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To cite this article:

Orhan, U., & Demirhan, E. (2025). Exploring the primary school students' cognitive structures of 3D printers from multiple perspectives. *International Journal of Education in Mathematics, Science, and Technology (IJEMST), 13*(5), 1159-1176. https://doi.org/10.46328/ijemst.5705

International Journal of Education in Mathematics, Science and Technology

2025, Vol. 13, No. 5, 1159-1176 https://doi.org/10.46328/ijemst.5705

Exploring the Primary School Students' Cognitive Structures of 3D Printers from Multiple Perspectives

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Article Info

Article History

Received:
11 January 2025
Accepted:
4 July 2025

Keywords

Educational technologies
Technology integration in education
3D printer
Primary school students
Phenomenology

Abstract

The aim of the current study is to develop a detailed understanding of how third-grade primary school students construct 3D printers in their minds based on their initial knowledge about 3D printers. This study, which was conducted with a phenomenological design, is one of the qualitative research methods. The participants of the study consisted of 52 third-grade students who were selected through a criterion sampling method. The implementation phase of the research was planned as two lesson hours. Data was gathered via semi-structured student interview form, semi-structured teacher interview form and unstructured researcher observation notes. The results of the research showed that participants have a high interest in 3D printers. Besides, it was found that the participants were willing to obtain detailed information about 3D printers. In addition, it was concluded that although students had a limited understanding of the usage areas of 3D printers, they could associate them with education.

Introduction

During the 21st century, called the "digital age" or the "age of technology", several new technological tools have entered our daily lives to fulfill individuals' needs and make life easier. New tools continue to emerge at an ever-increasing pace. The newly developed technological tools have a wide range of applications in various fields such as manufacturing, medicine, military, food, and construction, as well as individual usage. However, these tools are also gaining ground outside the areas targeted by the manufacturers, thanks to the spillover effect of technology (Lejeune, 2015). Education is unquestionably one of the most significant of these areas. The integration of newly developed technological tools is intended to improve the educational process. Overall, integrating new technologies into educational processes has advantages such as materializing concepts, individualizing teaching, and enabling each student to progress in their own style and at their own pace (Eisenberg, 2013; Makarova & Makarova, 2018). Thus, the integration of new technologies into educational processes is considered a goal to be achieved.

Following the trend emerging especially in developed and high-level prosperity countries, Türkiye is also closely monitoring assistive technologies to be used in education. Robotic coding tools, virtual reality/augmented reality

applications, and 3D printers have become prominent for this purpose. The integration of 3D printers into educational processes can yet be considered to be at an early stage since 3D printers are a relatively new technology. Therefore, the efforts to increase the effectiveness of the integration of 3D printers into education have gained momentum in recent years. However, Yıldırım et al. (2018) revealed that only 11 out of 1153 studies on the integration of 3D printers into teaching courses were conducted in the field of educational sciences. Thus, the necessity of addressing this issue from the perspective of educational sciences, especially science education, comes to the fore. The first step of the integration can be considered as introducing 3D printers to students, who are the main subject of the education, and providing them with information about the features and working principles of 3D printers. This study aims to identify and describe the subjective experiences of third-grade primary school students encountering 3D printers from multiple perspectives. Identifying how students construct 3D printers in their minds is expected to guide the next steps and studies for the integration of 3D printers into education.

3D Printers and Education

3D printers create a physical three-dimensional model from a digital file containing a three-dimensional (x-y-z axis) blueprint. The users can create their digital illustration files or they can also use websites where they can access pre-made illustrations for free or for a fee. It is also possible to digitize existing physical models using 3D scanners. The 3D printing process of a digital illustration is a process of melting the raw material, called a filament, and depositing very thin layers on top of each other in an orderly and automated way until the entire model is formed (Horn & Harrysson 2012). The working principle of 3D printers is also called additive manufacturing or layered manufacturing (Gokhare et al., 2017).

3D printers are a revolutionary technology as they have features that can turn design and production concepts upside down (Berman, 2012). It is therefore widely used in almost all industries, especially in construction (Bos et al., 2016), healthcare (Bergmann et al., 2010), nutrition (Lipton et al., 2015), and engineering (Hu & Jiang, 2017) (Bonfield et al., 2020). However, popular movements making design and production enjoyable for students, such as "Maker" (Dougherty, 2012) and "Do it yourself" (Holtzman et al., 2007) have led to the widespread use of 3D printers as an individual hobby. With the spread of 3D printers in society, it has become increasingly imperative to integrate them into the curriculum to qualify individuals with the necessary competencies. In addition, 3D printers have inspired STEM and STEAM studies, as the Next Generation Science Standards (NGSS, 2013) and Standards for Technology Literacy (ITEA, 2007) also focus on engineering and design.

Since the creation of 3D drawings and the use of printers requires technical knowledge and skills, their use in education has first started at the higher education level (Vaccarezza & Papa, 2015). In parallel to the positive results achieved at the higher education level, the increased availability of 3D printers owing to their low cost has led to the widespread use of these technologies (Eisenberg, 2013). However, the use of 3D printers in education has been paved with the development of modeling software (for example SketchUp, Tinkercad, Autodesk123D) and printer models (for example RepRap, Arçelik PT1000) (Ranellucci, 2013) that appeal to young age groups/novices (Chen et al., 2014; Grant et al., 2016; Maloy et al., 2017).

The use of 3D printers in education is based on well-established principles such as the activation of multiple sensory organs of students and the tangibility of teaching (Moyer, 2001). Romanek and Lynch (2020) report that course materials produced using 3D printers activate students' sense of touch, which is not often used in classical classrooms. Abouhashem et al. (2015) suggest that 3D printers have a facilitating effect on students' learning content knowledge. The use of 3D printers supports the development of many 21st century skills such as creativity (Chang et al., 2016; Hughes, 2017), design-oriented thinking (Greenhalgh, 2016; Leinonen et al., 2020), spatial reasoning (Chen et al., 2014; Yıldırım & Keşan, 2022), collaboration and problem-solving (Trust et al., 2018) as well as content knowledge when organized by constructivism (Trust & Maloy 2017). Furthermore, Brown and Hurst (2012) argue that the use of 3D printers to create objects related to students' interests supports their imagination. Additionally, Ford and Minshall (2019) suggest that 3D printers can be used to create experimental setups (Bull et al., 2014) as well as to develop students' scientific and mathematical comprehension. However, despite the significant potential of 3D printers, there is still very limited evidence on how to achieve meaningful integration at the K-12 level (Cheng et al., 2020).

While there are studies that 3D printers generally contribute to achieving positive educational outputs, there is no consensus on the way how to integrate them into education (Assante et al., 2020). Tillinghast et al. (2014) assert that 3D printers can be incorporated in three stages, from pre-school to high school level, and in two ways, active or passive (Figure 1). "*Active*" integration involves providing students with the knowledge and skills related to 3D printers. "*Passive*" integration is where the knowledge and skills related to 3D printers are positioned in a way that serves to achieve educational goals. Tillinghast et al. (2014) conceptualized active and passive integration along grade levels from preschool to 12th grade. The first stage aims to ensure "*active integration*", from pre-school to the fourth grade of primary school. Thus, students should be introduced to 3D printer technologies from preschool to the fourth grade of primary school, and in the second and third grades, progressive planning should be made in which students' knowledge and practice levels on 3D printers gradually increase.

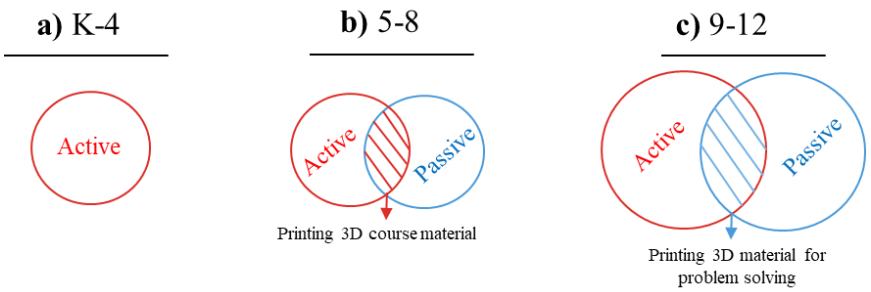


Figure 1. Integration of 3D Printers according to Grade Levels [a) 1st Stage, b) 2nd Stage, c) 3rd Stage]

The prerequisite for the integration of 3D printers into education is that teachers and students acquire fundamental knowledge and skills about 3D printers (Assante et al., 2020). While the teachers' knowledge is sufficient to develop materials and use them to support teaching, students should also have a basic knowledge and skills about 3D printers for a student-centered integration. Insufficient emphasis on this stage may lead students to perceive 3D printing as a difficult and laborious task, disappointing and/or frustrating because they cannot carry out the 3D printing process properly (Nemorin, 2017). Therefore, it is important that the active integration, often perceived as a prerequisite for passive integration, is implemented with precision. The introduction of basic

information by familiarizing students with 3D printers, the entry level of active integration for students, is considered appropriate for the primary school level (Tillinghast et al., 2014).

A review of the literature suggests that the use of 3D printers at the K-12 level has expanded and the issue has been addressed in different aspects (Cook et al., 2015). There are studies on the use at various levels such as preschool education (Avanzini et al., 2019; Farnicka & Serrano Diaz, 2019), primary school education (Anđić et al., 2023; Grant et al., 2016; Kwon et al., 2018; Leinonen et al., 2020; Spyros et al., 2021; Stansell & Tyler-Wood, 2016) and secondary school education (Monkovic et al., 2022). For example, Spyros et al. (2021) concluded that 3D printers positively affected elementary school students' conceptual understanding of friction force and reduced their anxiety. In Türkiye, studies on 3D printers are concentrated at the middle school level (Arık-Karamık, 2022; Avinal & Aydın, 2022; Çoklar & Çekirge, 2020; Gürel-Taşkıran, 2019; Küçüksolak, 2019; Şen et al., 2020; Yıldırım & Keşan, 2022). However, there are several studies that target high school students (Küçüksolak, 2019) and pre-service teachers (Arslan & Erdoğan, 2021; Güleryüz et al., 2019; Güleryüz & Dilber, 2022; Karagöz & Şahin-Çakır, 2020). At the primary school level, there is only one study that was conducted by Kavas (2021) on its use in the teaching of fractions in the 4th-grade mathematics course.

To the best of our knowledge, there are a limited number of studies on familiarizing the new generation, called the “alpha generation” (McCrindle, 2021) and “technology natives” (Prensky, 2005), with 3D printers and obtaining their opinions. However, the fact that primary school students are aware of this new technology, described as “The First Lady of Emerging Technologies” (Kaur, 2012), is believed to help take the first step in the integration of 3D printers into education. Vavra et al. (2011) emphasize that discovering how K-12 students can develop a deep understanding of the 3D printing and design process is important for devising an effective implementation of 3D technology in these classrooms. Thereby, the tendencies of students' cognitive and affective structures related to the later stages of integration can be identified based on their mental structures. Therefore, this study aims to identify and describe the subjective experiences of third-grade primary school students who were introduced to 3D printers for the first time and how they constructed 3D printers in their minds.

Method

The research was implemented following the phenomenological approach within qualitative research methods. The phenomenological approach is used to determine how phenomena, events, situations, or experiences are constructed within individuals, their perceptions, and interpretations of reality, in short, the "essence" of the "phenomenon" (Merriam, 2013). In the present research, the participants were allowed to experience the printing process of 3D printers, which is the phenomenon examined in the research. Based on the experiences, the participants' common understanding of the 3D printer, that is, the essence, was tried to be described in detail by considering the data holistically obtained from different sources.

Participants

The participants of the study were involved according to the criterion sampling method, one of the purposive

sampling methods, following the qualitative research paradigm. The criteria sampling is based on the principle of including participants who meet predetermined criteria in the research process (Patton, 1990). In line with the purpose of the study, the absence of a 3D printer was determined as a criterion for school selection. In the selection of the students, the criterion was that they had not experienced a 3D printer before. Hence, the data of one student who stated that he had previously observed and used a 3D printer were not included in the analysis.

The participants of the study included 52 (27 girls, 25 boys) third-grade students in two different public primary schools (School A 28, School B 24) of the Ministry of National Education in a province in the Western Black Sea region. Both schools are in the city center and have a similar socioeconomic environment. A variety of questions were formulated to determine the participants' relationship with technology. Based on this, 37 of the students have computers at home, while 15 do not; 35 have tablets, while 17 do not. Moreover, all except one participant have access to the internet.

Implementation

The research was conducted in the spring semester of the 2022-2023 academic year. The necessary permissions were first obtained before the study. Afterward, both the school principals and the teachers of the classes were contacted and informed about the content of the study. An appointment was requested for the day of implementation. Accordingly, the study was conducted by the first researcher in the school, School A, on 06.04.2023, and in the second school, School B, on 07.04.2023. Primary school teachers were in the classroom during the study and observed the students. The implementation process was similar for both schools, and the same 3D printer was used. The 3D printer was brought to the classrooms and set up by the researcher before the implementation. The implementation consists of two intertwined phases: Introducing the 3D printer and taking sample prints during two lessons (40 min + 40 min) (Figure 2).

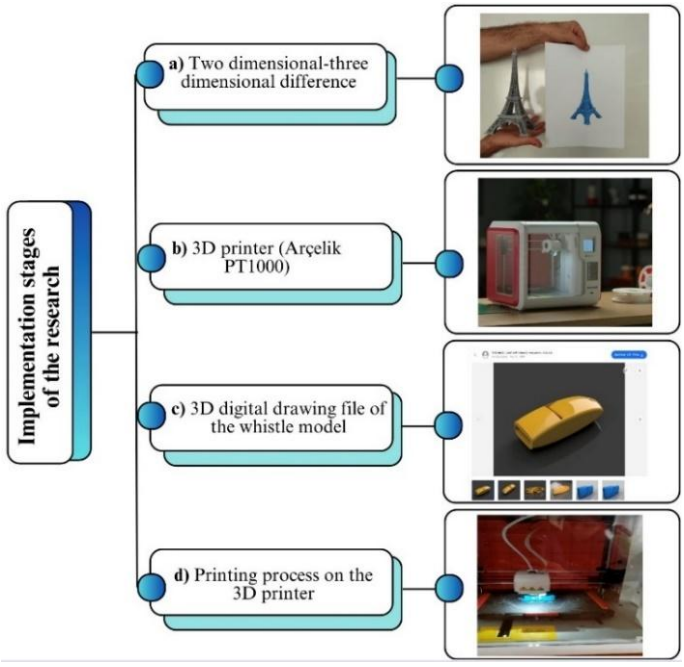


Figure 2. Implementation Stages of the Research

The first phase, the introduction of the 3D printer, started with an explanation of the difference between two and three dimensions. The x (width), y (height), and z (depth) axes are shown by juxtaposing the 2D print of the same object on paper and the 3D model obtained with a 3D printer (Figure 2a). Then the working principle of the 3D printer was briefly explained (Figure 2b). A pre-made 3D digital illustration file was used for the sample print. The pre-made 3D illustration file was downloaded from the website www.thingiverse.com in the classroom, and students were allowed to follow the process. The selected pre-made digital model (Figure 2c) was printed by adjusting the speed, quality, and filling settings before printing via the https://www.arcelik3dprint.com/ website, and the printing process was started at the end of the first lesson. Throughout the second lesson, while the printing process continued (Figure 2d), the properties of PLA (Polylactic Acid) and ABS (Acrylonitrile Butadiene Styrene), the consumables used in 3D printers, and 3D illustration software appropriate for students were introduced. The 3D printing process was presented through the interactive whiteboard (see Figure 3).

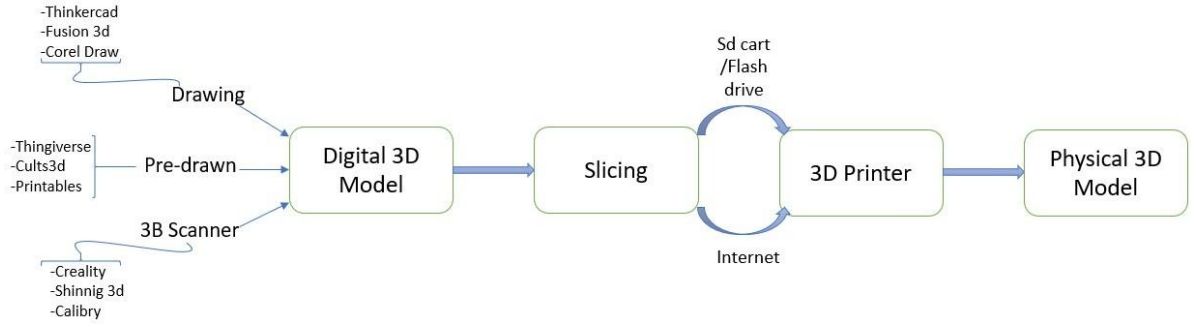


Figure 3. 3D Printing Process

Data Collection Tools and Data Analysis

A semi-structured student interview form, a semi-structured teacher interview form, and unstructured observation notes kept by the researcher were used to obtain data from different sources. The interview forms were prepared by the researchers, and the views of two primary school teachers and two experts in the field of science education with qualitative research experience were consulted. Following the revisions made based on expert opinions, the final versions of the forms were used in the study.

The data obtained from the data collection tools were analyzed using content analysis method. Content analysis is a data analysis technique where inductive inferences about the codes determined by systematically examining the data are specified under themes. The material where the data is obtained is studied in content analysis, and categories are tentatively determined and inferred step by step. These categories are revised in a feedback loop, eventually reduced to themes, and checked for reliability (Mayring, 2000). Throughout this process, the data from all three data sources were re-read from start to finish by two researchers. After having a general understanding of the data sets, the researchers coded the data separately. The relationship between the codes was examined after the coding process, and similar codes were combined under themes. The codes and themes derived were compared, and the inconsistencies were examined repeatedly until a consensus was reached by bringing the researchers together. The analysis results are presented with direct quotations, tables, and graphs. Participants were coded as S1, S2; classroom teachers as T1, T2; and schools as A, B.

Validity and Reliability

To ensure the validity and reliability of the research, evidence for credibility (internal validity), consistency (internal reliability), transferability (external validity), and confirmability (external reliability), was attempted to be presented (Arslan, 2022). Accordingly, during the process of creating the data collection tools, the opinions of experts in the field and the experts who had attended the students' classes and knew them closely were among the procedures carried out to ensure credibility. In addition, the literature review in the process of formulating the questions in the relevant forms is one of the steps taken to ensure credibility. Furthermore, direct quotations from the unstructured researcher's notes are presented along with examples of direct statements from the participants and primary school teachers.

In order to ensure the consistency of the research, detailed explanations were provided on how the data were collected and how decisions were made on the data obtained. The raw data obtained from all data collection tools is stored separately in both physical and digital media so that it can be accessed when necessary. To increase the transferability of the research, the participants were first identified through the purposive sampling method. The study model, participants, the implementation process of the study, data collection tools and analysis, and how the data were interpreted were presented in a clear and detailed. More than one data source was used to ensure confirmability, and an audit trail/confirmation (the process of at least two researchers agreeing on data analysis) was applied to the consistency of the research processes (Lincoln & Guba, 1985).

Findings

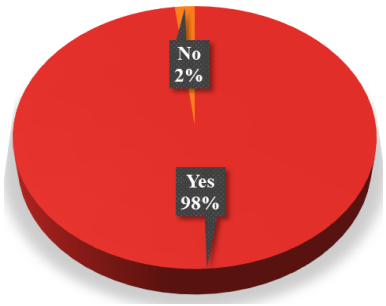
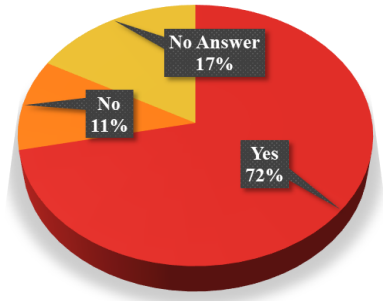
In this section, the data obtained from the semi-structured student interview form, semi-structured teacher interview form, and unstructured researcher observation notes are presented as themes. A holistic evaluation of the data obtained from all data sources revealed two main themes: "*The students' interest and curiosity towards 3D printers*" and " *The students' opinions on the usage of 3D printers*".

The Students' Interest and Curiosity Towards 3D Printers

The findings related to students' interest and curiosity towards 3D printers were derived from the student interview form. In the student interview form, questions "*Would you like to have a 3D printer in your school?*" and "*Would you like to attend an additional course about 3D printers?"* were asked, and the students were requested to explain their reasons for the answers. The graphs created based on students' answers and direct quotations are presented in Table 1.

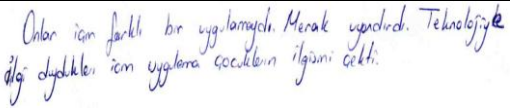
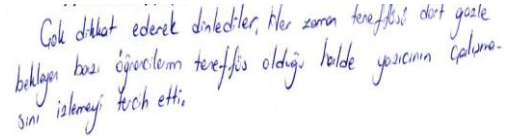
Table 1 revealed that 98% of the students would like to have a 3D printer in their schools. In addition, 72% of the students stated that they would like to attend an additional course about 3D printers. The participants desired to have a 3D printer in their schools and to attend an additional course on printing their own 3D designs. In line with that S36 and S21 stated that "*Because I would do something that was not done*", "*I would, because if I buy the 3D printer, I do not know how to design it*." respectively.

Table 1. Students' Opinions and Direct Quotations about their Interest and Curiosity

Questions	Distribution of Student Responses	Direct Quotations
Would you like to have a 3D printer in your school?		S15: *Yes. I will have fun and learn at the same time.* S36: *Yes. Because I would do something that has not been done.* S1: *Yes, I do, because I want to get one at home.* S42: *I would not want it because it makes too much noise.*
Would you like to attend an additional course about 3D printers?		S3: *Yes, because I want to learn more about it.* S11: *I would like one. Because I would like to be able to use it.* S21: *I would like to because if I got a 3D printer, I wouldn't know how to design for it.* S44: *I wouldn't want to. It seems like a bit of a waste of time.*

The teachers' direct quotations and researcher notes also expressed the students' interest in and curiosity about 3D printers (see Table 2).

Table 2. Direct Quotations from the Teacher Interview Form and Researcher Notes

	Teachers' Direct Quotations	Researcher Notes
School A_06/04/2023	 T1: *...It was a different exercise for them. The practice attracted the attention of children as they are interested in technology...*  T1: *...They listened very carefully. Some students, usually looking forward to recess, preferred to watch the printer working even though it was recess....*	...The students who had arrived early in the class pointed to the 3D printer and started to ask what it was and what it was for. When the presentation started, the students listened **quietly and carefully**. While examining the pre-made models on the www.thingiverse.com website, they asked for permission **to record the name of the website.** When I initiated the printing process, they got **very excited** and **stood up** to see it. Rather than going outside when the break time bell rang, most of them chose to **gather around the 3D printer** to **watch the printing process.**

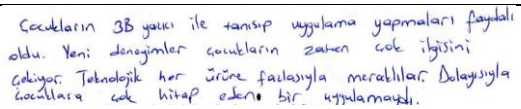
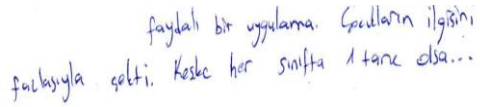
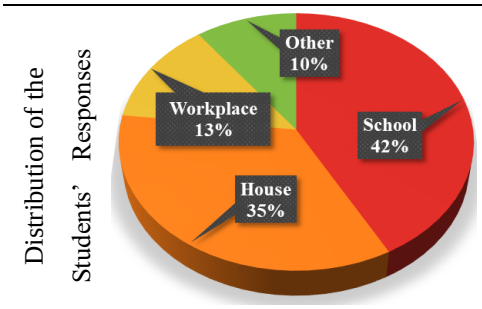
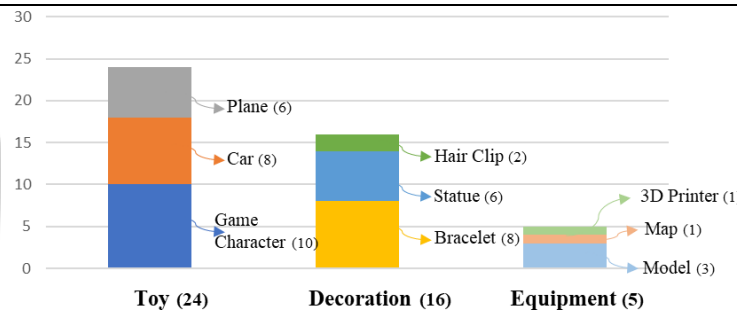
Teachers' Direct Quotations	Researcher Notes
 T2: *...It was useful for the children to be made familiar with the 3D printer and to practice with it. New experiences are already of great interest to children. They are extremely curious about everything technological. Therefore, it was a very appealing exercise for children…*  T2:*...It is a useful application. The children were very much interested. I wish there was one in every classroom...*	…When I entered the classroom to prepare, the students asked **curiously** what happened when they saw that I was carrying the 3D printer. When the presentation started, they followed the presentation **carefully and quietly**. ..... When I showed sample models from www.thingiverse.com, they wanted to see more models. .... When I started the printing process, they **stood up** to observe and **curiously watched**. They gathered around the 3D printer during recess to watch it closely. When the printing was finished and the model came out of the 3D printer, the class erupted in **applaus**e. When the presentation was over and I began to pack up, they surrounded me to ask if I would come again and bring the 3D printer.

Table 2 reveals that findings obtained from the teacher interview forms and the researchers' notes support each other. Accordingly, similar statements about students' interests, being curious and excited, and following carefully, are prominent. For example, while T1 stated that *"Some of my students who always look forward to recess preferred to watch the printer working even during the recess"* in the interview form, the researcher indicated that "students gathered around the printer during recess".

The Students' Opinions on the Usage of 3D Printers

To determine the students' association with 3D printers, areas of 3D printers, and what kind of model they would like to print were asked through the student interview form. The graphs generated based on the students' answers are presented in Table 3.

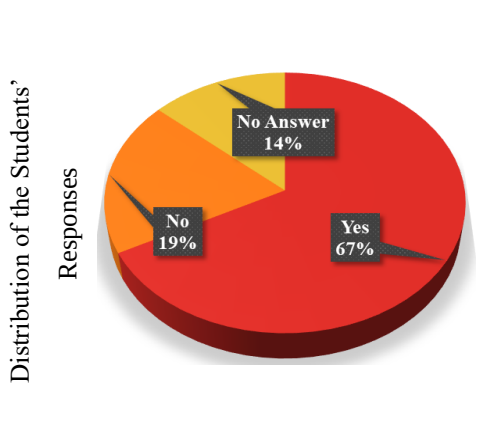
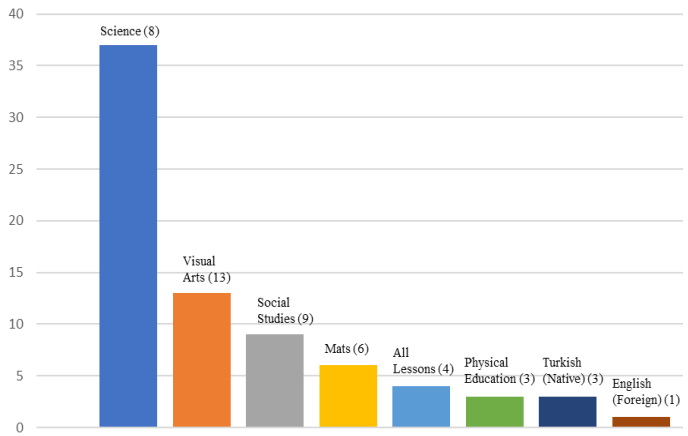
Table 3. The Students' Opinions on the Usage of 3D Printers

Where can 3D printers be used?	What kind of model would you like to print if you had a 3D printer?
	

When Table 3 is analyzed, the students indicate school (42%), home (35%), and workplace (13%) (toy stores, stationery stores etc.) as the usage areas of 3D printers. In response to the question "*What kind of model would you like to print if you had a 3D printer?*", they mostly gave answers related to toys (f=24), decoration (f=16), and various equipment (f=5). In the observations of the researcher, "*Can Minecraft characters be printed with a 3D printer*?" questions were asked by the students to obtain toys. With questions such as "*How much is the filament?*", "*How many whistles can be printed from one filament?*" and "*Can we make money if we sell the whistles?*", The researcher's notes revealed that the students also questioned the commercial dimension of 3D printers.

Furthermore, in the student interview form, the questions "*Can 3D printers be used in your courses?*" and "*In which courses can 3D printers be used?*" were asked through the student interview form. The graphs created based on the students' answers are presented in Table 4.

Table 4. The Students' Opinions on the Usage of 3D Printers in Courses

	Can 3D printers be used in your courses?	Which courses can 3D printers be used in?
		

According to Table 4 majority of the students (67%) pointed out that 3D printers can be used in courses. Meanwhile, 19% of the students reported that 3D printers could not be used in courses. Among the students who believe that 3D printers can be used in schools, especially science (f=37, 48.7%) and visual arts (f=13, 17.1%) courses.

Discussion and Conclusion

The purpose of the study was to identify and describe the subjective experiences of third-grade primary school students who were introduced to 3D printers for the first time and how they conceptualized 3D printers in their minds. The primary conclusion emerging from the research results is that third-grade students have a high level of interest in 3D printing, design, and production practices. The students displayed behaviors and expressions that showed that they were excited and curious from the moment they saw the 3D printer until the end of the study. The findings obtained from the student interview form frequently include statements along these lines. This was

reflected in the researcher's observations and confirmed by the teachers who are much better acquainted with the students. The students' interest in new technologies is known to be generally high (Arnone et al., 2011). Thus, the results obtained from third-grade students about 3D printers are consistent with other results obtained from studies on the integration of new technologies into courses. Concurrently, a large number of quantitative and qualitative studies emphasize that students' interest in 3D printers is quite high (Arslan & Erdoğan, 2021; Cheng et al., 2020; Karagöz & Şahin-Çakır, 2020; Van Epps et al., 2015). In a study conducted by Avinal and Aydın (2022) with middle school students using 3D organ models, it was reported that students' concentration levels were high, they were not bored or distracted during the activities, and they showed great desire and effort to participate in the activities. Küçüksolak (2019) stated that 70% of secondary and high school students who used 3D printers for the first time found 3D printing technology interesting and exciting. In the study by Saorin et al. (2017), the 3D printing technology was found to enable high school students to work better, increase their interest in the course, and success rates. Jo et al. (2016) argued that 3D printers facilitate students' recall and comprehension and bring vibrancy and fun to the classroom. Similarly, in studies on pre-service teachers (Arslan & Erdoğan, 2021; Karagöz & Şahin-Çakır, 2020), it was reported that 3D printers should be included in education-training processes because they would dynamize the learning-teaching process and increase students' interest and motivation in the subject.

The fact that 72% of the participants stated that they would like to attend an additional course on 3D printers can be interpreted as having intrinsic motivation in addition to their high interest. Similarly, in Küçüksolak's (2019) research, participants stated that they would like to attend an additional course on 3D printing processes. Moreover, Trust and Maloy's (2017) study, a participant stated that "*although students were not given enough time to work on the 3D printing project in their class, they worked on the project at home, on the phone or at lunch*", can be interpreted as high intrinsic motivation. Intrinsic motivation is a concept that is sometimes difficult to generate in students, but it's crucial for effective learning (Stipek, 1993). The evidence that 3D printers have the effect of activating intrinsic motivation emphasizes the importance of integrating this newly adopted technology into education (Cheng et al., 2023). Therefore, Tillinghast et al. (2014) suggested that when the 3D printers are integrated into education, students' willingness in the first stage of integration (active participation) can be considered a positive step towards ensuring their participation in the second and third stages of integration (active and passive participation).

Furthermore, the students stated that 3D printers can be used at school, home, and workplace in order from most to least. Similarly, Mohr and Khan (2015) revealed that the 3D printing technology has an increasingly wide range of applications in schools, homes, and workplaces, as expressed by students. However, the fact that students were able to express only a small number of these areas can be interpreted as their lack of comprehensive understanding of 3D printers. Accordingly, it can be said that the mental image in the students' minds about 3D printers seems to contain only a small part of the real image of the 3D printers. Nevertheless, this finding can be seen as an expected result considering that the participants were in the third-grade level of primary education and encountered 3D printers for the first time. However, although the students ranked schools in first place as the areas of use of 3D printers, toys, and ornaments ranked high when the models they wanted to print with 3D printers were questioned. In addition, although the students ranked schools as first place in the areas of 3D printer usage, toys, and decoration, staff ranked high when the models they wanted to print with 3D printers were questioned.

Therefore, it can be concluded that the students' first impression of 3D printers is in the form of a toy/entertainment tool. It should be taken into account that this may be caused by the use of the Eiffel Tower model to illustrate the 2D-3D difference and the use of the whistle model for the sample print. Likewise, it can be considered an expected result that the participants want to print toys/entertainment tools with 3D printers due to their age. Thus, Gonzalez and Bennetz (2016) concluded that 3D printers are generally perceived as an entertainment tool, while Jovanovic et al. (2023) indicated that they are also used to create toys. The fact that 67% of the participants responded positively about the use of 3D printers in classes indicates that the students were able to associate 3D printers with education. When their opinions on which courses it can be used in were analyzed, it was found that the students stated that 3D printers can be used in several courses, especially in science. Karagöz and Şahin-Çakır (2020) conducted a study with pre-service science teachers and found that 3D printers can be used to enrich courses and that science courses were the most prominent among these courses. Similarly, Karagöz and Şahin-Çakır (2020) found that 3D printers can be used to enrich lessons in several courses, mostly science courses, as a result of their research with pre-service science teachers. Similarly, Karagöz and Şahin-Çakır (2020) found that 3D printers can be used to enrich several courses, mostly science courses, as a result of their research with pre-service science teachers. This result can be explained by the fact that 3D printers are primarily seen in STEM fields shaped in science courses (Lee et al., 2015). However, in parallel with our findings, there are studies indicating that 3D printers can be used in social studies (Maloy et al., 2017), art (Menano et al., 2019; Mongeon, 2015), and mathematics courses (Budinski et al., 2019; Mavri, 2021). However, it is also noteworthy that students not only associated 3D printers with more than one course, but also stated that they can be used in all courses. In this context, it can be argued that students had no difficulty in associating 3D printers with courses.

To sum up, based on the data obtained in the current study, it is noteworthy that third-grade primary school students who were introduced to 3D printers for the first time showed a high level of interest in 3D printers. Furthermore, the participants were willing to attend an additional course about 3D printers. Moreover, even though students had a limited perspective on the areas of usage of 3D printers and considered them more as toys/entertainment tools, they were still associated them with school and several courses.

Educational Implications and Recommendations

Since the practice of getting acquainted with the 3D printer conducted as part of the study was met with interest by third-grade primary school students, conducting similar practices with students at the same level is believed to be valuable for gaining a positive understanding of 3D printers. Yet, at this point, it should be noted that the source of their interest may be that students are introduced with the 3D printer for the first time. It is worth noting that in a group with detailed knowledge about 3D printers, it is unlikely that the same effect will be achieved. Therefore, it is recommended to repeat the application in groups with similar participant characteristics, that is, to transfer rather than generalize due to the nature of qualitative research.

Just like with other technological tools, the age of having the knowledge and skills to use 3D printers is gradually decreasing. Considering the students' initial knowledge about 3D printers, it is suggested that the question "Can primary school students' knowledge and skills about 3D printers be further developed?" should be carefully

addressed by the researchers who will work on this issue, although it is considered appropriate for the 5-8 grade level in the literature. In addition, the fact that the students were able to mention the usage areas of 3D printers in a very limited framework may be considered because the implementation was planned as an introductory activity. Tillinghast et al (2014) indicated that this issue is crucial to compensate for it in the later stages of integration. Several arrangements can be made in the implementation phase for students to develop a more comprehensive understanding if desired. For example, the question "Where/in which areas can 3D printers be used?" can be posed to make students think more about the subject. Moreover, providing guidance when necessary or providing examples of use in unspecified areas is believed to support students in developing a more comprehensive understanding of the usage areas of 3D printers.

Most of the students believe that 3D printers can be used in schools and can associate 3D printers with various courses. To support and strengthen this association, printing educational materials in the familiarization activity may be recommended. In the selection of educational materials, courses such as foreign language (English), which students associate with relatively less, can be prioritized.

Ethical Approval

This manuscript has been approved by the Sakarya University Ethical Review Authority (number: E-61923333-050.99-308418).

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