Türkiye'de 3B Yazıcıların Matematik Eğitiminde Uygulanmasına İlişkin Yürütülen Çalışmaların Sistematik İncelemesi*

The Systematic Review of the Studies Conducted in Turkey on the Topic of Applying 3D Printing in Mathematics Education

Ayça Akın[1*]
Hayriye Seda Sezgin[2]

[1*]Antalya Belek Üniversitesi, Mühendislik Fakültesi, Yazılım Mühendisliği Bölümü, Antalya, Türkiye.

[2] Milli Eğitim Bakanlığı, Antalya, Türkiye.

*Sorumlu Yazar: aycaakin07@gmail.com

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Öz

Birçok araştırmacı, matematik eğitimi bağlamında 3B yazıcıların öğrencilerin matematiksel ve tasarımsal düşünme biçimlerini ortaya çıkardığını, uzamsal becerilerini geliştirmelerine yardımcı olduğunu ve özellikle kalkülüs ve geometrideki matematiksel kavramları görselleştirmek için önemli bir araç olduğunu vurgulamaktadır. Ancak, ilgili literatür incelendiğinde, Türkiye'de yapılan çalışmalar bağlamında 3B yazıcıların matematik eğitiminde nasıl uygulandığına dair literatürdeki bulguları kapsamlı bir şekilde tanımlayan ve sentezleyen mevcut bir sistematik derlemenin bulunmadığı görülmektedir. Bu araştırmanın amacı, 2015-2023 yılları arasında Türkiye'deki 3B yazıcıların matematik eğitiminde uygulanması konusunda yapılan çalışmaların sistematik bir incelemesini yapmaktır. Bu araştırmanın sonuçları, incelenen çalışmalarda nitel araştırma yönteminin daha fazla tercih edildiğini göstermektedir. Bu çalışmalarda en sık kullanılan bağımlı değişken matematik başarısıdır ve çalışmaların katılımcıları çoğunlukla ortaokul öğrencileridir. Bu sistematik derlemenin sonuçları, Türkiye'de yapılan çalışmalar bağlamında, matematik öğretiminde 3B yazıcı uygulamalarının genellikle öğrencilerin matematik okuryazarlığını ve matematik becerilerini geliştirmeye yardımcı olduğunu göstermiştir.

Anahtar Kelimeler: 3B Yazıcı, Eğitim Teknolojisi, Matematiksel Muhakeme, Uzamsal Beceriler

Abstract

3D printing technology is increasingly widely used in all areas of STEM education. Many researchers emphasize that 3D printing in the context of mathematics education unpacks students' mathematical and design thinking, as well as helps them develop spatial skills, and is a key tool for visualizing mathematical concepts, especially in calculus and geometry. However, when the relevant literature is examined, it is seen that there is no existing systematic review that comprehensively describes and synthesizes the findings in the literature on how 3D printers are applied in mathematics education in the context of studies conducted in Turkey. The purpose of this research is to make a systematic review of the studies conducted between 2015-2023 in Turkey on the topic of applying 3D printing in mathematics education. The results of this study show that qualitative research method is more preferred in the analyzed studies. The predominant dependent variable employed in these investigations is mathematics achievement, with the majority of participants being middle school students. The results of this systematic review indicated that applying 3D printing in mathematics instruction usually helps to improve students' mathematical literacy, and mathematical skills in the context of studies conducted in Turkey.

Keywords: 3D Printing, Educational Technology, Mathematical Reasoning, Spatial Skills

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1. Introduction

One of the technologies that has the potential to facilitate and transform individuals' lives and is becoming increasingly widespread today is three-dimensional (3D) printing technology (Demir et al., 2016). Three-dimensional (3D) printers are machines that can transform a 3D object in a computer environment into a solid form by processing various materials (Yıldırım et al., 2018). 3D printers are an important tool for all learners, especially for students who are tactile learners. In particular, visually impaired students need objects that they can touch to learn abstract concepts and topics in courses such as mathematics and science. Therefore, many researchers suggest that to help both students and teachers, educational materials should be prepared with easy, inexpensive, and customizable methods such as three-dimensional (3D) printing (Aslan, 2023; Aslan & Çelik, 2022; Horvath, 2014; Wonjin et al., 2016). In recent years, the significance of 3D materials has grown substantially, primarily due to the increased affordability and accessibility of 3D printers, contributing significantly to various production processes (Çoklar & Çekirge, 2020). In this respect, it is known that 3D materials provide some contributions such as touch, spatial perception, and production pleasure unlike the digital screen (Çoklar & Çekirge, 2020).

3D printing technology is increasingly widely used in all areas of STEM education, especially in mathematics education. Researchers widely agree that 3D printing offers significant benefits for mathematics education. By engaging students in design thinking and spatial reasoning, it enhances their understanding of abstract concepts, particularly in calculus and geometry (Çoklar & Çekirge, 2020; Kit et al., 2022). A restricted number of investigations in Turkey have explored the application of 3D printers within the domain of mathematics education. In one of these studies, the design and production stages of a tangram that can be used in a mathematics lesson were shown. It has been suggested that tangram, a material developed on the basis that the simultaneous use of visual and mental intelligence improves thinking power, contributes to the learning of subjects such as translation, reflection, and rotation in geometry (Yılmaz & Algil, 2018). In another study, which measured the effect of 3D printing in teaching fractions to 4th grade students, and whose method was based on a comparison between the control and experimental groups, it was observed that students found greater enjoyment and amusement in lessons that incorporated 3D printers, facilitating a more effortless understanding of the subject matter. Furthermore, the students in the experimental group, where 3D-printing-based teaching was carried out, stated that they grasped the concept of fractions more effectively, the activities stimulated their imagination, they acquired collaborative skills, and the lessons were far from dull (Kavas, 2022). The findings of the studies on 3D printing technologies in the context of mathematics education in Turkey generally showed that 3D printers had a significant positive contribution to mathematics education. In these studies, it was revealed that the active use of 3D printers in the lessons contributed to students' learning mathematics through trial and error, especially mathematical thinking, and spatial skills, and helped to observe the production process closely (Çoklar & Çekirge, 2020). The results obtained from these studies were generally that the 3D printer had a positive effect on the students' mathematics interest/motivation in mathematics courses and increases the students' mathematics achievement (Çoklar & Çekirge, 2020).

However, as far as we have examined the literature, there is no existing systematic review that comprehensively describes and synthesizes the findings in the literature on how 3D printing is applied in mathematics education in the context of studies carried out in Turkey. Therefore, the purpose of this research was to make a systematic review of the studies conducted between 2015-2023 in Turkey on the topic of applying 3D printing in mathematics education. This study provides an overview of the current trends of research related to 3D printing in mathematics education in Turkey. The research questions were given as follows:

1. How are the studies categorized based on the publication years, the dependent variable, and the profile of participants (i.e., background information)?

2. What pedagogical approaches and mathematical learning contents were classified 3D printing studies within the scope of mathematics education in Turkey?

3. What methodologies were employed in 3D printing studies related to mathematics education in Turkey?

4. Which assessment tools were used in 3D printing studies on mathematics education in Turkey?

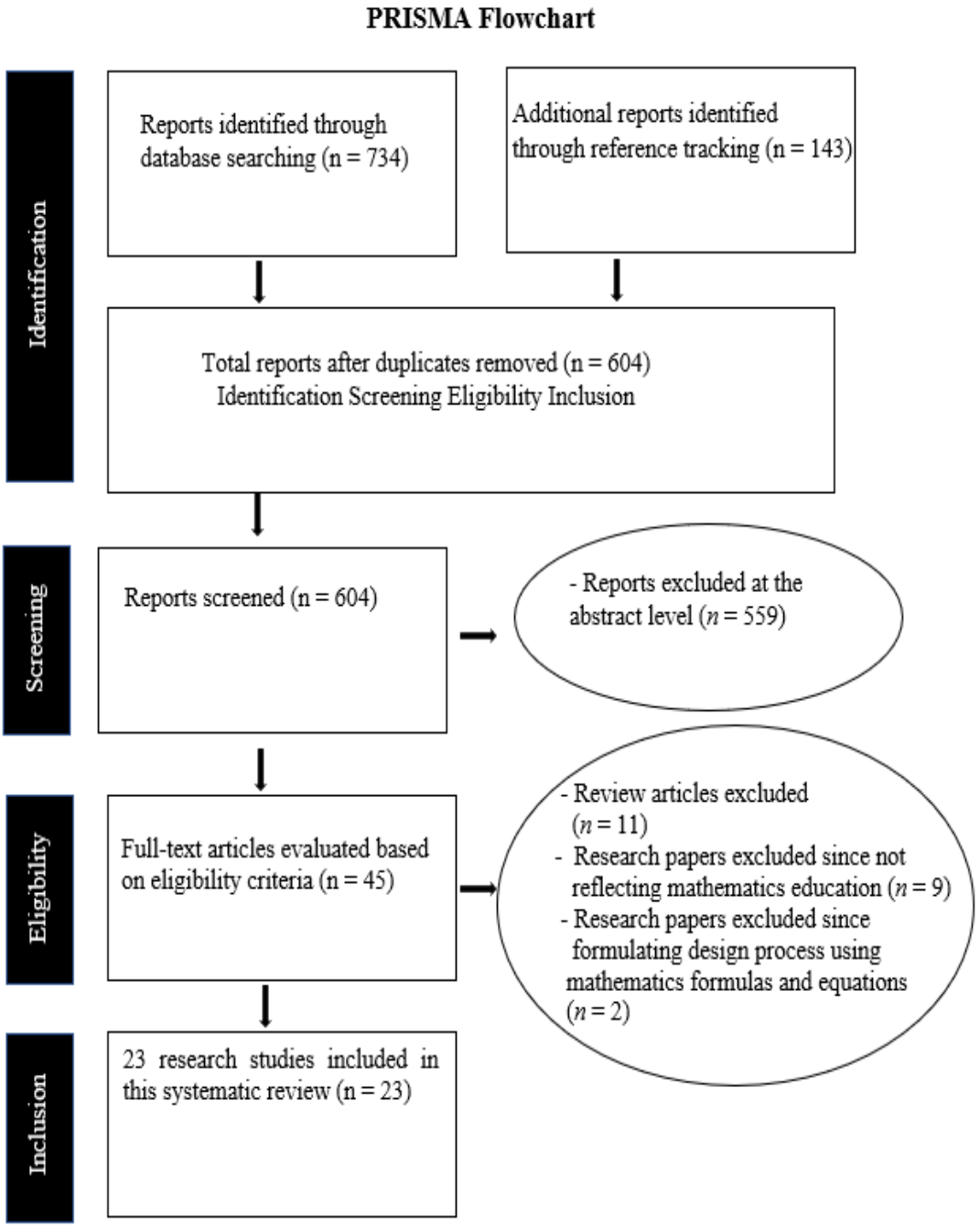
2. Material and Method

2.1. Study Design

The systematic review approach was used in this study. The systematic review methodology has recently gained popularity for evaluating research trends, particularly within the realm of education (Kit et al., 2022). In the systematic review approach, selected studies are applied content or thematic analysis to amalgamate the data into themes. (e.g., dependent variable, theoretical frameworks, and methodological approaches) based on the research problems (Kit et al., 2022). The general trends of 3D printing research in mathematics education in Turkey (for example, the most common tools/platforms and types of pedagogy used) were examined in depth and comprehensively in the context of a systematic review approach regarding this study.

2.2. Data Collection

The data of this research consist of research articles and graduate theses (i.e., dissertation) on the use of 3D printing technologies in mathematics education in Turkey between 2015-2023. The reason why 2015 was chosen as the starting year is that studies on 3D printers related to the learning and teaching process in the context of education have been published in Turkey since 2015. YÖKTEZ, Google Scholar, and Dergipark academic databases were used in the data collection to select appropriate studies for this study. The research was limited by using certain filters. Firstly, 3D printers used in the teaching process were searched for and then these technologies were used as keywords to search the literature, these are "3D printers", "three-dimensional printing", "three-dimensional design", "three-dimensional printer applications" and "CNC machine". Secondly, a general search was conducted using the keywords "mathematics education", "educational technologies" and "Turkey" in order to access studies in the context of mathematics education in Turkey. Additionally, the PRISMA protocol for Systematic reviews was used for displaying the research paper selection process (Moher et al., 2009). As a result of the screening, 23 research studies related to 3D printing technologies in the context of mathematics education in Turkey were reached. This article falls into the category of those that do not necessitate approval from the ethics committee, as it involves no acquisition of data from any living beings through any means throughout the research process. This elimination stage was shown in Figure 1 as a PRISMA flowchart.



Şekil 1. PRISMA Flowchart for Selected Papers

2.3. Data Analysis

The data were subjected to analysis through the method of content analysis. This analysis is a qualitative method in which previously published works are examined systematically within the framework of certain criteria (Şimşek & Yaşar, 2019). Content analysis provides an in-depth, interpretative, and general perspective on the data (Çalık & Sözbilir, 2014). Based on this framework, data was evaluated and analyzed according to the dependent variable, participants' profile (i.e., background information), learning contents, methodological approaches, theoretical frameworks, and pedagogies. Cohen's kappa coefficient calculation was preferred in the reliability analysis since scoring was done at the classification level. The researchers of this study found Cohen's kappa coefficient to be 0.94, indicating an almost perfect agreement in data analysis.

3. Results

In this study, background information in terms of the year of publication was addressed before the research questions were investigated. The results regarding the distribution of research papers by year are summarized in Table 1. Based on Table 1, it was seen that 1 of 23 research papers were published in 2015, 3 in 2018, 4 in 2019, 3 in 2020, 3 in 2021, 8 in 2022, and 1 in 2023. It was seen that the studies included in the scope of the research were published the most in 2022 and the least in 2015 and 2023. The number of studies carried out in 2017 decreased in 2018 and 2019. According to Table 1, although there was no clear trend over the years, the number of studies on 3D printing technologies in mathematics education has increased in recent years. The most research on this subject was conducted in 2022. The prevalent dependent variable employed in the research papers was mathematics achievement (n = 14), followed by spatial skills (n = 7) and arithmetic skills (n = 2). Regarding the participants' profile, the participants were middle school students in most of these studies (n = 7), while only one study had primary school students as participants.

Table 1. The Characteristics of Research Papers

Published year	***f***	***%***
2015	1	4
2018	3	13
2019	4	18
2020	3	13
2021	3	13
2022	8	35
2023	1	4
Dependent variable	***f***	***%***
Math achievement	14	61
Spatial skills	7	30
Arithmetic skills	2	9
Participants' profile	***f***	***%***
Primary school student	1	4
Middle school student	6	26
High school student	4	18
Undergraduate student	**7**	30
Teacher	5	22

In the context of mathematics education, it was seen that three main types of methodologies for teaching were applied in 3D printing studies. Based on table 2, the most common methodologies for teaching used in these twenty-three studies is design-based learning (n = 10), followed by project-based learning (n = 8), and collaborative learning (n = 5).

Table 2. Distribution of Methodologies for Teaching in The Context of Research Papers

Methodologies for teaching	***f***	***%***
Design-based learning	10	43
Project-based learning	8	35
Collaborative learning	5	22

Regarding mathematical learning contents, most of the research papers (n = 18) regarding this study addressed 3D printing as a tool for developing geometric concepts and geometric skills such as spatial visualization skills, the volume/area of geometric solids, and the definitions of geometric shapes. Only five research papers addressed 3D printing as a tool for developing arithmetical concepts/skills such as fraction and computational skills (see Table 3).

Table 3. Distribution of Mathematical Learning Contents in The Context of Research Papers

Learning contents	*f*	%
Geometric concepts	18	78
Arithmetical concepts	5	22

Concerning methodological approaches, it was found that the most commonly used method in these studies was quantitative (n = 11), followed by qualitative (n = 9) and mixed design (n = 3). This research indicated that quantitative research method was preferred more in these studies, a limited number of studies on mixed research method was used in these research papers (see Table 4).

Table 4. Distribution of Methodological Approaches in The Context of Research Papers

Methodological approaches	*f*	%
Quantitative method	11	48
Qualitative method	9	39
Mixed-research method	3	13

Regarding assessment tools, it was revealed that the most commonly used assessment tools in these studies was mathematical exams (i.e., open-ended mathematical problems and mathematics tests) (n = 11), followed by questionnaires (i.e., motivation or attitudes scales) (n = 7), student's artworks (i.e., portfolio, projects, and group assignments) (n = 5). This research showed that mathematical exams and questionnaires were preferred more in these studies, and a limited number of student's artworks was used as an assessment tool in these research papers (see Table 5).

Table 5. Distribution of Assessment Tools in The Context of Research Papers

Assessment tools	*f*	%
Mathematical exams	11	48
Questionnaires	7	30
Student's artworks	5	22

4. Conclusion

The results of this research indicated that research papers on 3D printers in mathematics education in Turkey have not shown a clear trend over the years. However, the number of studies on 3D printing has risen in recent years. Considering the technological developments in education and the widespread use of 3D printers, this increase is an expected finding. However, the lack of a clear trend over the years has revealed that the incorporation of 3D printers to mathematics education is slower in the Turkish context. The gradual adoption of 3D printers in mathematics education in Turkey is attributed to numerous challenges, including issues such as hardware and software optimization, processing, shaping, printing, and maintenance (Kit et al, 2022). On the other hand, within the framework of Turkey's Century 2023 targets, the Ministry of National Education organized workshops in many provinces called "Holistic Education: Turkey Century Education Model Curriculum Development" workshops were held in many provinces. In the mathematics curriculum implemented in our country since 2018 and in the curriculum focused on the newly proposed education model in the context of the Century of Turkey, it is emphasized to make use of information and communication technologies in mathematics courses and to use technologies such as dynamic mathematics/geometry software and 3D printers effectively (MEB, 2018a; MEB, 2018b).

In the 2023 Education Vision Model for a strong future, there are crucial emphases/plans at many points within the scope of 3D printer technologies. These are (i) Integration of informatics and production skills such as coding, 3D designs, and electronic design into learning processes with studies to be carried out at primary, secondary, and high school levels, at school and outside school, for students, teachers, education administrators, public, curriculum and educational content; (ii) Carrying out coding and 3D design activities with our students to provide them with IT production skills; (iii) Providing face-to-face workshop training to

teachers of subjects such as mathematics, science, physics, chemistry, biology, Turkish, social sciences, and geography in areas such as interdisciplinary project construction, 3D designs and smart devices (MEB, 2018b). Studies in the context of education related to the 2023 education vision and the Century of Turkey are gaining momentum day by day in our country. At this point, it is thought that in the coming years, 3D printer technology will be used in mathematics education in our country, and it will raise awareness about its strong effect on learning outcomes. At the same time, it is thought that the integration of 3D printers into the mathematics learning process will be strongly ensured in this context.

The findings unveiled that the predominant dependent variable in research on 3D printers in mathematics education in Turkey was mathematics achievement, with spatial skills and arithmetic skills being the subsequent focal points. It was pointed out that there were not enough of these studies in which the effects of mathematics motivation or mathematics anxiety variables have been investigated. The fact that these studies were limited to mathematics achievement, spatial skills, and arithmetic skills showed that other factors related to mathematics (i.e., motivational components of mathematics, interdisciplinary approach) were ignored. Since most of the research papers on instructional technologies in the context of mathematics education focus on mathematics achievement, this finding was consistent with previous studies (Yazıcı & Korkmaz, 2023). Similarly, other studies on education in Turkey have revealed that there is a very limited number of studies to measure students' skills such as interest, motivation, problem-solving, etc., and that students' skills and motivational beliefs cannot be measured in crowded groups (Aslan & Çelik, 2022; Çoklar & Çekirge, 2020). It was thought that the reason for this finding was that the studies on 3D printing are new, the technology cannot be widely used in classroom environments, especially in field education (i.e., mathematics and science), and 3D printing technologies are used only in certain areas of education (i.e., vocational, and technical courses). The reason for this finding may be related to the fact that the studies on 3D printing in education are new, the technology cannot be widely used in classroom environments because of including expensive tools, especially in the field of mathematics and science education, and 3D printing technologies are preferred to be used only in certain areas of education, especially in technically and vocational courses (Çoklar & Çekirge, 2020; Yazıcı & Korkmaz, 2023; Aslan et al., 2021; Karaduman, 2018).

The participants of the studies on 3D printers in the context of mathematics education in Turkey were university students, middle school students, teachers, and high school students. It was seen that there was a limited number of studies conducted with primary school students on this subject. The findings of another study, which systematically analyzed the studies on 3D printers in the context of mathematics education in the world, similarly showed that the participants in most of these studies were middle school students and at least primary school students were involved as participants (Kit et al., 2022). At this point, it can be said that this finding is consistent with the findings of the studies in the literature. Conducting research on 3D printers in the context of mathematics education with primary school students may be useful in closing the gap in the literature. Moreover, it is emphasized that teachers at all levels of education in Turkey have insufficient experience in designing and using 3D solid models, but teachers can actively carry out this process as a result of providing the necessary support (Aslan et al., 2021). It can be argued that if teachers at all levels of education in our country are adequately equipped with the experience of designing and using 3D solid models, active mathematics learning and teaching will take place through 3D printing at all levels of education, especially in primary school mathematics.

In terms of the methodologies for teaching in studies on 3D printers in the context of mathematics education in Turkey, it was revealed that design-based learning and project-based design were used the most. The prevalence of measuring mathematics achievement in studies on 3D printing for Turkish mathematics education reflects the recognition that such learning environments effectively facilitate students' success across various STEAM disciplines (Kit et al., 2022). Furthermore, numerous studies underscore the significance of integrating 3D printing, modeling, and building into STEAM projects, fostering a culture of reflective design iteration and revision through project-based learning (Aslan et al., 2021; Güneş et al., 2020; Lin et al., 2023; Özsoy & Duman, 2017). In previous studies, it has been emphasized that teachers and students can use 3D

printing technologies in the design and production process of models suitable for a STEM content topic or problem situation in the context of project-based learning activities, and thus the development of 21st-century skills of students and teachers can be supported by 3D printing technologies (Aslan et al., 2021; Güneş et al., 2020; Özsoy & Duman, 2017)Therefore, this result is an expected finding in terms of the literature and supports the emphasis that design-based and project-based studies in the context of STEAM, especially mathematics education, trigger participants' 21st-century skills.

In the context of mathematics education in Turkey, it was revealed that the research on 3D printers regarding mathematics education in Turkey mostly aimed to develop geometric concepts, and then to develop arithmetic concepts in terms of mathematical learning content. There are many reasons for using 3D printers in teaching geometric concepts. As a user-friendly tool, the 3D printing pen empowers children to embark on a journey of 3D design creation, introducing them to various geometric principles and promoting their geometric comprehension (Ng et al., 2020). Thanks to 3D printing, students can overcome challenges related to 3D geometry (Huleihil, 2017). Moreover, the study on expanding the understanding of geometry with 3D printers examined the use of 3D printers in subjects such as solids and volume was examined (Cochran et al., 2016). The researchers of this study emphasized that seeing the 3D printer create volume was extremely valuable in terms of helping students make mathematical connections with the theoretical volume concepts they learned in the classroom and greatly facilitated their ability to grasp geometric concepts (Cochran et al., 2016). In another study conducted in our country in the context of geometry, the opinions of sixth and eighth-grade students who studied the concept of volume that 3D printing contributed to their geometry achievement in the subject of volume were revealed (Yıldırım & Keşan, 2022). Our research findings overlapped with the findings of both national and international studies, especially in the acquisition of a long-term learning effect in geometric concepts, since the use of 3D printers to visualize geometry and gain conceptual knowledge about the properties of 3D objects has been emphasized in previous studies (Kit et al., 2022; Ng et al., 2020; Huleihil, 2017; Cochran et al., 2016; Yıldırım & Keşan, 2022). Although predominantly 3D printing technologies are used in teaching geometry, it is suggested that using 3D printers can make it easier for students to illustrate complex ideas in mathematics such as shapes, rates of change, and areas/volumes, many researchers have suggested helping students develop skills in mathematical problems, thinking about abstract concepts, learning calculus concepts and working in 3D space in the context of 3D printing technology (Kit et al., 2022; Chien & Chu, 2018; Dilling & Witzke, 2020). For example, one study found that even secondary school students benefited from using 3D printing to better understand functions and derivatives in the context of calculus (Dilling & Witzke, 2020). Since creativity is a big part of mathematics, it is emphasized that encouraging students to explore and design creatively in 3D printing can be particularly useful in promoting mathematical proof and mathematical creativity skills (Chien & Chu, 2018). At this point, it can be suggested to make use of 3D printing technologies in the teaching of calculus concepts and the development of mathematical proof and mathematical creativity skills.

Upon examining studies related to 3D printers in Turkish mathematics education, it was observed that the quantitative research method was more commonly favored, while the utilization of mixed research methods was relatively scarce. Quantitative research is thought to be frequently used by researchers because it includes experimental designs. Although mixed-method research combines the advantageous aspects of both qualitative and quantitative research to produce more in-depth results (Tunalı et al., 2016), it has not been sufficiently preferred in research on 3D printers in the context of mathematics education. It can be argued that it is a deficiency that mixed-research design is not preferred in research on instructional technologies and 3D printers in mathematics education in Turkey (Yazıcı & Korkmaz, 2023).

In terms of assessment tools on 3D printing technologies in the context of mathematics education in Turkey, it was revealed that mathematics exams and questionnaires were preferred more in these studies, and the limited number of student's artworks was used as an assessment tool in these research papers. In another study, a systematic review on education showed that questionnaires (33%) were mostly used as data collection tools in studies on the use of 3D printing technologies in education (Aslan & Çelik, 2022). Although our research

findings are consistent with previous studies in terms of assessment tools on 3D printing technologies in the context of mathematics education in Turkey, the limited number of studies on student's artworks is an indication that integration into the mathematics learning and teaching process has not been achieved. At this point, especially in the function drawing and derivative applications regarding calculus, the emergence of student's artworks in the context of 3D printing technologies can ensure that it is not limited to evaluations based on mathematics exams and questionnaires.

The findings of this research revealed that the use of 3D printers in mathematics education in Turkey generally yielded positive results. This study indicated that applying 3D printing in mathematics instruction usually helps to improve students' mathematical literacy, and mathematical skills in the context of studies conducted in Turkey. However, it can be argued that the use of 3D printers in mathematics education in Turkey has not yet become widespread based on findings. In this regard, there were both national and international studies that coincided with the general findings of this study. Similarly, an international systematic review found that while 3D printing has bright prospects for revolutionizing mathematics education, it still has many technical difficulties including hardware and software optimization, processing, formatting, printing, as well as maintenance factors (Kit et al., 2022). In another systematic review study conducted in our country, similar to the findings in this study, it was observed that the studies on 3D printing technology between 2009-2022 in the context of education were at the K-12 level (physics, chemistry, biology, mathematics) and the number of studies increased especially after 2017 (Aslan & Çelik, 2022). When the relationship between education and 3D printing technology was examined in the mentioned study, it was determined that it can be adapted to all ages and fields and provides great convenience in interdisciplinary studies (Aslan & Çelik, 2022).. For this reason, researchers have suggested that it would be more effective to focus on the instructional aspect of 3D printing technologies (Aslan & Çelik, 2022). Although 3D printing technology is expensive, it is emphasized that the preference of affordable 3D printing technologies in 3D material/model production can provide easier accessibility to this technology (Aslan & Çelik, 2022). The marker movement all over the world and in our country, the application of 3D printing to STEAM, especially mathematics education, makes it easier to collaborate with this educational trend in a holistic way (Asempapa & Love, 2021; Lin et al., 2020).Moreover, rapid developments in technology and artificial intelligence technologies in the context of industry 4.0 and 5.0 are considered a good opportunity to develop students' digital skills in 3D modeling, drawing, and printing, which they can apply in the mathematics learning environment in their future jobs and studies (Ng & Tsang, 2021).

Based on the findings of this study, it would be more appropriate for practitioners who use 3D materials/models, especially in teaching mathematics subjects and concepts to focus on the instructional aspect of 3D printing technology by addressing all sub-learning areas of mathematics education except geometry. It is pointed out that it is crucial for students to actively participate in the design process in the teaching of topics and concepts (Aslan & Çelik, 2022). Moreover, it may be useful to evaluate that 3D printing technology used in mathematics education can positively affect the process of establishing relationships between different subject areas and disciplines of students in interdisciplinary studies. In our country, important emphasis is made at many points within the scope of 3D printing technologies in the 2023 Education Vision Model for a strong future. Furthermore, it is envisaged that 3D printer technology will start to be used in mathematics education in Turkey and will raise awareness about its strong impact on learning outcomes as the studies in the context of education related to the 2023 education vision and Turkey's Century are gaining momentum day by day. At the same time, it is thought that the integration of 3D printers into the mathematics learning process will be provided strongly in this context. Although there are a limited number of studies on 3D printing technologies in the context of mathematics education in Turkey, it is predicted that the number of studies on 3D printing technologies in the context of mathematics education in Turkey shortly will increase rapidly in the coming years by bringing together mathematics education and 3D printing technologies. At this point, it is recommended to use 3D printers in the context of mathematics education, especially in the teaching of

geometric concepts at all levels of education in Turkey from preschool to university education by providing technical infrastructure support based on the results of this study.

In conclusion, this systematic review revealed that 3D printing technologies are in their infancy in the context of mathematics education. There may be many reasons for the limited use of 3D printing technologies in the context of mathematics education. These include financial difficulties, technical difficulties, and barriers experienced by students and teachers (Kit et al., 2022). In future studies, experimental interventions can be made to familiarize teachers and students with 3D printing technologies in the context of mathematics education and to overcome technical obstacles in this regard, and the effect of this process on mathematical outputs for teachers and students can be examined. Moreover, it is recommended to make a comparative analysis of the findings of this study with the systematic analysis of future studies that will emerge when the targets related to 3D printing technologies in the 2023 Education Vision Model for a strong future are achieved.

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