What Are the Benefits Of 3D Printer Usage in Science Course to Teaching?" are presented as follows: TC20: "… *Gave me the opportunity to materialize abstract concepts*…" TC21: "… *Thanks to* 3D *printer, I had the opportunity to design and produce the material I needed*…"

Table 4 depicts the answers of science teacher candidates to the question of "How Did you experience a change in your learning life after 3D activities?".

Table 4 How Did you experience a change in your learning life after 3D activities?

	f	%
Increasing interest and curiosity for science	30	81
Increasing motivation for science	24	64.8
Changing attitudes towards science	22	59.4
Increasing awareness about science	17	45.9
Increasing productivity and creativity	11	29.7
Paving the way for learning	8	21.6

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Examining Table 4, increasing interest and curiosity for science stood at %81, representing the highest rate, increasing motivation for science stood at %64.8, and paving the way for learning stood at %21.6, representing the lowest rate.

Thanks to 3D activities, students' concentration and interest in the course significantly increase, In particular, the use of 3D printing technology in science education enables students to better understand the subjects. For example, teaching the topic of cell division in a classical way might bore students. Thanks to 3D activities, students can see cell division in three-dimensional setting, allowing students to better understand the subject. The usage of 3D printing technology in education increases the quality of education and enhances students' success. Thanks to 3D activities, teacher candidates ' interest, curiosity, attitude and motivation into sciences increase. The statements of teacher candidates support this.

Some answers of science teacher candidates to the question of "How Did you experience a change in your learning life after 3D activities?" are given below:

TC22: "*…My interest in science courses increased thanks to 3D activities. I really enjoyed the course…*".

TC23: "*…I can now design and produce something thanks to 3D activities. This is the most exciting part…*".

Table 5 depicts the answers of science teacher candidates to the question of "What are the limitations of giving 3D printing training in science course?".

Table 5 What Are the Limitations of Giving 3D Printing Training in Science Course?

	f	%
Lack of educators using 3D printers	27	72.9
Lack of 3D printers	25	67.5
Lack of technological equipment	21	56.7
Inadequate course hours	16	43.2
Insufficient students' readiness	8	21.6

Examining Table 5, lack of educators using 3D printer stood at %72.9, representing the highest rate, lack of 3D printers stood at %67.5, inadequate course hours stood at %21.6, representing the lowest rate.

3D printing technology has key importance today. It is envisaged that 3D printing technology can bring significant advantages both in the training process and in the post-training business life. Since it is not very common in education, it is necessary to look for ways to use this technology more effectively. It is believed that educational efficiency can be increased by integrating educational content and 3D printing technology and adapting educational policies to this new technology. The lack of equipment in the STEM lab and educators are important shortages in 3D printer training. The statements of teacher candidates support this.

Some answers of science teacher candidates to the question of "What Are the Limitations of Giving 3D Printing Training in Science Course?" are as follows: TC26: "*…There is not enough printers in STEM laboratory. Only four students can print in each lesson…*" TC27: "*…These activities should be given more importance in the weekly course schedule…*"

The answers of science teacher candidates to the question of "What Are the Advantages Of 3D Printing Training in Science Course?" are given in Table 6.

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Table 6 What are the advantages of 3D printing training in science course?

	f	%
Having 21st century skills	33	89.1
Producing solution to problems	26	70
Using methods from different disciplines	19	51.3
Enabling three-dimensional thinking	14	37.8
Self-production	10	27

Examining Table 6, having 21st century skills stood at %89.1, representing the highest rate, producing solutions to problems stood at %70, self-production stood at %37, representing the lowest rate.

Science courses with 3D STEM activities provide permanent learning. A must of quality education is to be able to convey the subjects to the students with the right sample and tools. 3D printers introduce our children to advanced technology with the goal of having a bright future.

Some answers of science teacher candidates to the question of "What Are the Advantages of Giving 3D Printing Training in Science Course?" are as follows: TC11: "*… I can produce materials for overcoming problems I experienced…*" TC9: "*… Thanks to STEM activities, solution-oriented thinking is the foundation of our work…*"

Converting Knowledge into Reality

Design programs also helps teacher candidates enhance their imagination. Thanks to 3D printers, students can easily convert designed objects into realistic products. Thus, it is a unique experience for students. Teacher candidates can identify the problems they face and produce solutions using design programs. Then, by using 3D printers, they can convert solutions into practice, allowing them to be solution-oriented and more creative. Thanks to 3D printers, they can design the material needed in the science course and produce the product themselves. Teacher candidates can convert their ideas into realistic products. Examining studies on 3D printers in the literature, most of the studies are focused on developing three-dimensional materials Carroll (2015), Lu, Su, Wang & Lu, 2017).

TC32: "*… Thanks to 3D printers, I had opportunity to convert abstract concepts related to the science into perceptible information…*" TC17: "*… The most enjoyable part is imagined, design and create…*". TC15: "*… I can produce materials by myself…*". TC13: "*… I can't believe that I touched objects in my dream…*"

Providing 21st Century Skills

In 3D STEM activities, it is necessary to constantly control the problem status and stages of production. 3D STEM activities allow students to internalize scientific and systematic thinking, and 21st century skills by providing students with best solutions to the problem statue with science, technology, engineering and mathematics tools Beswick and Fraser (2019), Stehle and Peters-Burton (2019), Walan (2019). Learning environment through3D printing STEM activities contribute to the development of 21st century skills Bell (2010), Ravitz et al. (2012).

Teacher candidates have also become aware of this situation. TC23 expressed this situation as follows: "*… I am now aware that my high-order thinking skills have improved thanks to 3D activities…*". ÖA27: "*... We must be equipped with 21st century*

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skills as a teacher of the future...". ÖA31: "*... we must keep up with the digital age... we must be equipped*…"

Increasing Permanent Learning

3D printers provide the opportunity to present concepts and abstract information to the student in a concrete form in the course of science. 3d printers make it easier for students to understand objects that are difficult to visualize. Thus, products obtained through 3D printers significantly increase permanent learning by addressing more than one sense organ. It is a unique experience for students to see their designs as a realistic product Carroll (2015), smiling face, 200). TC19: "… *I do not think that I will forget things that I produced in STEM activities*…" TC14: "… *I learn science subjects better and easier*…".

Imagine, Design, Create

Three-dimensional design has taken its place within STEM education technologies. The importance of 3D printing technology, which has revolutionized manufacturing, is enormous. It also has a very important place in education in terms of students ' motivations. A training system based on design, engineering and production can be provided with 3D printers. Seeing students' own designs in reality is very important for motivation. Design programs also helps teacher candidates enhance their imagination. Through STEM activities, students can imagine, then design and produce through 3D printers. Thanks to 3D printers, students can easily convert their designs into realistic products Karaduman (2018), Güleryüz (2020).

TC7: "… *First I imagine, then design and can touch it*…" TC36: "… *When I get print of three-dimensional materials, I am now aware that my interest, motivation and eagerness to learn in science course increase*…"

It can be said that the training given in has positive effects on teacher candidates in the study which is aimed to disclose their views about 3D STEM activities. This finding is based on positive feedbacks obtained through answers of interviews questions and activities. Four 3D activities were conducted with teacher candidates. In these activities, 3D Builder program and Zaxe (Desktop) PLA program were taught to teacher candidates. Thanks to the activities, teacher candidates designed all kinds of materials for the project using computers within the framework of innovative ideas and produced with a 3D printer. This shows that teacher candidates have the ability to use 3D Builder and Zaxe PLA programs.

The results of this study support the study of Güleryüz et al. (2019) which revealed opinions of teacher candidates about the use of 3D printer in the context of STEM activities. In the study, teacher candidates stated that 3D printers contributed to creating new learning materials. 3D activities help teacher candidates design unique models using their own knowledge and skills and produce with the help of a 3D printer. Such activities contribute positively to the development of teacher candidates ' skills to use technology effectively. These findings are similar to other studies' findings in the literature Campbell et al. (2011), Berman (2012), Güleryüz (2020), Prince (2014), Ratto and Ree (2012).

Today, 3D printers are used in various areas such as education, medicine, construction, aerospace, manufacturing, and architecture. Using 3D printing technology will provide significant benefits both in the education process and business life. Since it is not very common in education, it is necessary to look for ways to use this technology more effectively. As a result, it is proposed that

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educational efficiency can be increased by adapting educational policies to 3D printing technology and modifying educational content according to this technology.

As the widespread use of 3D printing technology in education increases, the interaction between the student and the educator will increase further, and it will be easier for students to gain innovative thinking and creativity skills by creating realistic products. Considering the analysis of data, important findings of the study are as follows: helping teacher candidates use and develop 21st century skills, facilitating their learning and teaching, improving their thinking skills and providing the opportunity to convert their knowledge into a realistic product.

As part of STEM activities, different educational methods that will be formed with the contribution of 3D printers have the effect of facilitating understanding of mathematical and scientific data in more complex structures. Three-dimensional printers are now being used in almost all areas of the industry, especially in the field of prototyping. In addition, it is rapidly entering our daily lives. It increases students ' motivation to learn and allows them to learn by having fun. One of participants stated; "*… 3D printer helped me produce objects in my dream … transferring knowledge to different fields…", "…Giving me opportunity to materialize knowledge*…". Moreover, these activities contribute to teacher candidates' thinking skills, productivity and innovation skills.

4. CONCLUSIONS AND RECOMMENDATIONS

In this study aiming to determine the impact of 3D activities in science course on the awarness of teacher candidates, the following themes are covered related to 3D printer: "21st Century Skills", "Converting Knowledge into Reality", "Mental Skills", "Permanent Learning", "Self-Production", "convenience Of Learning", "Three-dimensional Thinking", and "Imagine, Design, Create". 3D printers provide teachers with creating new learning materials, as well as enabling them to print their own designs, contributing to the development of their skills to use technology effectively. Science course subjects should be taught to students by materializing many abstract concepts in elementary and secondary education. As supported by references to the teacher candidates, 3D printers provide students with materializing concepts, visual information, abstract concepts, especially in biology, chemistry and physics courses. Products obtained through 3D printers increase permanent learning by addressing more than one sense organ.

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