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THE IMPACT OF ROBOTICS CODING AND 3D PRINTING STEM ACTIVITY ON 21ST CENTURY LEARNER SKILLS OF TEACHER CANDIDATES

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ABSTRACT

STEM education focusing on students' 21st century skills aim to increase interest in engineering fields such as 3D printing and robotics coding, which have an important place in the future education system. The aim of this study is to examine the effect of 3D printing and robotics coding STEM activities on the 21st century learner skills of teacher candidates and its sub dimensions (Autonomous, Cognitive, Innovativeness, Flexibility, and Collaboration). 37 science teacher candidates participated in the study which lasted 13 weeks. In this study, mixed research method was used. Quantitative data was obtained through 21st Century Learner Skills Use Scale and qualitative data was taken from the field notes and semi-structured interview. According to the study's findings, teacher candidates used the 21st century learner skills and its sub dimensions at an advanced level. Within the scope of the study, 3D printing, and robotics coding trainings were given to science teacher candidates within the scope of STEM education and activities were made within the scope of these trainings. Four activities were done for 3D printing and three activities for robotics coding. Out of 3D printer programs, 3D-Builder and Zaxe (Destop) PLA were taught. Arduino-IDE and Fritzing for circuit diagram from robotic coding programs were taught. With robotics coding and 3D printing STEM activities, teacher candidates improved 21st century skills such as critical thinking, collaborating, communicating, productivity and creativity. In addition, they have a positive attitude towards science-technology- engineering-mathematics.

Keywords: Robotics Coding, STEM Activities, 21st Century Learner Skills, 3D Printer

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1. INTRODUCTION

Each country's priority is to train individuals who are curious about science and technological developments; can constantly renew themselves; can solve problems and learn throughout their lives. In order to achieve these goals, individuals should be offered learning environments where they can use their existing knowledge and skills, develop new ones Güleryüz, (2020). Today, in the educational system of many countries, it is aimed to train individuals who are interested in science, technological developments; can contribute to social and economic developments and have 21st century skills Güleryüz and Dilber (2021), Güleryüz et al. (2019). STEM education is a holistic approach integrating different disciplines

Smith and Karr-Kidwell (2000). STEM education enables students to establish relationships between the fields of science, technology, engineering, and mathematics through an interdisciplinary approach Thomas (2014), Furner and Kumar 2007).

In our education system, 21st century learners hold an important place. Therefore, it is beneficial to define 21st century learners' skills. This ensures the effectiveness of teaching processes. 21st century skills are one of the main achievements of the STEM education approach. STEM is a new education approach aiming to provide students with critical thinking, creativity, communication, problem solving skills Bybee (2010). STEM education, which enables the integration of science, technology, engineering, and mathematics, is an innovative approach, and creates learning environment that enable students to acquire the 21st century skills. The design thinking process is a model that can be used in STEM activities Simeon et al. (2020), Carroll (2014). STEM education aims to enable students to solve real-world problems, learn knowledge in a more holistic and organized way, relate the knowledge they have learned interdisciplinary and produce by using different disciplines and skills Sweller (1989), Jacobs (1989), Childress (1996), Capraro and Slough (2008), Burrows et al. (1989), Beane (1995), Aydın et al. (2017).

3D printers: It is a tool for our children of learning age, who are curious and have unlimited imagination, to turn their ideas into results. 3D printers contribute to the physical, mental, professional, and social development of students after they enter schools. Students can 3D print the structure of a cell and reproduce an organ by copying it exactly. In addition, it is possible for children to design and produce whatever they want without limiting their imagination. The contribution of 3D printers to education can be briefly listed as follows.

- Thanks to the 3D visuals, it becomes easier to explain the subjects that are difficult to understand by the students.
- By printing out small models of the examples related to the topics to be covered in the lesson, the interest and motivation of the students in the lesson is maintained for a longer period of time. You can also benefit from our 3D Printing Service for printing out models.
- Students are allowed to switch to project-based learning. In addition, students are provided to turn their own projects into products by making them in a non- computer environment.
- Interactive classroom activities are provided. The information that teachers share with their students does not stay only between the pages of the book, and teachers can create any example they want and share it with students Güleryüz et al. (2019), Güleryüz (2020), Güleryüz and Dilber (2021).

Robotic coding is aimed at writing a computer program using a software language. Robotic coding has now become an indispensable part of our lives. We use coding in microwave, vehicle, telephone, TV and many other areas. Robotic coding is written instructions that a robot or computer program can detect and execute. The code needs to be designed so that the task to be given to the robot can be done. The robot performs the requested task with the instructions given by the code. Robotic coding allows the robot's movements to be controlled and its task to be reconfigured as expected. The most important key point in robotic coding is that the robot can provide you with notifications about your work Güleryüz et al. (2020).

Benefits of Robotic Coding Training; Robotics is seen as the technology of the future by developing day by day. For this reason, countries are making significant investments and incentives in this field. So much so that robotics education was given at a young age and children were trained in robotic coding. Thanks to robotics education, children and young people are both prepared for the future by receiving robotics education at a young age, and their analytical skills are improved. Robotic coding contributes to the development of individuals' problem solving, organizational and responsibility skills. Coding also teaches academic skills. With robotic coding, individuals can combine their coding and programming skills in STEM (science, technology, engineering, art, and mathematics) fields. Robotics coding gives individuals the skills of struggle, problem solving, team sense and cooperation and perseverance Güleryüz (2020).

Creative thinking: Robotics coding is an application that requires creativity. Children who attract attention with their creativity during training can better observe which areas they are prone to, and their analytical and innovative thinking skills develop with robotic coding.

Problem Solving Skill; Robotics coding enables productivity and creativity to flourish. In order for these aspects to develop, problem solving skills must also be developed. Those who deal with this field gain the ability to produce alternative solutions to the problems they experience with robotic coding.

Technical Skills: With the robotics education, the motor skills of the students also develop. Coding also develops math skills. In addition, one of the benefits of the education that provides the comprehension of technical basic information is that it enables students to establish interdisciplinary connections Güleryüz (2020), Güleryüz and Dilber (2021).

1.1. 21ST CENTURY LEARNER SKILLS

Many projects (Apple skills classes, the FATIH project etc.) aiming to improve learning processes paves the way for technology integration. The success of the projects mainly depends on the criteria of ensuring the adaptation of the pedagogical skills of students and teachers NCES (2002). The technologies used in educational environment are not only outdated, but also have instrumental function Kaya et al. (2012).

Identifying the 21st century learner skills will benefit in getting to know them better and ensuring the effectiveness of teaching processes. The 21st century learner skills have been mentioned in Turkish Industrialists' and Businessmen's Association's study TÜSİAD (1999).

STEM education offers students a chance to improve 21st century skills Bybee (2010). In the sample activity plans prepared in accordance with the achievements in the curriculum of the Ministry of Education; students are encouraged to unveil a product by using 21st century skills. Thus, it is believed that the knowledge and skills obtained as a result of such a teaching process will have a more permanent effect Göksün and Kurt (2017).

1.2. SUB-DIMENSIONS OF 21ST CENTURY LEARNER SKILLS

Within the framework of the study, 21st century learner skills of teacher candidates have been studied in four dimensions.

Autonomous Skill: It arises from the integration of self-control, self-management, ability to work with a group or individually.

Cognitive Skill: It provides encoding information in mental processes and forming information as a result of mental processes.

Innovativeness Skills: It means to adapt to new technologies. It is also known as keeping up with the digital age.

Collaboration and Flexibility Skills: It enables the success of activities based on collaboration and makes learning environments more flexible Güleryüz, (2020).

21st century skills.

With this concept, it is explained what skills they should be equipped with when preparing our children for the future Güleryüz, (2020); Zeybek (2019).

- Raising STEM literate individuals,
- Ability to use English at a high level,
- Information and technology literacy,
- Advanced transferring skill
- Able to use the mother tongue effectively,
- Critical thinker
- Able to speak two foreign languages
- Advanced three-dimensional thinking skills,
- Improved sense of rhythm,
- Able to produce solutions against the problems,
- Designing his own future,
- Advanced communication skills, leader in the field,
- Capable of designing and manufacturing (using three-dimensional design, robotics, and wood workshops.)
- Capable of coding, preparing algorithms, having a high level of knowledge and transactional thinking skills,
- Able to communicate and work cooperatively,
- Sensitive to the world and the environment,
- Enhanced sports and arts skills,
- Creating solutions,
- Taking initiative,
- Coding,

1.3. IMPORTANCE OF RESEARCH

STEM education aims to up skill students through collaboration, systematic thinking, creativity, and skills to solve the problems optimally by focusing on integrating science, technology, engineering, and mathematics within the framework of 21st century skills.

Ministry of National Education, General Directorate of Innovation and Educational Technologies shared views about 21st century skills, STEM education, robotics coding and 3D printing within the scope of the 2023 education vision.

"…Many countries want their students to produce, contribute to social and economic developments, and have 21st century skills…."

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

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

1.4. PURPOSE OF RESEARCH

The concept of 21st century learner skills has been mentioned frequently in the literature. This study investigates the impact of STEM activities on 21st century learner skills of teacher candidates.

In this context, the sub-objectives of this research are shown below.

1) Do 3D printing and robotics coding STEM activities have an impact on 21st century learning skills of teacher candidates?

- What were the levels of 21st century learning skills of teacher candidates before robotics coding and 3D printing STEM activities?
- What are the levels of 21st century learning skills of teacher candidates after robotics coding and 3D printing STEM activities?
- Is there a significant difference between before and after the levels of 21st century learning skills of teacher candidates in terms of robotics coding and 3D printing STEM activities?

1.5. RESEARCH PROBLEM

What is the impact of robotics coding and 3D printing STEM activities on the levels of 21st century learning skills of teacher candidates and sub-dimensions (collaboration, autonomous, cognitive, flexibility, and initiative)?

2. MATERIALS AND METHODS

In this study, mixed research method was used. Mixed method integrates quantitative and qualitative data. It has also been reported that more extensive data can be collected by using mixed method. The content analysis method was used for the analysis of qualitative data. The content analysis method means that the qualitative and quantitative studies carried out independently of each other in a specific subject or field are examined and organized in depth. Thus, the general trends in that subject or field are determined Büyüköztürk et al. (2013).

2.1. SAMPLING

37 Science teacher candidates participated in the study voluntarily.

2.2. APPLICATION

In this study, STEM education program covering robotics coding and 3D printing activities, which made learning simple and fun for science teacher candidates, were implemented. This program lasted 2-hours a week for 13-weeks (52-hours). Within the scope of STEM education, Arduino-IDE, and Fritzing for circuit diagram for robotic coding programs and 3D-Builder and Zaxe PLA for 3D printer programs were taught in robotics coding and 3D printing activities. A brief summary of the application on STEM activities with 3D printing and robotics coding 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 candidate was asked to draw on the shape they would make before designing in the 3D-Builder Program. Then they were asked to design the two-dimensional shapes in the 3D-Builder program. They were then taught Zaxe 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.
- During the next three weeks, teacher candidates were given robotics coding training as part of STEM activities. As part of this training, Arduino-IDE and Friztzing programs were taught.
- During the following three weeks, three activities related to robotics coding were done.

Table 1 STEM Activity Program for Robotics Coding and 3D Printer

Week 1	What is STEM Education?
Week 2	Teaching of 3D-Builder
Week 3	Teaching of Zaxe PLA
Week 4	3D Printer Activity; Making Stick Man
Week 5	3D printer activity; Making Key Holder
Week 6	3D Printer Activity; Making A Van
Week 7	3D Printer Activity; Making A Tank
Week 8	Teaching of Arduino-IDE Program
Week 9	Teaching of Arduino-IDE Program
Week 10	Teaching of Fritzing Program
Week 11	Robotics Coding Activity; Led Bulb
Week 12	Robotics Coding Activity; Making A Sensor
Week 13	Robotics Coding Activity; Making A Parking Sensor

1. Activity 2. Activity 3. Activity

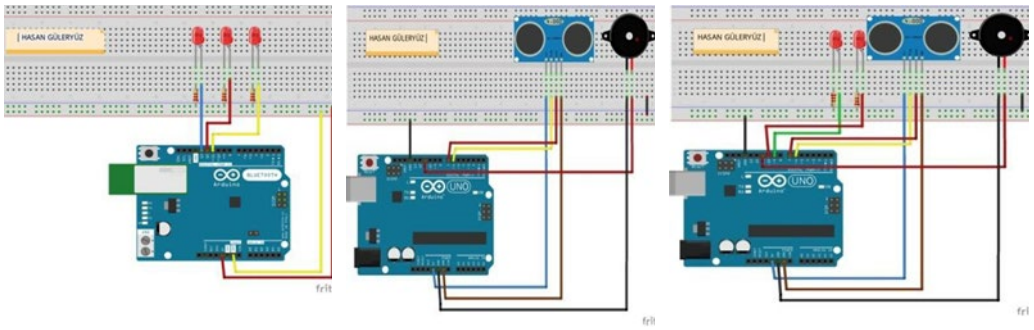

Figure 1 Robotics Coding Activities

1. Activity 2. Activity 3. Activity 4. Activity

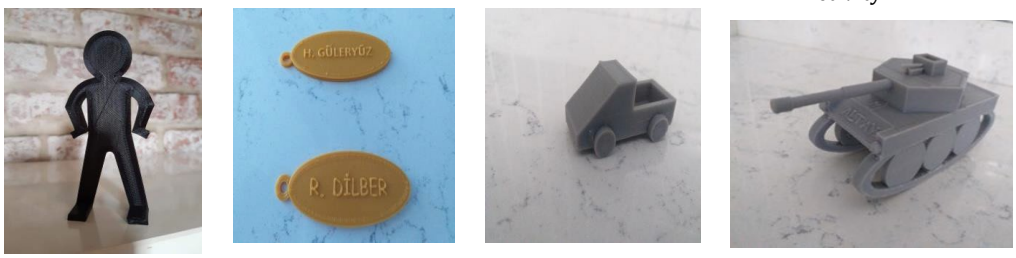

Figure 2 3D Activities

2.3. DATA COLLECTION TOOLS

Quantitative Data

21st Century Learner Skills Use Scale

21st century learner skills use scale was developed by Göksun (2016). The objective of the scale is to determine teacher candidates' level of 21st century learner skills use. Validity and reliability of the scale were conducted. The Cronbach Alpha coefficient was used to determine the reliability of the scale. The Cronbach alpha value of the scale was .892. According to Ozdamar (2013), if the Cronbach alpha coefficient is in the range of 0.70 to 0.90, the data collection tool has a high level of reliability. In terms of sub dimensions, Cronbach alpha values were .877 for cognitive skills, .706 for autonomous skill, and .818 for innovativeness. The same judgment can be reached for the mentioned factors. Cronbach alpha value of collaboration and flexibility skills was 672. According to Ozdamar (2013), these values indicate a sufficient level of reliability. 21st century learner skills scale (five-point Likert scale) consists of 31 items and four sub-dimensions.

1) Sub-dimensions
2) Autonomous skills
3) Cognitive Skills
4) Innovativeness Skills
5) Collaboration and Flexibility Skills

2.4. QUALITATIVE DATA

Interview questions prepared by the researcher were examined by two experts. In line with feedback from experts, some changes were made to the first questions prepared. Five students who did not participate in the study examined new questions. According to feedback from students, researcher and experts, interview questions were put into their final form. 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 course, confirming the accuracy of the notes. Field notes were used in the analysis of qualitative data and the interpretation of events.

Semi-structured Interview On 21st Century Skills

1) Which skills can make you learn effectively as a 21st century learner?
2) What are the points you pay attention to when structuring your learning processes as a 21st century learner?
3) What are 21st century skills?

2.5. ANALYSIS OF THE DATA

Paired sample t-test was performed for the data being homogeneous. On the other hand, Wilcoxon test was performed for the data not being homogeneous. In addition, the Cronbach alpha value was considered in determining the reliability of quantitative data collection tools.

After completing the activities, the semi-structured interview form prepared with expert opinions was given to the teacher candidates. In this way, an environment was provided for teacher candidates to express their ideas in a more comfortable and neutral way.

By analysing qualitative data, an attempt was made to obtain thoughts of teacher candidates on the effect of robotics coding and 3D printing STEM activities on 21st century skills.

3. RESULTS

3.1. FINDINGS OF QUALITATIVE DATA ANALYSIS

This section presents the results of analysis.

1) Do STEM activities on 3D printer and robotics coding have an impact on 21st century learning skills of teacher candidates?

Table 2 21st Century Learner Skills Use Levels: Paired Sample Test

		x̄	Ss	shx	Lower	Upper	t	df	P
1. Variable	PRETEST-POSTTEST	-12.02	5.91	0.97	-14	-10.05	-12.36	36	0

According to the results of paired sample t test in Table 4, there was a statistically significant increase in teacher candidates' 21st century learner skills

use after practices had been completed [t (36) = -12.36, (p = 0.00)]. The calculated Cohen D effect size (d=2.03) showed that the difference was significant. Based on this finding, STEM activities had a positive effect on 21st century skills of teacher candidates.

a) What were the levels of 21st century learning skills of teacher candidates before robotics coding and 3D printing STEM activities?

As stated in the data analysis section, in answering this research question, the pre-application score of the 21st century learner skills usage scale of the pre-service teachers of STEM activities with robotics coding and 3D printers was obtained.

Table 3 The Levels Of 21st Century Learner Skills Use Before Activities

Score	n	x̄	ss
Use Of Cognitive Skills	37	3.92	0.31
Use Of Autonomous Skills	37	2.97	0.37
Use of Collaboration and Flexibility Skills	37	3.17	0.4
Use of Innovativeness Skills	37	3.61	.56
Total Score of 21st Century Learner Skills Use	37	3.41	.41

Table 3 shows the scores obtained from sub dimension of 21st century learner skills of teacher candidates. The main reason why cognitive skills were the most used skill could be explained by the fact that our students used their cognitive processes more in the education system. The fact that autonomous skills were the least used skills among the learner skills could be seen as an indication of the teacher candidates utilizing self-management skills less than other skills. Because 21st century learner skills use score was standardized, a teacher candidate could obtain (1 – 5) points. The fact that 21st century learner skills use score of teacher candidates before activities was higher than the midpoint 3 (x̄= 3.41) could be accepted as an indicator that teacher candidates use 21st century learner skills at a level over the average.

b) What are the levels of 21st century learning skills of teacher candidates after STEM activities on robotics coding and 3D printer?

As stated in the data analysis section, in answering this research question, a standardized post-application total score was obtained from the 21st century learner skills use scale of pre-service teachers of STEM activities performed with robotics coding and 3D printing was obtained.

Table 4 The Levels of Sub Dimensions Of 21st Century Learner Skills Use Before Activities

Score	n	x̄	ss
Use of Cognitive Skills	37	4.13	0.23
Use of Autonomous Skills	37	3.66	0.28
Use of Collaboration and Flexibility Skills	37	3.78	0.24
Use of Innovativeness Skills	37	3.69	0.5
Total Score of 21st Century Learner Skills Use	37	3.81	0.31

Table 4 shows the scores obtained from sub dimension of 21st century learner skills of teacher candidates. The reason behind the fact that cognitive skills were the

most used skills is the higher rate of utilization of cognitive skills by students in the education system. The fact that autonomous skills were the least used skills among the learner skills could be seen as an indication of the teacher candidates utilizing self- management skills less than other skills. The fact that 21st century learner skills use score of teacher candidates after activities was higher than the midpoint 3 ($\bar{x}$= 3.81) could be accepted as an indicator that teacher candidates use 21st century learner skills at a level over the average.

c) Is there a significant difference between before and after the levels of 21st century learning skills of teacher candidates in terms of STEM activities on robotics coding and 3D printer?

The analysis of autonomous, collaboration, cognitive and innovativeness skills, sub dimensions of 21st century learner skills, is given below.

3.2. AUTONOMOUS SKILLS T-TEST.

The paired sample t-test was used to determine the effect of the activity on autonomous skills.

Table 5 Autonomous Skills Paired Samples T Test

		x̄	ss	shx	Lower	Upper	t	df	p
1.Variable	Pretest-	-4.45	2.74	0.45	-5.37	-3.55	-9.88	37	0
	Posttest								

According to the results of paired sample t test in Table 5, there was a statistically significant increase in autonomous skills use after activities had been completed; [t (37)= -9.88, (p = 0.00)]. The calculated Cohen D effect size (d=1.6) showed that the difference was significant.

3.3. COLLABORATION AND FLEXIBILITY SKILLS T TEST

The paired sample t-test was used to determine the effect of the activity on collaboration skills.

Table 6 *Collaboration Skills Paired Samples T Test*

¤		x̄	ss	shx	Lower	Upper	t	df	p
1.Variable	Pretest-	-3.67	2.45	0.4	-4.49	-2.85	-9.12		0
	Posttest							37	

According to the results of paired sample t test in Table 6, there was a statistically significant increase in collaboration skills use after activities had been completed; [t (37) = -9.12; (p = 0.00)]. The calculated power rating (d= 1.5) indicates that the power of the analysis is quite high according to Cohen's (1988) criteria.

3.4. COGNITIVE SKILLS T-TEST

Wilcoxon signed-ranks test was conducted to determine the effect of the activity on the cognitive skills of teacher candidates.

Table 7 ***Cognitive Skills Wilcoxon Test***

	Posttest – Pretest
Z	-5.129[b]
Asymp. Sig. (2-tailed)	0

Table 7 reveals whether variables obtained from the results of cognitive skills were meaningful [(Z= -5.13), (p= .00)]. The calculated power rating (r= .60) indicated that the power of the analysis was quite high according to Cohen (1988) criteria.

3.5. INNOVATIVENESS SKILLS T TEST

Wilcoxon signed-ranks test was conducted to determine the effect of the activity on the innovativeness skills of teacher candidates.

Table 8 Innovativeness Skills Wilcoxon Test

	Posttest – Pretest
Z	-1.342[b]
Asymp. Sig. (2-tailed)	.018

Table 8 reveals whether variables obtained from the results of innovativeness skills were meaningful [(Z= 1.342), (p= .018)]. Power rating was (R= .15). According to Cohen (1988) criteria, the power of the analysis was quite high.

3.6. FINDINGS OF QUALITATIVE DATA ANALYSIS

Structured interviews were conducted with teacher candidates to further examine their 21st century learner skills. Some of teacher candidates' views on 21st century learner skills are given in tables below.

"Which skills can make you learn effectively as a century learner?" was asked to teacher candidates and the codes based on the content analysis are given in Table 9.

Table 9 21. Which skills can make you learn effectively as a century learner?

	F	%
Having 21st century skills	32	86.4
Being aware of technological developments	24	64.8
Having a grasp of his field	21	56.7
Ability to relate to other disciplines	17	45.9
Having sufficient knowledge and skills	15	40.5

Ability to use technological tools in learning environment	9	24.3
Empathy and relationship with students	6	16.2
Knowing the level of readiness of each student	4	10.8

Examining Table 9, "having 21st century skills" stood at 86.4%, followed by "being aware of technological developments" at 64.8%. At 10.8%, "knowing the level of readiness of each student" was ranked the lowest.

What students will do and how they will behave cannot be known in advance. Therefore, the most important teaching material of the teacher is himself. A good teacher is one who develops existing opportunities, stands on his dignity and, can adapt to new situations. In addition, he is ready to take possible risks. Teachers should not only be practitioners of the educational program, but also can change and renew it for the effectiveness of the program. It is necessary to prepare teachers for challenges of the 21st century because teachers are the first to be affected by changes. The quality of teacher training is the main element in ensuring that teachers voluntarily participate in the process of renewing the educational program. Today, teachers are supposed to have full knowledge of their field, constantly update themselves, and have sufficient knowledge and skills. To put it simply, a teacher needs to be equipped with 21st century skills.

Some answers of science teacher candidates to "Which skills should a teacher have for effective learning?" are presented below:

TC1 (Teacher Candidate): "…. Teacher candidates, that is, in particular, must have full knowledge of our field…"

TC2: "…. I keep up with the technological developments that occur in daily life and constantly adapt myself to them…"

Answers to the question of "Which Points Do You Pay Attention to When Structuring Your Learning Processes as A Century Learner? "Are given in Table 10.

Table 10 What are the points you pay attention to when structuring your learning processes as a 21st century learner?

	F	%
Translating theoretical knowledge into practice	14	37.8
Researching an interesting topic	11	29.7
Choosing the best resources for personal interests and needs	9	24.3
Passing judgement on a topic	7	18.9
Using critical thinking skills	6	16.2
Participating in group works	5	13.5
Having an exchange of ideas in learning environment	5	13.5
Ability to practice what they have learned	4	10.8

Examining Table 10, "putting theoretical knowledge into practice" stood at 37.8%. It was followed by "researching an interesting topic" at 29.7%, and "practicing what they have learned" at 10.8%.

21st century skills are intertwined skills that cannot be separated from each other. Collaboration and communication, in particular, are considered to be the basis of all other skills. In this study, as the communication and cooperation of the group grew stronger over time, teacher candidates began to perform their duties by

demonstrating critical thinking skills. Communication and collaboration from 21st century learner skills enable structuring of knowledge and emerging of other 21st century skills. Teacher candidates as 21st century learners are expected to have solution-oriented thinking, clearly express their ideas, and have critical thinking skills.

Some answers to the question of "Which Points Do You Pay Attention to When Structuring Your Learning Processes as A Century Learner? "Are given below:

TC3: "…We receive positive criticism from each other in our group or individual work…"

TC4: "…We took opinions of our friends to come up with solutions to the problems we faced…"

Science teacher candidates were asked the question of "What do you understand from 21st century learner skills?". The answers of them are seen in Table 11.

Table 11 21. What Do You Understand from Century Learning Skills?

	F	%
STEM activities	35	94.5
Robotics coding	32	86.4
3D printing	29	78,3
Artificial intelligence	21	56.7
Digital age	17	45.9

Examining Table 11, STEM activities stood at 94.5%, robotics coding at 86.4%, and the digital age at 45.9%.

Recent scientific and technological developments are unwittingly changing how we learn, communicate, and work. Recently, experts have been pondering the consequences of these changes and what kind of world awaits us in the future. Various theories are being prepared about what we need to do in order to adapt to the changes that technology has brought about in our lives, and what skills we need to give our children to be able to exist in this new world in a happy, successful and productive way. In the STEM Education Report (2016) published by the Ministry of education, it was emphasized that Turkey needed innovative individuals who kept up with the digital age and had research skills. Through STEM activities, teacher candidates expressed their interest in robotics coding and 3D printing which were related to 21st century skills.

The answers of science teacher candidates to "What do you understand from 21st century learner skills?" are given below:

TC5: "… 21. Century skills remind me of the digital age. Robotics, coding…"

TC6: "…Without STEM activities, we would not be successful at robotics coding and 3D printing…"

4. DISCUSSION

This part covers the results of the study into the effect of STEM activities on 21st learner skills of teacher candidates.

In this study which examined the effects of STEM activities on the 21st century learner skills of teacher candidates, considering the results of the analysis, the 21st century learner skills of teacher candidates improved after the activities on 3D printing and robotics coding (see Table 2). Thanks to STEM activities, the interest of teacher candidates in STEM fields will increase. Thus, the teacher candidates will become skilful at the 21st century skills such as information and technology literacy, critical thinking, collaboration, communication, and creativity. The integration of STEM into the education system has led to teacher candidates being productive and creative.

Since 21st century learner skills use score was standardized, a science teacher candidate could obtain 1 – 5 points Göksün and Kurt (2017). The fact that 21st century learner skills use pre-test score of teacher candidates was higher than the midpoint 3 ($\bar{x}$= 3.41) could be accepted as an indicator that teacher candidates used 21st century learner skills at a level over the average before the activities. The fact that 21st century learner skills use post-test score of teacher candidates was higher than the midpoint ($\bar{x}$= 3.81) could be accepted as an indicator that teacher candidates improved significantly 21st century learner skills after the activities. Moreover, cognitive skills were the most used skills (pre-test $\bar{x}$ = 3.92 andpost-test $\bar{x}$ = 4.12), and autonomous skills were the least used skills (pre-test $\bar{x}$ = 2.97 and post-test $\bar{x}$ = 3.66). Although autonomous skills were the least used skills among the learner skills, significant differences were found between the pre-test and post-test (see Table 3 and Table 4). In short, STEM-based science activities has contributed to the development of learning skills of students.

Cognitive skills are products that are formed as a result of the processing and coding of information in mental processes. Autonomous skills are autonomous learning skills that arise from the integration of self-control, self-management, ability to work with a group or individually. Innovation skills are about adapting to new technologies and keeping up with the digital age. Collaboration and flexibility skills are to increase efficiency and to make learning environments flexible.

Examining the results of the analysis, there were positive significant differences in sub dimensions of 21st century learner skills of teacher candidates after STEM activities (See Table 5, Table 6, Table 7 and Table 8).

The reason why cognitive skills were one of the most used skills in the study could be explained by the fact that our students used their cognitive processes more in the education system. But the fact that autonomous skills were less used in learner skills compared to other skills could be explained as an indicator that teacher candidates used their self-government skills less than other skills. On the other hand, unfortunately, teacher-centred education still prevails in many of our classrooms. This, in turn, leads students ' self-management skills, such as decision-making, planning, communication, time management and motivation, to not fully develop. As a result of the studies conducted in 2006, the curriculum of undergraduate teacher training programs (2006- 2007) is still applied in the faculties of education. Although this program is flexible, it usually covers field knowledge and skills (50%), professional teaching knowledge (30%) and general culture studies (20%) for each field YÖK (2007). As another reason why the cognitive skill of teacher candidates attending teacher training programs is higher than their other skills, it can be explained that teacher training programs have lots of field knowledge courses, on the other hand, the number of culture courses in which they can transfer this information is limited. These results are similar to the study conducted by Göksün and Kurt (2017). Robotics coding and 3D printing STEM

activities affected 21st century learning skills of teacher candidates positively. According to the analysis of sub-dimensions (Autonomous, cognitive, innovativeness, collaboration, and flexibility skills), teacher candidates used the cognitive skills the most frequently and they used autonomous skills the least frequently.

Similarly, Eryılmaz and Uluyol (2015) revealed the relationship between the FATIH project, a technology integration project, and 21st century skills. As a result of this research, the FATIH project was the key to the success of individuals in their business and education life. It also helped individuals gain 21st century skills including information, technology, and media literacy. Anagün et al. (2016); Günüç et al. (2013); Güleryüz (2020); and Yalçın (2018) found similar results in the literature.

5. CONCLUSIONS

According to the results of the qualitative analysis, it was observed that there was a significant difference in the development of 21st century skills of teacher candidates receiving STEM education and that they used these skills at an advanced level. In addition, in the structured interviews, teacher candidates stated that the activities performed positively contributed to problem solving, creativity, critical thinking skills and cooperation-communication. These skills are among skills of 21st century. From this aspect, STEM activities performed have been influential in the development of 21st century skills of teacher candidates. According to a teacher candidate, "… As the teacher of the future, STEM activities on 3D printing and robotics coding allow us to keep up with the digital age…". One of the most important aims of STEM education is to develop individuals' 21st century skills. Another aim is to create awareness in students in teaching science and to reveal their potential. Some comments of teacher candidates were as follows.

"… STEM activities are informative, very useful, and entertaining…". "… We are not aware of how time passes in class…".

"…We feel ourselves as engineers…",

"… Thanks to these activities, I now realize that I am a teacher candidate equipped with 21st century skills…".

Teacher candidates expressed that STEM education integrated into education system enabled making learning permanent, improving imagination, and raising individuals equipped with 21st century skills.

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