ULUSLARARASI 3B YAZICI TEKNOLOJİLERİ
VE DİJİTAL ENDÜSTRİ DERGİSİ

INTERNATIONAL JOURNAL OF 3D PRINTING TECHNOLOGIES AND DIGITAL INDUSTRY

ISSN:2602-3350 (Online)

URL: https://dergipark.org.tr/ij3dptdi

A LITERATURE REVIEW ON 3D PRINTING TECHNOLOGIES IN EDUCATION

Yazarlar (Authors): Aysegul Aslan*, Yaren Celik

Bu makaleye şu şekilde atıfta bulunabilirsiniz (To cite to this article): *Aslan A., Celik Y., "A Literature Review on 3D Printing Technologies In Education" Int. J. of 3D Printing Tech. Dig. Ind., 6(3): 592-613, (2022).*

DOI: 10.46519/ij3dptdi.1137028

Derleme Makale/ Reviewers Article

Erişim Linki: (To link to this article): https://dergipark.org.tr/en/pub/ij3dptdi/archive

A LITERATURE REVIEW ON 3D PRINTING TECHNOLOGIES IN EDUCATION

Aysegul Aslan[a]*, Yaren Celik[b]

[a]Trabzon University, Fatih Faculty of Education, Mathematics and Science Education Department, Turkey
[b]Trabzon University, Fatih Faculty of Education, Mathematics and Science Education Department, Turkey

* *Corresponding Author: aysegulaslan@trabzon.edu.tr*

(**Received:** 19.07.2022; **Revised:** 10.08.2022; **Accepted:** 15.09.2022)

ABSTRACT

This study will offer domestic and foreign studies on the application of 3D printing technologies in the fields of education. The aim of this study was to review the studies that had been done in the literature on the application of 3D printing technology in the field of education. Purposive sampling method was used in the study. In this context, it was decided that in the current study, variables such as the distribution of studies on the use of 3D printer technology in the field of education by years, publication types, sample types and sizes, data collection tools and analysis methods were planned to be examined, and at the same time, in-depth analysis of the results was the most appropriate method. 101 studies were accessed in accordance with this research. One of the qualitative research methods used in the study was document analysis, and the data was analysed by examining at the documents that contained details regarding the facts that were the focus of the study. According to the data obtained, it is seen that the studies carried out on 3D printing technology between 2009-2022 are within the scope of educational activities at the K-12 level (physics, chemistry, biology, mathematics) and their numbers have increased especially after 2017. It was determined that undergraduate students were preferred the most as the sample group. It was found that, on general, qualitative research methodologies were preferred in the studies under consideration. It was seen that in-class assessments, observations and questionnaires were mostly used as data collection tools. It has been determined that content analysis is generally used in the analysis of the collected data. When the relationship between education and 3D printing technology was examined, it was determined that it can be adapted to all ages and fields and provides great convenience in interdisciplinary studies. Based on these findings, it is thought that it will be more effective to focus on the instructional aspect of 3D printing technology.

Keywords: 3D printing technology, Education, K-12, Graduate students, Literature Review.

1. INTRODUCTION

Technology is now advancing quickly. There have been advancements in numerous sectors owing to Industry 4.0. One of the most significant places where these improvements are occurring is in production. Positive changes in production have been made possible by 3D printing technology, one of Industry 4.0's components. In addition to conventional production techniques, 3D printing technologies are now widely used and developing quickly.

Despite the fact that 3D printing is thought to be a recent innovation, it originally appeared in 1984. Over time, this technology has undergone a number of advancements. Additive manufacturing is made possible by gadgets known as 3D printers. Compared to manufacturing made with the conventional production techniques, it is more favorable in terms of cost and production speed.

3D printing technologies are used in many fields today: Aerospace, health, education, automotive, food, jewelry, defense industry, textile, construction etc. Many products that you can imagine can be produced in hours or even minutes by creating models with computer-aided software 3D printing technologies may be utilized in our homes, allowing us to create our own designs, parts, and

a variety of items. In the field of health, the studies are carried out on topics 3D printing technologies, such as artificial tissue production in the medical education. In addition to the use of 3D printers in the production of spare parts for vehicles in the automotive sector, various options are offered to the user by customizing some parts of the vehicles. In the food sector, for creation of patterns is carried out, while in the textile field, the modeling of the clothes, the creation of patterns and the production of the clothes are carried out. Thanks to the 3D printing technologies used in the defense industry and aerospace fields, both spare parts are produced and advantages are obtained thanks to the durable and light weight of the parts. With 3D printing technologies, which have also taken their place in the construction sector, it is possible to build houses with faster and lower costs.

In order to address the technical demands for quick design prototypes, the first 3D printing technology appeared in the early 1984s. It later developed into "rapid prototyping" and "additive manufacturing," and has been widely utilized since 2010. The development of 3D printers in a variety of designs and sizes, as well as the entry of personal printers into our daily lives, can be used as evidence for this extensive use. The production process used by 3D printers is known as additive manufacturing. Although there are numerous raw materials available for printing, 3D printing technologies often use thermoplastic filaments, photopolymer resins, and powder-based materials. 3D model design is needed for 3D printers to work. Drawings designed in a computer environment with a CAD (Computer-Aided Design) program such as AutoCAD, Solidworks, 3DsMax, or objects scanned with a 3D scanner are converted to the '.stl' (standard triangle language) extension. The 3D printer detects the file with the '.stl' extension and prints it.

The primary processing step in the production process of a 3D object is the 3D computer-aided design model of the object. At this stage, designers can follow two different paths. First, the object to be produced is transformed into a 3D computer-aided design model by transferring it to digital media via 3D modeling software. The second way is to model an existing object so that it can be used in digital environments using 3D scanners. In both cases, the file extension of these models is kept in digital media as ".stl", which is a 3D computer-aided design format. After this stage, the model is divided into layers by performing the slicing process through the relevant slicing software. In the last stage, the final model is produced with the layered production process feature found in 3D printers. As new uses for additive manufacturing (AM), 3D printing, and related technologies are discovered, these technologies are being more widely used in industry. There are worries that training and skill development are lagging behind these technical gains, which could prevent a wider adoption of the technology, even as technical advancements in terms of productive throughput and quality continue [1]. In order to eliminate these concerns, "Where and how are 3D printing technologies used in the education system?" questions must be answered.

It is possible to use 3D printing technology in the field of education, but in order to use it correctly and efficiently, it is necessary to provide the necessary infrastructure at the point of access to qualified personnel, technical support, hardware and software. For children who are curious, inquiring and have unlimited imagination, 3D printing technologies are a necessary tool to bring ideas to fruition. As a result of the use of 3D printing technologies in the education sector, students will transform their ideas into concrete objects and develop their imaginations [2]. In the study conducted by Yıldırım, Yıldırım and Çelik, [3] to determine the current status of 3D printing technologies in the literature and their use for educational purposes, it is stated that there is no study on the expected level for the use of 3D printing technologies in the field of education in Turkey, and that the studies in the field of education are health, medicine, engineering and even instrumentation. It has reached the result that it lags far behind compared to fields based on these results, it is recommended to focus on the instructional aspect of this technology, especially in the field of education, and to conduct interdisciplinary studies for the development of 3D models and real 3D objects. In contrast to the research done in the fields of engineering and health, there aren't enough studies on the usage of 3D printing Technologies in education [4]. In a manner similar to this, the literature review by Ford and Minshall, [5] found that the majority of additive

manufacturing and 3D printing equipment adopted for teaching purposes in the educational system are low-cost 3D printing technologies, as opposed to more complex additive manufacturing equipment used in the manufacture of advanced prototypes and finished goods. As a result of the analyzes made, it has been revealed that 3D printing technologies are adopted especially in K-12 school types, universities, libraries, application areas and special education environments. At this stage, "How was 3D printing technology used in the education system?" It is necessary to look at the question from five different points [5]. These:

- To impart 3D printing technology to pupils,
- To educate teachers about 3D printing technology,
- To impart design and creative thinking techniques,
- To create goods that support learning,
- Development of assistive technology.

According to Eisenberg [6], 3D printing technologies can be useful for creating hands-on learning opportunities, fostering creative problem-solving abilities, and learning while having fun. In this context, it is deemed crucial to assess the overall trends in research as well as the current status of 3D printing technologies, which have a lot of promise. The objective of the current study is to assess the state of the literature's studies on 3D printing technologies and their potential applications in education. The following research questions are being asked in order to achieve this goal.

• How are 3D printing technologies studies distributed throughout different scientific disciplines?
• How are 3D printing technologies research distributed over years?
• How are studies on 3D printing technologies distributed in terms of sample sizes and groups?
• How are studies on 3D printing technologies distributed based on data collection tools?
• How are studies on 3D printing technologies distributed using data analysis techniques?
• What are the trends in research on 3D printing technology in education?

2. METHOD

2.1. Research Model

The research's objective, to ascertain the current state of 3D printing technology in the literature and their usage for educational purposes. Within this purpose, document analysis was used as the research model and the data were analyzed with the content analysis method. According to Stone, Dunphy, Marshall, and Ogilvie [7], content analysis is a technique that is typically used to provide systematic findings based on specific characters described in a given text. In addition, Cohen, Manion, and Morrison [8] state that content analysis is a very important method in producing theoretical results from texts.

2.2. Data Collection

Purposeful sampling method was used in the study [9]. The sample that is considered to reflect the entire universe is chosen in purposive sampling, which is also known as monographic or theoretical sampling in the literature [10]. The scope of the study comprised papers (n=101) directly relevant to the field of education in the ERIC database, one of the key databases in the field, and in the TR database, as well as master's and doctoral theses in the YOK thesis center and Proquest databases. In the process of data collection, the relevant databases were searched according to the *"3D printer, 3D printers, 3D Technologies, 3 dimensional printers, 3D technology and education"* keywords. Results are limited to full-text articles and thesis in indexed journals.

2.3. Data Analysis

In the current study, descriptive statistical methods were used to examine the content analysis-subjected data. Data and frequencies relevant to each study's questions were obtained. A total of 101 studies examined within the framework of the study were evaluated in terms of the disciplinary fields of the research, the type of publication of the research, the year of publication, the database where the articles in the relevant field were published, the method preferred in the studies, data collection tool, data analysis techniques, sample type and number, and the effects of 3D printer technology on the study group. The studies coded T_7,R_9,R_{21},R_{22},R_{23},R_{25},R_{45}, R_{49},R_{56},R_{78} (f=10) were conducted with more than one sample type. For this reason, the total number of studies indicated in Table 2 (f=111) is higher than the number of studies analyzed.

3. FINDINGS

When the relationship between education and 3D printing technology was analyzed in terms of subject area, it was determined that there were subject areas shown in the following figure according to the studies specified in Table 1. Information on how 3D printing technology is applied for educational purposes in many fields may be listed in Table 1. Based on this facts, Figure 1 depicts how the subject areas are distributed.

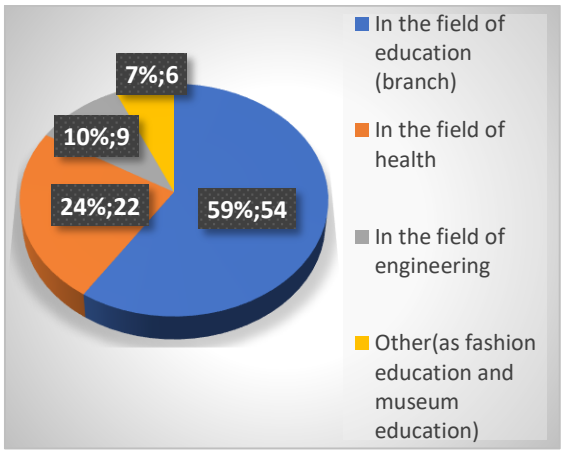

Figure 1. Distribution of the studies according to disciplinary fields.

According to Figure 1, 3D printing technologies were mostly utilized in subject areas such as science, physics, chemistry, biology, mathematics, geometry, history, social studies and pre-school education (59%). These studies were followed by 3D printing technology applications in health education (22%). It was determined that there were a limited number of studies (10%) in engineering education and (7%) in areas such as fashion education and museum education using 3D printing technology.

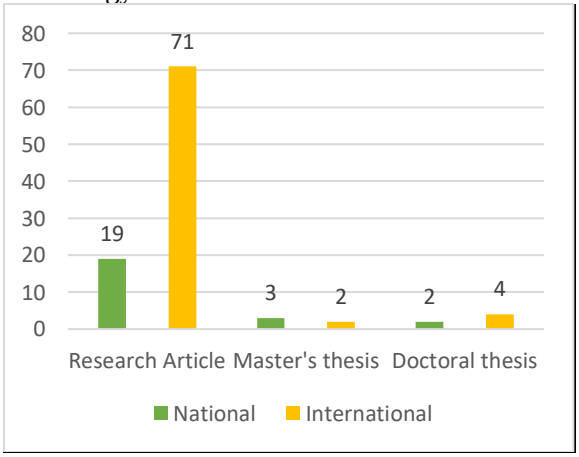

Figure 2. Distribution of the studies according to publication types.

According to Figure 2, it was seen that the researches on the use of 3D printing technologies in the field of education were generally published in national and international databases as article studies (f=90). In addition, a total of 6 doctoral dissertations and 5 master's theses were conducted in this field, both nationally and internationally. Within the scope of the research, 71 of the article studies examined were accessed from international and 19 from national databases. Of the postgraduate theses, 5 were national and 6 were international theses.

The distribution of studies on the use of 3D printing technology in education according to years is presented in detail in Figure 3.

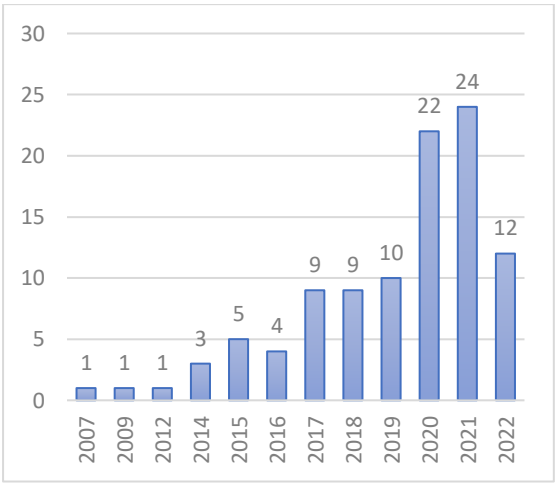

Figure 3. Distribution of the studies by years.

According to Figure 3, it was determined that the studies on the use of 3D printing technologies in education showed a significant increase after 2019. The studies conducted in 2007 (f=1), 2009 (f=1) and 2012 (f=1) were found to be considerably less than the studies conducted in 2014 and after.

Table 1. General characteristics of the studies examined within the scope of the research

Code	Author [year] Research article MsC/PhD	Purpose of study	Method [Data Type - Model - Sample - Data Collection Tool- Practical- Theoretical]	Results
R_1	[11]	The advantages and logistical difficulties of 3D printing technology in education were investigated in this study.	Practical	When printable educational models are combined with a rich library, usability and use of applied teaching devices will increase and may provide an impetus to design more models in the future.
R_2	[12]	Support learning effectiveness by creating and implementing 3D datasets into standard healthcare curricula and spreading awareness of the possible educational benefits of learning anatomy and physiology in 3D.	Quantitative-3rd and 4th grade medical students – Survey-Theoretical	Anatomy, physiology, and potentially pathophysiology learning material could take on a new level thanks to 3D visualizations built on real-world data. It has proven successful to incorporate 3D pictures with existing educational program themes.
R_3	[13]	It is intended to concretize 2-dimensional mathematical concepts with a 3D printer.	Theoretical	More research can be conducted in this area and various models can be produced.
R_4	[14]	In this article, we have created a number of digital 3D design files of molecular structures that can be used to teach students about symmetry and dot groups in chemistry education.	Literature review Practical	Molecular structures that are difficult or impossible to replicate with conventional manufacturing methods or commercially available molecular model kits can now be turned into tangible models thanks to 3D printing.
R_5	[15]	The role of e-Making in bringing together virtual and physical elements as an e-Learning tool for design education is explored.	Practical	In this study, the fact that the responsibility of delivering information to the group was provided by students as well as teachers may be a complementary feature of technological developments online for both students and teachers at the same time.
R_6	[16]	Fast prototyping technology is covered by considering the use of a printer suitable for the laboratory stand designed for 3D printing.	Theoretical	The conducted study provided a better understanding of the process of creating printed models. It also increased students' engagement in the lessons.
R_7	[17]	This article intends to change students' knowledge skills in technology/mechanics teacher training courses.	Quantitative-Preservice physics and mathematics teachers and undergraduate students of civil engineering, electrical engineering, aviation - Observation-Practical	The definition of visual literacy's essential competences can be found in educational literature. The literature emphasizes the necessity of changing the emphasis of CAD instruction from exercise in tool use to practice in visual literacy and design competencies.
R_8	[18]	It is recommended to develop a 3D printing curriculum and assess it in Mechanical Engineering education.	Quantitative-Mechanical engineering undergraduate students- Survey-Practical	An educational method combining classroom and applied lessons is an effective way to increase students' understanding of 3D printing.
R_9	[19]	This study investigated the motivation and satisfaction of 3D printing technology for students and adults.	Quantitative-Survey-Group of 38 people [34 students and 4 adults]-Achievement test-Theoretical	As a result of the research, it is concluded that the student group showed more self-efficacy and in-class task allocation than the adult group, and the student group participated in more 3D printer training. In both groups, task allocation and self-efficacy have a positive relationship with learning satisfaction.
R_{10}	[20]	Using an example from Macquarie University and Western Sydney University in Australia, it examined how	Literature review-Practical	The application of 3D printing will further spread and expand to other subjects. Medical education resources, like the world we live in,

		3D printing can be successfully utilized in anatomy education.		will continue to evolve and increase in the wake of both technological development and growing educational demands for the development of clinical competencies that are constantly changing and increasing in complexity.
R_{11}	[21]	A one-year process of skill development, concept acquisition and use of 3D printing activities among teachers was explored.	Qualitative-Teachers-Observation and discussion-Theoretical	In the research, the use of 3D printing technologies among educators was examined for one year. More detailed research on the subject is recommended.
R_{12}	[22]	Students are asked to design something and build a prototype of it in order to assess how 3D printing affects student experiences and learning of the design process.	Quantitative-Experimental-Interior design undergraduate students-Scale assessments within the scope of the project- Practical	It has been demonstrated that 3D printing can affect students' experiences in a design-based course and that students can have a different kind of learning about the design process.
R_{13}	[23]	It was looked into how 3D printing technology may be used to create educational materials that would give visually challenged pupils complete access to excellent historical instruction.	Literature review - Visually impaired students-Practical	In the classroom, the 3D materials had a positive impact on both teaching and learning. The students and teachers who participated in this project strongly acknowledged several benefits, including the empowerment of 3D tactile teaching materials, while noting that the material properties and robustness of 3D printed objects need to be improved for further application.
R_{14}	[24]	It was aimed to determine students' perceptions about using 3D printing technology inside and outside the classroom.	179 Engineering undergraduate students-Classroom assessments, exams, Likert type scale-Theoretical	It was concluded that the class average increased in the three classes that implemented the 3D printing technology project within one year and this trend was maintained and increased in the second year of the study.
T_1 PhD	[25]	The purpose of this study is to investigate how people in the layered manufacturing field can gain the necessary knowledge and training about the 3D printing machine.	Mixed method-Content analysis-questionnaire-descriptive statistical tools - 226 undergraduate students at different grade levels - Practical	It is necessary to have applications for material science manufacturing processes, management, quality enhancement, prototyping/STL, 3D printing, setup, slicing, and additive manufacturing. These competencies and subject-specific specialties in other engineering focuses, such as materials or design, can be reintegrated into a core additive manufacturing concentration.
T_2 MSc	[26]	It was aimed to determine teacher efficacy regarding teachers' self-created mathematics teaching skills and to identify whether preservice and in-service teachers can use 3D printing..	Qualitative - Teachers-Form- - Practical	Due to the fact that visual learning is significantly more successful than reading, when students use the 3D printer to make their creations, the idea they are trying to understand will already be there. While producing a design that is utilized to understand the notion given to them, 3D printing encourages pupils to consider various ideas.
R_{15}	[27]	The importance of 3D printing studies in fashion design for educators has been investigated.	Qualitative and Quantitative-Case study method-17 students - Theorectical	Thanks to 3D printing technology, pedagogical formation opportunity was provided in fashion design courses.
R_{16}	[28]	Review of current technologies and forecasted trends for 3D printing materials and their application in medical education.	Literature review-Practical	A desirable, potent, and adaptable technology, 3D printing has the potential to be available to anyone. Developing the physical contact and motor abilities required for surgical training has been shown to be made possible by 3D printing.
R_{17}	[29]	The usage of 3D printing technology by teachers and students in four history/social studies classrooms at a secondary school was the subject of this exploratory study.	Qualitative-Brainstorming-Open-ended study area-Practical	It demonstrates how creating, designing, and printing 3D models of objects connected to earlier standards-based subjects can give students a framework for active and involved learning in background and social education classes.

R_{18}	[30]	It aims to assess the influence of 3D models on pediatric assistants' comprehension and learning of Fallot tetralogy after a teaching session.	Quantitative-Pediatric assistants - Practical	Physical 3D models enhance situated learning on the topic of Fallot's tetralogy by increasing student satisfaction. Future work examined the impact of models on instruction that is more complex and detailed.
R_{19}	[31]	The purpose of the study is to ascertain pre-service social studies instructors' perceptions about 3D printers, the models produced by these printers, and the relevance of these models to the social studies curriculum.	Qualitative- Semi-structured interviews with 20 students-Interview-Practical	Pre-service teachers described 3D printers as a ground-breaking technology that makes the abstract tangible, can produce materials that usefully support the learning-teaching process, adds a third dimension to the learning-teaching process, activates the sense of touch, and offers simplicity in this context.
R_{20}	[32]	To determine the usage areas of 3D printers in education and social studies education and to explain their connections with the 2017 Social Studies Curriculum with examples.	Literature review-Practical	The program's principles, core competencies, abilities, and objectives may all be acquired using 3D printers. Additionally, 3D printers have helped to create 3D Printed Artifacts Museums [3D-PAM], a brand-new approach to museum education and extracurricular learning.
R_{21}	[33]	The role of schools in 3D printing production and their responsibility to act as soon as possible to design people action plan.	A reference and experimental group test-Theoretical	Teachers and students have both displayed persistence, creativity, and a great deal of curiosity in their want to learn more about 3D printing.
R_{22}	[34]	3D printers can be used to gain all of the program's concepts, key competencies, talents, and objectives. A brand-new method of museum education and extracurricular learning called 3D Printed Artifacts Museums [3D-PAM] was also made possible by 3D printers.	Quantitative -7th and 12th grade students survey-Theoretical	The 3D printing and design class had a positive impact on the student's motivation, interests, math skills and real life skills.
T_3 PhD	[35]	The aim of the study is to describe the experiences of 5th grade primary school students in learning entrepreneurship-related knowledge and producing with 3D computing tools in a Design-Oriented Improvisation [DOD] activity.	Qualitative and quantitative data analysis-5th grade students – Test-Practical	In the DOD event, which aims to provide production experience with 3D computing tools, participants' entrepreneurship knowledge and awareness of entrepreneurship concepts are increased.
R_{23}	[36]	The effect of 3D design applications, which are part of Hackidhon activities, on students' spatial skills is examined.	Qualitative-53 teachers, 159 students-Spatial skills test-semi-structured interviews-Practical	All of the teachers' opinions are positive. This shows that there are no serious problems with the design of the activities.
R_{24}	[3]	It was aimed to determine the current status of 3D printer technologies and their use for educational purposes.	Literature review-Theoretical	It was also concluded in the study that there are fewer studies directly related to educational sciences compared to other fields.
T_4 MSc	[37]	By exploring the use of 3D technologies, current museum and digital heritage research is examined.	Literature review-Practical	By allowing for scholarly research and remote viewing of the collection, it also presents an opportunity to advance the initiative. The collection's digitalization demonstrates how 3D models are essential to a new approach to digitally recording museum exhibitions.
R_{25}	[38]	It is aimed to examine in depth the effects of 3D design education for children in terms of students.	Qualitative-79 students-Practical	It is observed that students do not have any problems in establishing part-whole relationships. The fact that the ability to establish a part-whole relationship, which is included in the definition of spatial thinking, was observed with indicators in students as a result of the activities is thought to be a result that supports the contribution of such activities to spatial thinking.
R_{26}	[39]	In this study, the use of 3D printers in education and their potential areas of use were examined.	Review article-Theoretical	It is believed that by adjusting educational policies to this new technology and translating instructional content into a more integrated structure with these technologies, educational efficiency can be boosted.
R_{27}	[40]	To evaluate the viability of creating prosthetic teeth for endodontic teaching using 3D printing technology, examine the printing process' precision, and gauge	Undergraduate dentistry students 3rd and 4th grades-Practical	For the purpose of creating replicas of teeth for endodontic training, the printing process' precision is adequate. The undergraduate students expressed their appreciation for the accessibility

		how well the teeth perform when used by students.		of these replicas and their standardization's contribution to instruction.
R_{28}	[41]	Mesoreactors created and used in 3D printing for chemical engineering education.	Chemical engineering students-Practical	
R_{29}	[42]	To introduce the use of 3D printing technologies in the field of health, to explain the relationship between its use in the nursing profession and to examine how it is used in our country and in the World.	Qualitative-Content analysis-Literature review-Theoreatical	3D printers have also managed to become the center of attention in almost every field as the favorite of technology. It has been observed that 3D printers, which are used for many purposes in the field of health, are mainly used for simulation and training purposes in the field of nursing.
R_{30}	[43]	This study aims to summarize the current state of 3D printing for STEM education at university level. It also aims to examine the current methods and best practices used in 3D printing in the classroom.	Literature review-Theoretical	Due to the low cost of the equipment and supplies, as well as the relatively straightforward and secure printing and post-processing, this technology is perfect for hobby and consumer printing for educational needs.
R_{31}	[44]	This study aims to examine the effect of 3D design clubs in secondary schools on students' design and 3D thinking skills.	Qualitative- 10 5th grade students-Rubric form-Practical	In general, individuals who learn by doing, experiencing and having fun have high motivation to study and students are happy while doing their studies and their participation in the lesson has increased and they have exhibited positive behaviors by completing their studies.
T_5 PhD	[45]	TeachersS use of 3D printing, holograms, VR and augmented reality and its impact on learning in education were investigated.	Qualitative-21 Secondary school teacher-Online forms and interviews-Theoretical	It shows that 3D tool types such as computer games and simulations support different learning domains. Such tools help with problem solving and decision making and even motor skills.
R_{32}	[46]	Within the context of Senirkent Vocational School, it seeks to evaluate the viability of using 3D printing technology in education.	Qualitative-Phenomenological method -6 male associate degree students Semi-structured interview-Practical	Thanks to 3D printing, it is easier to explain subjects that are difficult to understand by students. In addition, interactive classroom activity was provided. In theoretical lessons, small models of the examples given in order to understand the subject were printed to increase the interest and motivation of the students.
T_6 MSc	[47]	It is aimed to examine "The Effect of 3D Printer Use on Academic Achievement, Attitude, Motivation and Critical Thinking Tendencies" by focusing on 3D printers.	Quantitative-35 7th grade students-Attitude, motivation and critical thinking scale-Practical	The physical presentation of the digital materials developed by the students during the education process increased the academic success of the students. Seeing the students' tangible and tactile designs also increases their design competencies.
R_{33}	[5]	In order to give a cutting-edge literature overview of where and how 3D printing is being employed in the educational system, the report reviews sporadic bodies of research.	Literature review-Theoretical	Students of all ages have learned about 3D modeling through online courses or trainings.
T_7 MSc	[48]	The study was conducted to examine the effectiveness of worksheets designed compatible with 3D printer pen in teaching.	Qualitative-12 10th grade students-Descriptive analysis-Observation, clinical interview-semi-structured interview-interview form-Practical	Worksheets and 3D printouts provide a high level of efficiency in exploring the formula. This is especially important when it is considered that students are participating in such a study for the first time. It is seen that the lessons taught with high-tech devices such as 3D pens give students confidence in the future and a sense of professional enthusiasm and desire.
R_{34}	[49]	Through intensive applied sessions, educators in all areas of teaching will gain an understanding of the basic principles of 3D printing, become aware of the opportunities and limitations, and together develop strategies for implementation in their curricula.	Literature review-Theoretical	
R_{35}	[50]	To design and create 3D printed teeth with anatomical details to be used in pre-clinical dental education.	Quantitative-47 dental students Survey-Practical	Students were asked about their interest in improving their tooth preparation skills with imprinted teeth and rated them as good.

T_8 MSc	[51]	The aim of this study is to examine the education and use of 3D printing technologies in undergraduate level education in Architecture programs in Turkey and to make a situation assessment.	Qualitative-Descriptive survey model-Bologna information form-Practical	Digitalization has changed the process of architectural thinking and thus architectural education and architecture. Therefore, it is necessary to prepare a new architectural education curriculum in universities, introduce new technologies and new strategies, and lay the foundations of digital thinking in the design process.
R_{36}	[52]	It is aimed to examine the effect of using physical materials in addition to 3D digital materials on academic achievement, course attitude and motivation by centering on 3D printers.	Quantitative - 35 7th grade students - Assessment rubric, Attitude scale, Motivation scale-Practical	The physical presentation of the digital materials developed by the students during the education process increased the academic success of the students. Seeing the students' tangible and tactile designs also increased their design competencies.
R_{37}	[53]	It is aimed to examine 20 years of literature on the use of 3D printing in biological education.	Literature search-Theoretical	We were taken aback by the dearth of comprehensive studies analyzing how 3D printing has affected students' learning of the life sciences. The advantages of incorporating students in interdisciplinary project solving have been shown in historical and theoretical studies in the past, but the adoption of this instructional technique in the life sciences has been notably absent from the general study literature.
R_{38}	[54]	It aims to determine what information is available about the use of 3D printing technology.	Quantitative-430 students-Survey-Theoretical	It shows that students mainly have knowledge about 3D printing obtained from the internet. They were happy to deepen their knowledge in specialized courses in this field.
R_{39}	[55]	The role of 3D printing models on human anatomy learning is examined.	Meta-analysis-Literature review-Practical	The 3D group performed better on the post-training test than the cadaver or 2D groups. Compared to the conventional group, more students in the 3D printing group were pleased with their education.
R_{40}	[56]	The study concentrated on first-year university students' ability to create three-dimensional [3D] representations of objects from two-dimensional [2D] perspectives using their visuospatial cognition.	100 engineering graphics students in Africa-Practical	
R_{41}	[57]	By assessing current peer-reviewed studies that make use of this technology to improve chemistry education, we hope to serve as a resource for educators interested in integrating 3D printing into chemistry classrooms.	Literature review-Theoretical	
R_{42}	[58]	It examines the impact of 3D printing technologies on visually impaired students learning Chemistry structures.	Qualitative - 17 students with visual impairment - Question and Answer, Observation-Practical	Students were asked specific questions. According to their answers, 3D printed models are preferred.
R_{43}	[59]	It examines the effect of augmented reality supported geometry teaching on students' 3D thinking skills.	Qualitative-5th and 8th grade students - Pre-test, post-test - Practical	After the 4-week experimental study, it was observed that 3D printers contributed positively to thinking skills.
R_{44}	[60]	To identify how students use their spatial reasoning skills and knowledge to solve geometric problems in order to implement instruction and design interventions.	Quantitative-1357 students-Questionnaire, observation-Practical	At the end of the studies, it is shown that students' spatial reasoning skills increase positively.
R_{45}	[61]	The study looked into how project-based learning, particularly for 3D modeling, affected university students.	Qualitative -49 2nd grade visual arts students-Focus group discussions -Practical	Students expressed greater interest in 3D design and appreciated the modeling process. Their attitudes and learning patterns changed as a result of frequent sharing and feedback.

R_{46}	[62]	To improve the critical thinking abilities and scientific attitudes of high school students, the study creates a 3D visualization tool in virtual reality.	Qualitative-96 10th grade students-Quasi-experimental-post-test, -Practical	A different section can be added to suggest applications for 3D visualization goods and the virtual reality environment. Additionally, chemistry instructors can use this material as part of an in-class action research project with a different variable.
R_{47}	[63]	The impact of 3D printed function graph models on the conceptualization processes of the idea of derivative will be examined in this paper.	Qualitative - Content analysis method-Practical	A parabola model that was 3D printed was in the hands of the kids. They described feeling the parabola as they did so. Overall, the models' sensory and qualitative treatment turned out to be a significant part of the students' expressions.
T_9 PhD	[64]	To collect past and future sustainable, collaborative and purposeful 3D printing works of university students.	Qualitative case study - 12 students-Practical	The number of women and students from different backgrounds graduating with STEM degrees has been increasing over the last three decades.
R_{48}	[65]	Its objective is to provide the findings of a study done as part of the European project "3D Printing in VET" from the viewpoint of the current applications of 3D printing in education and the sector's stakeholders.	Quantitative-Survey- Engineering students-Practical	Teachers need to acquire specific competencies to introduce 3D printing in their training programs and to use printers and related tools independently.
R_{49}	[66]	To investigate the differences in geometry learning in terms of 3D pencils.	Qualitative-174 6th grade students, 7 teachers-Pre-test, post-test-Practical	It shed light on the impact of visual and sensory-motor experiences on math learning in school and confirmed previous work showing that the effects of gestures are particularly good at promoting long-term learning.
R_{50}	[67]	The aim of the study is to investigate the use of 3D printing technology for the production of personalized surgical teeth.	Literature review-Practical	Individual surgical training models created using 3D software and based on actual patient data provide more accurate substitutes for commercially available models. It is anticipated that it will be crucial for dentistry students' future instruction, preparation, and exams.
R_{51}	[68]	To determine the views of pre-service science teachers about the 3D printer.	Qualitative-33 pre-service teachers-semi-structured interview form-Practical	It can be said that some pre-service teachers were able to define the 3D printer by using the printer's intended function, were aware of the benefits and drawbacks of 3D printers in the educational process, and provided logical ideas for its use.
R_{52}	[69]	To create a model of technical pedagogy that allows universities to more efficiently integrate additive manufacturing production into their curricula.	Literature review-Theoretical	The curriculum process with a 3D printer perspective presented in this study can be used to apply the 3D printer to any engineering education as it provides a clear process model for curriculum work. This has been applied to curricula in technical subjects for educators in their curriculum development work.
R_{53}	[70]	To teach how to use 3D printers and software that students can use to turn 3D product designs into prototypes.	Ostim vocational school mechatronics students-Practical	It was observed that students who produced using 3D printers were more problem-solving oriented, did not hesitate to use initiative in problem solving, and were more successful in finding, proposing and implementing innovative and alternative solutions than students who only did written projects.
R_{54}	[71]	It focuses on different initiatives that help the educational process worldwide and methods of applying 3D printing in education.	Literature review Discussion-Theoretical	It has been reported to increase design thinking skills, teaching and learning efficiency, and reduce anxiety about teaching specific subjects.
R_{55}	[72]	Focuses on the pedagogical possibilities of 3D printing	63 16-year-old secondary school students [pilot study] Online learning-Practical	The usage of 3D technology by art teachers can serve as a stimulating tool. The project that is the subject of this article shows how it may foster both digital and visual creativity.
R_{56}	[73]	A new approach to 3D modeling for drawing chemical models is described.	34 secondary school students, 47 high school students-Practical	Construction is really straightforward and independent of user craftsmanship skills when using 3D printing. This fact has made it possible for teachers and trainers to use these tools both during autonomous student inquiry projects and basic measurement lab work.

R_{57}	[74]	The study was conducted to investigate the effect of the worksheet designed compatible with the 3D printer pen on the learning of the solid objects subject.	Qualitative-12 10^{th} grade students - observation, clinical interview, video recording, worksheets-Practical	It is revealed that the instructions in the worksheets have a structure that positively manages and supports the processes of moving from concrete thinking to abstract thinking and spatial reasoning. With all these aspects, it is clear that worksheets designed compatible with the 3D printer pen will provide great support to student-centered education in almost every aspect.
R_{58}	[75]	To ascertain how 3D printing activities affect pre-service teachers' perceptions of 3D printing activities as well as their self-efficacy in technology pedagogical field knowledge (TPFK).	Qualitative-Exploratory sequential mixed method design- Pre-test and post-test-Practical	The vast majority of participants had favorable opinions on how 3D objects affected learning. They claimed that 3D objects turn abstract ideas into tangible visual examples, facilitate learning, make lessons enjoyable, encourage students to learn more about their field, pique their interest, and aid in the development of creative thinking and design skills, allowing them to produce a variety of subject-specific educational materials.
R_{59}	[76]	It explores three multilingual students' conceptual understanding of 3D shapes displayed through peer and classroom interactions in his classroom.	Qualitative - Focus group interviews-Practical	The analysis concluded that there is a need to develop a comprehensive understanding of what is meant by the dimensions of mathematical structure in curriculum documents.
R_{60}	[77]	Students' perceptions of completing 3D printing of a physical model in two different Biology courses, Anatomy and Physiology and Molecular Biology	Qualitative and quantitative - Undergraduate students - Survey - Pre-test - Post-test-Theoretical	Future research has been included.
R_{61}	[78]	The pedagogical possibilities associated with the use of 3D printing technologies in a middle school classroom [11-12 years old] were investigated.	Qualitative and Quantitative research methods-Theoretical	In this study we investigate the extent to which 3D printing is failing and contribute to the literature on its benefits in STEM disciplines.
R_{62}	[79]	Model production with 3D printer technology has been studied in dentistry education.	Experimental-Control and experimental groups-Practical	The overwhelming majority of participants were in favor of the way 3D items improved learning. They asserted that 3D objects transform abstract concepts into concrete visual illustrations, facilitate learning, make lessons enjoyable, pique students' interests, encourage them to learn more about their field, and support the growth of creative thinking and design skills, enabling them to produce a variety of subject-specific educational materials.
R_{63}	[80]	Aimed to describe the use of 3D printing technology to support teaching and learning in health care education and the implications for 3D technology from a teaching and learning perspective.	Quantitative-Literature review-Quasi-experimental evaluations-Practical	The main conclusion of this scoping review finds that there are a variety of 3D technologies that teachers can use to support their teaching in health education.
R_{64}	[81]	The purpose of the study is to identify the requirements of physics, chemistry, and biology teachers for the creation of 3D solid models and their application in instructional procedures.	103 teachers Design and Use of 3-Dimensional Models in Science Teaching Form - content analysis-Theoretical	Considering that all of the teachers in the sample of this study [f=103] have not received any training to use 3D printer technologies before, it can be said that teachers will gain very important experiences in enriching the learning environment with a training to be designed on using 3D printer technologies.
R_{65}	[82]	One of the schools that has absorbed the mission and has a long history is ISTE [Iskenderun Technical University] Iskenderun Vocational School, and its programs have looked at the potentials and utilization areas of 3D printers.	İskenderun Vocational School students-Theoretical	It is expected to develop 3D printer technologies capable of producing parts with high manufacturing speed, low surface roughness and high reliability features, which are primarily needed in areas such as aviation, automotive and machinery where 3D printing technologies are used intensively, and to replace conventional production methods.
R_{66}	[83]	To examine studies with 3D printing of brain and skull vault pathology data.	Literature review-Practical	Systems supporting 3D printing in neurology education have not fully increased despite the growing literature. 3D printed surgical phantoms offer a pathway for the advancement of global surgical training initiatives.

R_{67}	[84]	Aimed to determine the effectiveness of STEM-based inquiry learning packages in simple machine material to improve middle school students' critical thinking skills	Qualitative and quantitative-2nd Class students- pre, post test· critical thinking skills test questionnaire-Theorectical	STEM was found to have a positive impact in areas such as learning activities, questioning students' critical thinking skills, collaboration and capturing technology through 3D printing.
R_{68}	[85]	The benefits of using 3D printer technology in dental preclinical education were examined.	Compilation-Practical	3D printers, which are included in production technologies with technological developments, have brought a new vision to the practice of dentistry as well as the field of health.
R_{69}	[86]	To examine the effects of the developments after Industry 4.0 on education in the world and Turkey.	Qualitative study-Theoretical	The introduction of artificial intelligence and robots in the production process with the advances in technology has raised concerns about employment on the one hand, but has also led to the emergence of new professions and areas of specialization on the other hand.
R_{70}	[87]	It aims to thoroughly analyze how 3D printing technology is used in environmental design practice.	Literature review-Theoretical	Students may swiftly turn virtual answers into finished objects that are visible to the naked eye thanks to the use of 3D printing technology in the teaching process.
R_{71}	[88]	To develop a wearable fashion product with 3D printed parametric structural compositions.	Mixed-Literature review-Practical	If the 3D modeling process is adapted to the size of the human body, it offers the possibility of producing a customized fashion product that can meet the needs of the individual.
R_{72}	[89]	The importance of using 3D printers for technological education in the fields of technical creativity and design, product manufacturing technology and home economics is addressed.	Theoretical	As a result, it is important to teach students the techniques of tomorrow, not yesterday or today. Therefore, it was seen that it is important to train technological education students in higher education institutions to use 3D printers.
R_{73}	[90]	The educational methods in which 3D printing is used were investigated.	Qualitative research method-Theoretical	It was analyzed that 3D printing helps students develop creativity and problem solving skills.
R_{74}	[91]	The application possibilities of 3D printing technology in both education and landscape design are examined.	Literature review-Theoretical	Design workshops using 3D models can help students understand 3D design and, above all, have been found to be effective in increasing students' interest and triggering participation.
R_{75}	[92]	A novel preclinical teaching method of caries removal in 3D printed teeth is investigated.	Quantitative-Dentistry last grade students Survey-Practical	Teaching caries removal with 3D printed teeth can help students gain confidence and feel better prepared to treat patients in clinics.
T_{10} PhD	[93]	It was investigated that spatial thinking skills should be used while 3D modeling with middle school students and providing inferences for the future.	Quantitative-Question-answer, survey-Theoretical	It shows that there are ways to encourage novices and underrepresented students to engage with and develop an interest in using and engaging with advanced technologies such as 3D printing and modeling.
R_{76}	[94]	Describes an educational innovation for geoscience class with 3D printing technology to improve structural interpretation skill at higher education level in Thailand.	Quantitative - Geological engineering students Observation – discussion-Practical	It shows that the use of a 3D printing model can lead to better development of structural interpretation skills than those developed using the traditional teaching method.
R_{77}	[95]	We aimed to evaluate the usefulness of 3D printed models for teaching medical students.	Quantitative-5th grade medical students Questionnaire [multiple choice]-Theoretical	Using 3D printed models increases both objective knowledge and student satisfaction for medical students. The practice should be widespread.
R_{78}	[96]	The Contribution of 3D Printing to the Education of Primary and Secondary School Students	Qualitative - Observation-Practical	The introduction of 3D printing technology into the classroom will certainly enhance students' hands-on skills, independent innovation, teamwork and independent thinking skills.
R_{79}	[97]	The usage areas of 3D printer in education were investigated.	Theoretical	We continue to be astounded by the potential and applications of 3D printing, which is anticipated to be accessible in all colleges and institutions so that students have the essential space for imagination and innovation.

R_{80}	[98]	This study aims to investigate the role of 3D printer technology in medical education from past to future.	Literature review-Theoretical	Over the past ten years, 3D printing has significantly changed a number of industries. It is an astonishing and fascinating instrument. By incorporating more modern and effective additive manufacturing processes into existing methodologies and research, it is possible to make better use of this important resource.
R_{81}	[99]	To design various instructional materials to teach biological systems in the "Systems in Our Body" unit to 6th grade students with visual impairment and to evaluate the effectiveness of these materials.	Qualitative data analysis 6 visually impaired students-Observation-observation form-Practical	It is thought that this study may contribute to closing the gap in finding appropriate teaching materials in science courses for students with different needs and increase their academic achievement.
R_{82}	[100]	To develop and test a prototype of an innovative tool for medical education in human anatomy.	Quantitative-62 second-grade medical students Survey-Practical	As the potential of AR and 3D modeling in medical education expands, further refinement of the tool is expected to increase learning efficiency.
T_{11} PhD	[101]	9th grade chemistry course within the scope of "Atom and Periodic System" and "Interactions between Chemical Species" units, it is aimed to design and implement a learning environment in which 3D design applications will be used.	Mixed method-63 9th grade students-pre-test post-test-'Chemistry Achievement Test' and 'Motivation and Self-Regulation Scale for Technology Learning'-Practical	It is thought that the use of 3D materials designed to concretize the teaching of abstract subjects in chemistry courses taught face-to-face in the classroom environment and for fast, easy and permanent learning can further increase both the efficiency of the course and the academic success averages of the students. It has been observed that as a result of the appropriate and correct use of technological tools and equipment for educational purposes in school and out-of-school environments, students' interest and desire for the lesson, their attention to the lesson and the efficiency of the lesson can increase.
R_{83}	[102]	We examined the meta-analysis of the use of 3D printers in otolaryngology education.	Qualitative-Content analysis-Theoretical	It suggests that additional studies on the use of 3D printing for medical students could benefit the medical education literature. This study concluded that there is a high degree of surgical skill utility, anatomical similarity, and educational value of 3D printed models by otolaryngology trainees and physicians.
R_{84}	[103]	It aims to investigate the role of a 3D congenital heart model in improving knowledge acquisition and long-term knowledge retention among medical students.	Meta-analysis -Test, survey Literature review-Theoretical	It revealed that with the use of the 3D printer compared to traditional teaching methods, there was no significant improvement in knowledge acquisition information accumulation. Obviously, there are positive benefits that the 3D printer brings. These should be addressed in another study.
R_{85}	[104]	The aim of the paper is to examine 3D printing, robotics education and finally, how 3D printing contributes to robotics education over a ten-year period between 2011 and 2020.	Qualitative - content analysis-Literature review-Theoretical	
R_{86}	[105]	To determine the student's understanding of 3D printing and self-assessment of primary skin lesions.	Quantitative-222 students-Online interviews Self-assessments of examination skills - opinion surveys-Practical	This study demonstrates the benefit of tactile experience in dermatology education not only at the time of COVID-19 but also afterwards.
R_{87}	[106]	This study is based on a program where teachers learn to integrate 3D printing into education.	Quantitative-38 teachers Survey-Theoretical	In the research, it is seen that it positively affects students' mathematical and engineering education, as well as learning by doing and experiencing, and the acquisition of spatial skills.
R_{88}	[107]	The study tries to understand the relative importance of different attributes for 3D printed anatomical training models, including touch, accuracy and costs.	Quantitative-Survey-Practical	60% of clinicians left the exhibition believing that 3D printing plays a moderate or important role in the hospital/healthcare system, while 100% of other healthcare professionals shared the same view.

R_{89}	[108]	In this study, students' views on teaching geometry with the three-dimensional dynamic geometry software Cabri 3B were examined.	Qualitative -16 8th grade students-Practical	The results obtained from the student'' views on teaching geometry with Cabri 3B provided new results to the existing literature, such as supporting autonomy, allowing interaction, and prioritizing individuality over group work in geometry teaching at the secondary school level.
R_{90}	[109]	The research aims to explore the current and future potential of 3D printing technology in various aspects of spine surgery.	Literature review-Practical	3D printing applications in spine surgery can be broadly categorized under patient-specific applications or condition-specific applications, depending on the geometry or biomechanical properties with 3D printing, respectively. Promising clinical results have been reported in many publications.

R: Research article, T: Thesis, PhD: Doctoral dissertation, MSc: Master thesis

The methods used in the studies on the use of 3D printing technology in education are shown in Figure 4 below.

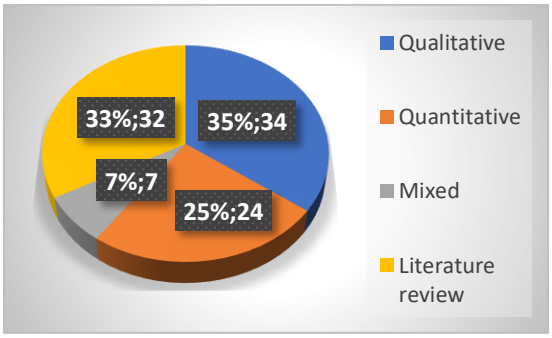

Figure 4. Distribution of the studies according to method types.

According to Figure 4, it was seen that qualitative methods (f=34) were mostly used in the studies conducted within the scope of the use of 3D printing technologies in education. There are also studies conducted using quantitative methods (f=24) and literature review (f=32). It was determined that mixed method approach (f=7) was preferred the least in the studies examined.

The findings on what kind of data collection tools were used in the studies examined within the scope of the methods presented in Figure 4 are shown in Figure 5 below.

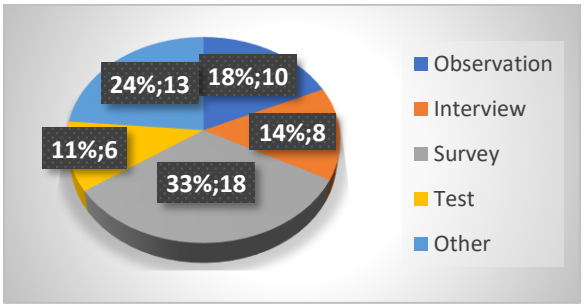

Figure 5. Distribution of the studies according to data collection tools.

According to Figure 5, it was seen that mostly questionnaires (33%) were used as data collection tools in studies on the use of 3D printing technologies in education. In addition to these data collection tools, interviews (14%) and observations (18%) were also used.

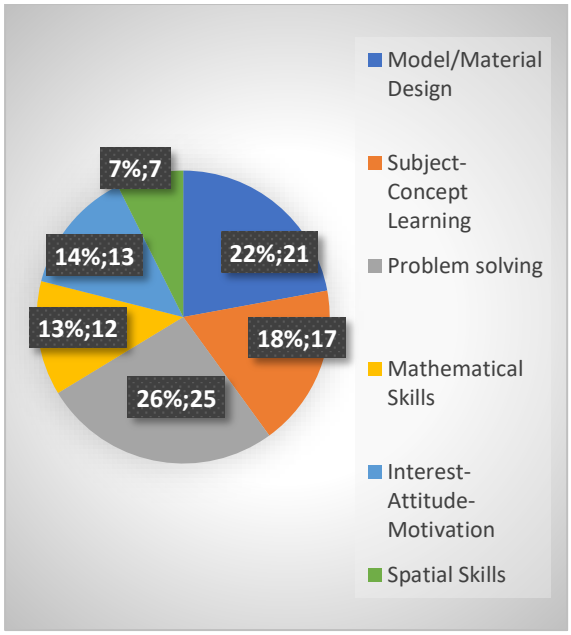

Figure 6. The purposes of usage 3D printing technologies in studies.

When Figure 6 is analyzed, it was determined that 3D printing technologies mostly improved students' problem solving (26%) and model/material design skills (22%). On the other hand, it was examined that 3D printing technology also contributed to the teaching of topics and concepts related to the course (18%) and the development of mathematical skills (13%).

When the studies were examined in terms of sample size, as shown in Table 2, it was seen that 26 studies were conducted with a sample size of 10 to 50 people, 7 studies with a sample

size of 50 to 100 people, 4 studies with a sample size of 100 to 200 people, 6 studies with a sample size of 200 or more, 38 studies did not specify the sample size and 31 studies were conducted as literature reviews. When the studies are evaluated in terms of quality, R_2,R_3,R_6,R_9,R_{11},R_{14},R_{15},R_{21},R_{22},R_{24},R_{26},R_{29},R_{30}, T_5,R_{33},R_{34},R_{37},R_{38},R_{41},R_{52},R_{54},R_{60},R_{61},R_{64},R_{65},R_{67},R_{69},R_{70},R_{72},R_{73},R_{74},T_{10},R_{77},R_{79},R_{80},R_{83},R_{84},R_{85},R_{87} coded studies are theoretically; R_1,R_4,R_5,R_7,R_8,R_{10},R_{12},R_{13},T_1,T_2,R_{16},R_{17},R_{18},R_{19},R_{20},T_3,R_{23},T_4,R_{25},R_{27},R_{28},R_{31},R_{32},T_6,T_7,R_{35},T_8, R_{36},R_{39},R_{40},R_{42},R_{43},R_{44},R_{45},R_{46},R_{47},T_9,R_{48},R_{49},R_{50},R_{51},R_{53},R_{55},R_{56},R_{57},R_{58},R_{59},R_{62},R_{63},R_{66},R_{68},R_{71},R_{75},R_{76},R_{78},R_{81},R_{82},T_{11},R_{86},R_{88},R_{89},R_{90} coded studies were carried out practically.

Table 2. The frequency of selection of sample groups and sizes.

Sample Groups	Sample Size (Number of Sample)					
	10-50	50-100	100-200	200^+	Number of Persons Unknown	f
Primary School Students (1.-4.)	R_{45}^*/R_{47}			R_{45}	R_{78}^*	4
Secondary School Students (5.-8.)	$R_{31}/T_6/R_{36}/R_{56}^*/R_{59}/R_{81}/R_{89}$	R_{25}	R_{23}^*/R_{49}		$R_{17}/R_{21}^*/R_{22}^*/R_{43}/R_{61}/R_{67}/R_{78}/T_3/T_{10}$	19
High School Students (9.-12.)	$R_9/R_{25}^*/R_{42}/R_{56}/R_{57}/T_7$	$R_{46}/R_{55}/T_{11}$		R_{44}	R_{22}	11
Teachers	$T_5/T_7^*/R_9^*/R_{49}^*/R_{51}/R_{87}$	R_{23}	R_{64}		$R_{21}/R_{11}/T_2$	11
Undergraduate Students	$T_9/R_{19}/R_{32}/R_{35}/R_{45}$	R_{40}/R_{82}	R_{14}	$T_1/R_{38}/R_{86}$	$R_2/R_5/R_7/R_8/R_{12}/R_{18}/R_{27}/R_{28}/R_{48}/R_{53}/R_{60}/R_{62}/R_{65}/R_{75}/R_{76}/R_{77}/T_8/R_{79}/R_{83}/R_{88}$	31
Sample Group not Specified	$R_1/R_3/R_{72}/R_{73}$					4
Literature review	$R_4/R_{10}/R_{11}/R_{13}/R_{15}/R_{16}/R_{20}/R_{24}/R_{26}/T_4/R_{29}/R_{30}/R_{33}/R_{34}/R_{37}/R_{39}/R_{41}/R_{50}/R_{52}/R_{54}/R_{63}/R_{66}/R_{68}/R_{69}/R_{70}/R_{71}/R_{74}/R_{80}/R_{84}/R_{85}/R_{90}$					31
Total	26	7	4	5	34	111

According to Table 2, undergraduate students were mostly preferred as the sample group in the studies carried out for the use of 3D printing technology in the field of education (f=31). On the other hand, similar studies were conducted with secondary school students, high school students and teachers working at different grade levels (Table 2). It has been determined that there are a small number of studies carried out with primary school students (f=4).

3. CONCLUSION, DISCUSSION AND RECOMMENDATIONS

In this research, it was aimed to conduct a content analysis of the studies on the use of 3D printing technologies in different fields of education. When the studies conducted in this context were examined, it was determined that there were mostly 3D printing technology studies conducted at the K-12 education level, as well as 3D printing technology was utilized in areas such as health education, engineering education, fashion education and museum education at the higher education level (Figure 1). It is considered that usage of 3D printing technologies can be effective in helping learners develop concrete learning experiences, develop creative thinking skills and learn by having fun [6]. When the studies on 3D printing technologies in the field of education are examined, it can be mentioned that most of the studies focus on 3D material development [110]. Although it has provided great convenience in terms of material/model development, it was stated that 3D printing technologies are expensive in terms of time and cost, so the level of accessibility is low [72]. As a result of the current research, it has been seen that 3D printing technologies have a very wide range of uses and have the potential to be used in almost all fields of science [3]. It has been observed that it is used much more than other field especially in fields such as health /

medicine, engineering / material sciences and science (physics, chemistry, etc.) [111]. In this sense, it is similar to the findings of the content analysis. It was determined that the studies examined within the objective of the study were of different types (Figure 2).

It was detected that these studies were mostly research articles and were scanned in international databases. Although the fact that 3D printing technology has made great progress in our country in recent years has led to an increase in the number of studies conducted in this field, the fact that the use of this technology is much more widespread in other countries affects whether the studies are national or international. On the other hand, it is thought that the higher number of the studies conducted in the form of research articles is related to the variability in the duration and quality of the application.

When the distribution of the years in which the studies were published was analyzed, it was observed that studies on the use of 3D printing technologies continued to increase with each passing year (Figure 3). This result shows that the use of in various fields of education in our country and in the world has started to be seen as remarkable by researchers working on this subject. It is thought that the developments in 3D printing technology and the relatively widespread use of these technologies compared to previous years have an important effect on this situation [3]. It is noted that the first studies on the use of 3D printing technologies in the field of education were conducted in national databases in 2017 (Figure 3). It was identified that there were more studies in international databases in this field and that they were integrated into various fields of education more rapidly. In our country, 3D printing technologies were first used in various fields of engineering and later adapted to various fields of education. In addition, the very limited number of laboratories with 3D printing technologies in our country may also have a significant impact on the number of studies carried out [32].

When the studies on 3D printing technologies in the field of education are examined, it can be mentioned that most of the studies focus on 3D material/model development [110]. It is seen that such studies are especially important in determining the potential of 3D printing technologies. In addition, there are also studies in which literature review and positive and negative aspects of the existing technology are stated [112]. It has been observed that there is a very limited number of studies to measure students' skills such as achievement, interest, motivation, problem solving, etc. and that students' skills cannot be measured in crowded group [39]. It is thought that the newness of the studies, the fact that the technology cannot be widely used in classroom environments, and the use of 3D printing technologies only in certain areas of education are effective in this situation. It is thought that with the rapid development of technology, access to 3D printing technologies will become easier and their use will be positively affected. In the studies conducted, it is seen that there are efforts to establish various laboratories around the world for the use of 3D printing technologies [113]. On the other hand, it is also thought that 3D printers will expand the field of 3D printers in the coming years and these technologies may be frequently used especially in the education of visually impaired individuals [114]. When the study coded Kwon, Lee and Kim [27] was examined, it was determined that visually impaired individuals understood the subject better and contributed positively to their education thanks to the material/model produced with 3D printing technologies. This result shows us that the materials/models produced using 3D printing technologies should be increased, so that individuals with any disability (vision, hearing, etc.) will also benefit greatly from participating in education.

According to the content analysis conducted for the use of 3D printing technologies for educational purposes, it was observed that the applications made in some fields were more than other fields and had positive effects. For instance, materials produced with 3D printing technologies in the field of health education have benefited this field in many ways. The 3D

printing technology used by medical and dental students during their education and the materials produced using this technology contributed to their better understanding of the relevant field courses and to improve themselves more by practicing. (R_2,R_{27},R_{35},R_{39},R_{50},R_{62},R_{63},R_{66},R_{68},R_{75},R_{77},R_{80}, R_{82},R_{83},R_{84},R_{86},R_{88},R_{90}) In addition, the materials/models created with 3D printing technologies positively affected students' interest, attitude and motivation (R_2,R_{27},R_{35}). The materials/models, which the students previously designed in 2D and concretized with the help of 3D printing technologies, helped them develop their spatial and mathematical skill areas and improved their motor skills (Figure 6).

When the relationship between education and 3D printing technology was investigated, it was found that the latter is very practical for interdisciplinary studies and can be applied to all ages and fields. Considering the findings, it was seen that the process of designing 3D materials/models, in which students, especially at the secondary school level, first design and draw in 2D and then produce them using a 3D printer, motivates students, improves their imagination and helps them become self-confident individuals (R_{22},R_{25},R_{26},R_{28},R_{38},R_{45},R_{51},R_{82},R_{90},T_5,T_9).
Within the context of the research conducted, it is thought that studies that bring together education and 3D printing technology will increase in the coming years. In particular, it would be more accurate for practitioners who use 3D materials/models in teaching subjects and concepts to focus on the instructional aspect of 3D printing technology by addressing all areas of education. In the teaching of subjects and concepts, it is very important that students participate actively in the process of designing 3D materials/models. For this reason, it is recommended that students' opinions and suggestions should be taken at every stage from 2D design to 3D production. Preferring affordable 3D printing technologies in 3D material/model production can provide easier accessibility to this technology. 3D printing technology used in education positively affects the process of establishing relationships between different subject areas of students in interdisciplinary studies. Further research on instructional effects can improve teaching environments by bringing all individuals with or without disabilities under the umbrella of education. In addition, considering the principles of instructional material design, in-depth research can be conducted on the process of 3D material/model development with 3D printing technology, the instructional effects of this technology and the skill areas it affects.

ACKNOWLEDGES

The abstract of this study was presented at IX. International Eurasian Educational Research Congress June 22-25, 2022.

REFERENCES

1. Aslan A., Durukan Ü.G., Batman D., "Fizik, Kimya Ve Biyoloji Öğretmenlerinin 3-Boyutlu Katı Model Tasarım Ve Kullanım İhtiyaçlarına Genel Bir Bakış" Int. J. of 3D Printing Tech. Digital. Indutries, Vol. 5, Issue 3, Pages 515-534, 2021.

2. Silén, C., Wirell, S., Kvist, J.; Nylander, E., Smedby, Ö., Advanced 3D visualization in student-centred medical education. Medical Teacher, Vol. 30 Issue 5, Pages 115-124, 2008.

3. Segerman, H., 3D Printing for Mathematical Visulation. The Mathematical Intelligencer, Vol. 34, Issue 4, Pages 56-62, 2012.

4. Scalfani, Vincent F.; Vaid, Thomas P., Simetri ve Nokta Gruplarının Öğretimi için 3B Baskılı Moleküller ve Genişletilmiş Katı Modeller. Kimya Eğitimi Dergisi, Vol. 91, Issue 8, Pages 1174-1180, 2014.

5. Loy, J., "e-Learning and eMaking: 3D Printing Blurring the Digital and the Physcal". Education Sciences, Vol. 4 Issue 1, Pages 108–121. 2014.

6. Szulżyk-Cieplak, J., Duda, A., & Sidor, B., 3D printers – new possibilities in education. Advances in Science and Technology Research Journal, Vol. 8, Issue 24, 96-101, 2014.

7. Verner, I., Merksamer, A., "Digital design and 3D printing in technology teacher education", Procedia CIRP, Vol 36, Pages 182-186, 2015.

8. Byun, M. K., Jo, J. H., & Cho, M. H., The analysis of learner's motivation and satisfaction with 3D printing in science classroom. Journal of the Korean Association for Science Education, Vol.35 Issue 5, 877-884, 2015.

9. Lee, I. H., Shin, J. M., & Cho, H. Y., Design and operation of 3D printing education curriculum in mechanical engineering. Journal of the Korean Society of Manufacturing Process Engineers, Vol. 14, Issue 3, 21-26, 2015.

10. AbouHashem Y, Dayal M., Savanah S. & Štrkalj G., "The application of 3D printing in anatomy education", Medical Education Online, Vol.20, Issue 1, Pages 29847, 2015.

11. Brown, A., "3D Printing in Instructional Settings: Identifying a Curricular Hierarchy of Activities," Techtrends Tech Trends, Vol. 59, Pages 16–24, 2015.

12. Greenhalgh, S., "The effects of 3D Printing in Design Thinking and Design Education", Journal of Engineering, Design and Technology, Vol. 14, Issue 4, Pages 752-769, 2016.

13. Wonjin, J., Jang, HI, Harianto, RA, So, JH, Lee, H., Lee, HJ, & Moon, M.-W., "Introduction of 3D Printing Technology in the Classroom for Visually Impaired Students". Journal of Visual Impairment & Blindness, Vol. 110, Issue 2, 115-121, 2016.

14. Perez, O. A., Espinoza, P. A., Gomez, H., Pitcher, M. T., Anaya, R. H., Hemmitt, H., & Nevarez, H. E. L. (2016, June). Year Two: Analysis of 3-D Technology Impact on STEM-based Courses; Specifically, Introduction to Engineering Courses. In 2016 ASEE Annual Conference & Exposition.

15. Colletti, R. C., "A study of positions available in additive manufacturing/3D printing and the education and skill requirements for these positions." Master Thesis, Eastern Michigan University. Michigan, 2016.

16.Lipson, H., "Printable 3D models for customized hands-on education". Mass Customization and Personalization (MCPC), 2007.

17. Kwon, Y. M., Lee, Y. A., & Kim, S. J., "Case study on 3D printing education in fashion design coursework". Fashion and Textiles, Vol. 4, Issue 1, Pages 1-20, 2017.

18. Jackson, S., "Mathematics and 3D Printing", Texas A&M University-Central Texas, 2017.

19. Garcia, J., Yang, Z., Mongrain, R., Leask, R. L., & Lachapelle, K., "3D printing materials and their use in medical education: a review of current technology and trends for the future". BMJ simulation & technology enhanced learning, Vol. 4, Issue 1, Pages 27, 2018.

20. Maloy, R., Kommers, S., Malinowski, A., & LaRoche, I., "3D modeling and printing in history/social studies classrooms: Initial lessons and insights". Contemporary Issues in Technology and Teacher Education, Vol. 17, Issue 2, Pages 229-249 2017.

21. Loke, Y. H., Harahsheh, A. S., Krieger, A., & Olivieri, L. J., "Usage of 3D models of tetralogy of Fallot for medical education: impact on learning congenital heart disease", BMC Medical Education, Vol. 17, Issue 1, Pages 1-8, 2017.

22. Karaduman, H., "Soyuttan somuta, sanaldan gerçeğe: öğretmen adaylarının bakış açısıyla üç boyutlu yazıcılar", Abant İzzet Baysal Üniversitesi Eğitim Fakültesi Dergisi, Vol. 18, Issue 1, Pages 273-303, 2018.

23. Karaduman, H., "Using Three-Dimensional Printers in the Social Studies Education", Anadolu Journal of Educational Sciences International, Symposium on Social Studies Education Special Issue, Pages 590-625, 2017.

24. Huleihil, M. "3D printing technology as innovative tool for math and geometry teaching applications", International IOP Conference Series: Materials Science and Engineering, Vol. 164, Issue 1, Pages 012023, IOP Publishing, 2017.

25. Kwon, H., "Effects of 3D printing and design software on students' interests, motivation, mathematical and technical skills", Journal of STEM Education, Vol.18, Issue 4, Pages 2017.

26. Çelik, A., "Bilişimle girişimcilik: 5. sınıf öğrencilerinin tasarım odaklı doğaç yapma etkinliğinde bilişimle üretim yapmalarına ilişkin bir durum çalışması", Doctoral dissertation, Gazi Üniversitesi, Eğitim Bilimleri Enstitüsü, Ankara, 2018.

27. Atasoy, B., Yüksel, A. O., & Özdemir, S., 3B tasarım uygulamalarının uzamsal beceriye etkisi: Hackidhon örneği, Gazi Üniversitesi Gazi Eğitim Fakültesi Dergisi, Vol. 39, Issue 1, Pages 341-371, 2019.

28. Yıldırım, G., Yıldırım, S., & Çelik, E., "Yeni bir bakış-3 boyutlu yazıcılar ve öğretimsel kullanımı: Bir içerik analizi", Bayburt Eğitim Fakültesi Dergisi, Vol. 13, Issue 25, 163-184, 2018.

29. Awayda, C., "Cravens Virtual Museum Project A case study of digital heritage and museum education", Doctoral dissertation, State University of New York at Buffalo, 2018.

30. Yüksel, A. O., Çetin, E., & Berikan, B., "3d Tasarım Öğrenme Deneyiminin Süreç Değerlendirmesi ve Eğitsel Çıktılarının Keşfedilmesi", Eğitim Teknolojisi Kuram ve Uygulama, Vol. 9, Issue 1, Pages 21-49, 2019.

31. Kökhan, S. & Özcan, U., "3D yazıcıların eğitimde kullanımı", Bilim, Eğitim, Sanat ve

Teknoloji Dergisi, Vol. 2, Issue 1, Pages 81-85, 2018.

32. Reymus, M., Fotiadou, C., Kessler, A., Heck, K., Hickel, R., & Diegritz, C., "3D printed replicas for endodontic education", International Endodontic Journal, Vol. 52, Issue 1, Pages 123-130, 2019.

33. Tabassum, T., Iloska, M., Scuereb, D., Taira, N., Jin, C., Zaitsev, V., & Kim, T., "Development and application of 3D printed mesoreactors in chemical engineering education", Journal of Chemical Education, Vol. 95, Issue 5, Pages 783-790, 2018.

34. Kürtüncü, M., Arslan, N., Yaylacı, B., & Eyüpoğlu, N., "Sağlıkta Gelişen Teknoloji: Üç Boyutlu Yazıcılar", International Journal of 3D Printing Technologies and Digital Industry, Vol. 2, Issue 2, Pages 99-110, 2018.

35. Moeck, P., DeStefano, P., Kaminsky, W., & Snyder, T., "3D printing in the context of Science, Technology", Engineering, and Mathematics education at the college/university level, 2019.

36. Şengel, E., Koçak, F., & Güleryüz, B. G., "Öğrencilerin Tasarım Becerilerinin Değerlendirilmesi: 3b Tasarım Dersi Örneği", Turkish Studies Information Technologies and Applied Sciences, Vol. 14, Issue 4, Pages 641-654, 2019.

37. Rahman-Shams, S., "The Effect of 3D Virtual Reality Technologies on Learning", A Qualitative Research. American College of Education. Doctoral Dissertation, American College of Education, 2019.

38. Özsoy, K., "Üç boyutlu (3B) yazıcı teknolojisinin eğitimde uygulanabilirliği: Senirkent MYO örneği", Düzce Üniversitesi Bilim ve Teknoloji Dergisi, Vol. 7, Issue 2, Pages 111-123, 2019.

39. Çekirge, E., "3b yazıcı kullanımının akademik başarı, tutum, motivasyon ve eleştirel düşünme eğilimlerine etkisi", Doctoral dissertation, Necmettin Erbakan University, Turkey, 2019.

40. Ford, S., & Minshall, T., "Invited review article: Where and how 3D printing is used in teaching and education", Additive Manufacturing, Vol. 25, Pages 131-150, 2019.

41. Çopur, S., "3D Yazıcı kalem teknolojisinin geometri derslerinde kullanımının etkililiğinin incelenmesi", Master's thesis, Eğitim Bilimleri Enstitüsü, 2019.

42. Novak, J.I., "Re-educating the educators: collaborative 3D printing education", International Interdisciplinary and international perspectives on 3D printing in education Pages 28-49, IGI Global 2019.

43. Höhne, C., & Schmitter, M., "3D printed teeth for the preclinical education of dental students". Journal of dental education, Vol. 83, Issue 9, Pages 1100-1106, 2019.

44. Gür Karabulut, B. Y., "Mimarlık eğitiminde üç boyutlu yazıcılar: Türkiye durum değerlendirmesi", Master's thesis, Fen Bilimleri Enstitüsü. 2019.

45. Çoklar, A. N., & Çekirge, E., "3B Tasarımların Fiziksel Materyallerle Desteklenmesinin Akademik Başarı, Ders Tutum ve Motivasyonuna Etkisi", Ahmet Keleşoğlu Eğitim Fakültesi Dergisi, Vol. 2, Issue 2, Pages 181-193 2020.

46. Hansen, A. K., Langdon, T. R., Mendrin, L. W., Peters, K., Ramos, J., & Lent, D. D., "Exploring the Potential of 3D-printing in Biological Education: A Review of the Literature". Integrative and Comparative Biology, Vol. 60, Issue 4, Pages 896-905, 2020.

47. Wilk, R., Likus, W., Hudecki, A., Syguła, M., Różycka-Nechoritis, A., & Nechoritis, K., "What would you like to print? Students' opinions on the use of 3D printing technology in medicine" , PloS one, Vol. 15, Issue 4, Pages 23-51, 2020.

48. Ye, Z., Dun, A., Jiang, H., Nie, C., Zhao, S., Wang, T., & Zhai, J., "The role of 3D printed models in the teaching of human anatomy: a systematic review and meta-analysis" BMC medical education, 20, Issue 1, Pages 1-9, 2020.

49. Kok, P. J., "Pre-service Teachers' Visuospatial Cognition: 2D to 3D Transition", African Journal of Research in Mathematics, Science and Technology Education, Vol. 24, Issue 3, Pages 293-306, 2020.

50. Pinger, C. W., Geiger, M. K., & Spence, D. M., "Applications of 3D-printing for improving chemistry education", Journal of Chemical Education, Vol. 97 Issue 1, Pages 112-117, 2019.

51. Smith, D. W., Lampley, S. A., Dolan, B., Williams, G., Schleppenbach, D., & Blair, M., "Effect of 3D Manipulatives on Students with Visual Impairments Who Are Learning Chemistry Constructs: A Pilot Study", Journal of Visual Impairment & Blindness, Vol. 114, Issue 5, Pages 370-381, 2020.

52. İbili, E., Çat, M., Resnyansky, D., Şahin, S., & Billinghurst, M., "An assessment of geometry teaching supported with augmented reality teaching materials to enhance students' 3D geometry thinking

skills", International Journal of Mathematical Education in Science and Technology, Vol.51, Issue 2, Pages 224-246, 2020.

53. Mou, T. Y., "Students' evaluation of their experiences with project-based learning in a 3D design class", The Asia-Pacific Education Researcher, Vol. 29, Issue 2, Pages 159-170, 2020.

54. Astuti, T. N., Sugiyarto, K. H., & Ikhsan, J., "Effect of 3D Visualization on Students' Critical Thinking Skills and Scientific Attitude in Chemistry", International Journal of Instruction, Vol. 13, Issue 1, Pages 151-164, 2020.

55. Fujita, T., Kondo, Y., Kumakura, H., Kunimune, S., & Jones, K., "Spatial reasoning skills about 2D representations of 3D geometrical shapes in grades 4 to 9", Mathematics Education Research Journal, Vol. 32, Issue 2, Pages 235-255, 2020.

56. Dilling, F. and Witzke, I., "The use of 3D-printing technology in calculus education: Concept formation processes of the concept of derivative with printed graphs of functions", Digital Experiences in Mathematics Education, Vol. 6, Issue 3, Pages 320-339, 2020.

57. Nightingale, L. R., "Possible Self Dynamics of Community College Students Engaged in 3D Printing in Informal Environments", Doctoral dissertation, Old Dominion University, 2020.

58. Assante, D., Cennamo, GM ve Placidi, L.,. "Eğitimde 3D Baskı: Avrupa perspektifi", IEEE Global Engineering Education Conference EDUCON, Pages 1133-1138, April, 2020.

59. Ng, O. L., Shi, L., & Ting, F., "Exploring differences in primary students' geometry learning outcomes in two technology-enhanced environments: dynamic geometry and 3D printing", International Journal of STEM Education, Vol.7, Issue 1, Pages 1-13, 2020.

60. Hanisch, M., Kroeger, E., Dekiff, M., Timme, M., Kleinheinz, J., & Dirksen, D., "3D-printed surgical training model based on real patient situations for dental education", International Journal of Environmental Research and Public Health,Vol. 17, Issue 8, Pages 2901, 2020.

61. Karagöz, B., & Çakır, Ç. Ş., "Fen bilgisi öğretmen adaylarının 3 boyutlu yazıcılar hakkındaki görüşlerinin belirlenmesi", Karaelmas Eğitim Bilimleri Dergisi, Vol. 8, Issue 2, Pages 303-317, 2020.

62. Pikkarainen, A., & Piili, H., "Implementing 3D Printing Education Through Technical Pedagogy and Curriculum Development", Int. J. Eng. Pedagog, Vol. 10, Issue 6, Pages 95-119, 2020.

63. Güneş, S., Yurdakul, M., Kalaycı, U., Uyanık, U., & Şentürk, S., "3 Boyutlu Yazıcı Kullanımının Öğrencilerin Ar-Ge Yeteneklerinin Gelişimine Etkisinin İncelenmesi: Ostim Teknik Üniversitesi Meslek Yüksekokulunda Örnek Bir Uygulama" International Journal of 3d Printing Technologies And Digital Industry, Vol. 4, Issue 1, Pages 1-11, 2020.

64. B., Pál, M., Dimovski, V., Adamović, S., & Lilić, A. 3d Prıntıng In The Educatıon Of Graphıc Engineerıng and Design Students, 10th International Symposium on Graphic Engineering and Design, University of Novi Sad, November 2020.

65. Klima, G., & Kárpáti, A., "Digital creativity development in an e-learning environment A 3D design Project", Central European Journal of Educational Research, Vol 3, Issue 3, Pages 49–54, 2021.

66. Bernard, P., & Mendez, J. D., "Low-Cost 3D-Printed Polarimeter", Journal of Chemical Education, Vol. 97 Issue 4, Pages 1162-1166, 2020.

67. Çopur, S., and Türkdoğan, A., "3D Yazıcı Kalem Teknolojisinin Matematik Dersinde Uygulanmasından Yansımalar", Van Yüzüncü Yıl Üniversitesi Eğitim Fakültesi Dergisi, Vol. 18, Issue 1, Pages 106-136, 2021.

68. Arslan, A., and Erdogan, I., "Use of 3D Printers for Teacher Training and Sample Activities", International Journal of Progressive Education, Vol. 17, Issue 3, Pages 343-360, 2021.

69. Sharma, S., "Conceptualising 3D Shapes in New Zealand Primary Classes", Mathematics Education Research Group of Australasia, Meeting Report, Eric No. ED616171, New Zealand, 2021.

70. Guenther, C., Hayes, M., Davis, A., & Stern, M., "Building Confidence: Engaging Students through 3D Printing in Biology Courses", Bioscene: Journal of College Biology Teaching, Vol. 47, Issue 1, Pages 40-58, 2021.

71. Dickson, B., Weber, J., Kotsopoulos, D., Boyd, T., Jiwani, S., & Roach, B., "The role of productive failure in 3D printing in a middle school setting" International Journal of Technology and Design Education, Vol. 31, Issue 3, Pages 489-502, 2021.

72. Lugassy, D., Levanon, Y., Rosen, G., Livne, S., Fridenberg, N., Pilo, R., & Brosh, T., "Does augmented visual feedback from novel, multicolored, three-dimensional-printed teeth affect

dental students' acquisition of manual skills?" Anatomical Sciences Education, Vol. 14, Issue 5, Pages 629-640, 2021.

73. Alhonkoski, M., Salminen, L., Pakarinen, A., & Veermans, M., "3D technology to support teaching and learning in health care education, A scoping review", International journal of Educational research, Vol. 105, Pages 101699, 2021.

74. Çakır, M., & Mıstıkoğlu, S. 3b Yazıcıların Mesleki ve Teknik Eğitimdeki Uygulamalarının Ve Potansiyellerinin İncelenmesi: İskenderun Meslek Yüksekokulu Örneği" International Journal of 3D Printing Technologies and Digital Industry, Vol. 5, Issue 3, Pages 488-500, 2021.

75. Thiong'o, G. M., Bernstein, M., & Drake, J. M., "3D printing in neurosurgery education: a review", 3D Printing in Medicine, Vol. 7, Issue 1, Pages 1-6, 2021.

76. Yavuz, E., & Yılmaz, S., "Diş Hekimliğinde Yeni ve Hızla İlerleyen Üretim Teknolojisi: 3 Boyutlu Yazıcılar" Akdeniz Tıp Dergisi, Vol. 7 Issue 2, Pages 197-205, 2021.

77. Bayburt, B., and Eğin, F., "Teknoloji Ve Sanayideki Gelişmelerin Yansıması Olarak Eğitim 4.0", Bilgi Ekonomisi ve Yönetimi Dergisi, Vol. 16, Issue 2, Pages 137-154, 2021.

78. Jeong, J., Park, H., Lee, Y., Kang, J., & Chun, J., Developing parametric design fashion products using 3D printing technology. Fashion and Textiles, 8(1), 1-25, 2021.

79. Chun, H., A Study on the Impact of 3D Printing and Artificial Intelligence on Education and Learning Process. Scientific Programming, 2021.

80. Kim, S., Shin, Y., Park, J., Lee, SW ve An, K., Exploring the Potential of 3D Printing Technology in Landscape Design Process,Vol.10, Issue 3, Pages 259, 2021.

81. Chaudhari, P. K., Dhillon, H., Dhingra, K., & Alam, M. K., 3D printing for fostering better dental education. Evidence-Based Dentistry, Vol. 22, Issue 4, Pages 154-155, 2021.

82. Bhaduri, S., Teach3d: Toolkit for Effective Teaching of 3d Modeling and Spatial Thinking Skills in Middle School, Doctoral dissertation, University of Colorado at Boulder, 2021.

83. Chenrai, P., Case study on geoscience teaching innovation: Using 3D printing to develop structural interpretation skill in higher education levels. Frontiers in Earth Science, Vol. 8, Pages 590062, 2021.

84. Karsenty, C., Guitarte, A., Dulac, Y., Briot, J., Hascoet, S., Vincent, R., ... & Acar, P., The usefulness of 3D printed heart models for medical student education in congenital heart disease. BMC Medical Education,Vol. 21, Issue 1, Pages 1-8, 2021.

85. Chen, J., & Cheng, L., The influence of 3D printing on the education of primary and secondary school students. In Journal of Physics: Conference Series, Vol. 1976, Issue 1, Pages 012072, 2021.

86. Nazha, H., 3D Printing in Education: An Overview. Available at SSRN: https://ssrn.com/abstract=3968190 http://dx.doi.org/10.2139/ssrn.3968190, November 20, 2021.

87. Leung, G., Pickett, A. T., Bartellas, M., Milin, A., Bromwich, M., Shorr, R., & Caulley, L., Systematic review and meta-analysis of 3D-printing in otolaryngology education. International Journal of Pediatric Otorhinolaryngology, 111083, 2022.

88. Yazici, F. & Sözbilir, M., "Designing and evaluation of 3D materials for teaching biological systems to 6th grade students with visual impairment (SVI)", Journal of Biological Education, 2022.

89. Cercenelli, L., De Stefano, A., Billi, A. M., Ruggeri, A., Marcelli, E., Marchetti, C., & Badiali, G., "AEducaAR, anatomical education in augmented reality: A pilot experience of an innovative educational tool combining AR technology and 3D printing" International Journal of Environmental Research and Public Health, Vol. 19, Issue 3, Pages 1024, 2022.

90. Topçuoğlu, N., "Kimya eğitiminde atom ve molekül yapılarının öğretiminde üç boyutlu tasarım uygulamaları" Doctoral dissertation, Kastamonu Üniversitesi, 2022.

91. Lau, I., & Sun, Z. "Tıp eğitiminde hızlı ve uzun vadeli bilgi edinmede 3D baskılı kalp modellerinin rolü" Kardiyovasküler Tıp İncelemeleri, Vol. 23, Issue 1, Pages 22, 2022.

92. Abdullahi, A. Y., Hamza, M. F., & Isa, A. I., "A Survey on the Contributions of 3D Printing to Robotics Education, A Decade Review", Recent Trends in Mechatronics Towards Industry 4.0, Recent Trends in Mechatronics Towards Industry 4.0. Lecture Notes in Electrical Engineering, Vol. 730, Pages 289-302, 2022.

93. Clanner-Engelshofen, B. M., Frommherz, L., Mitwalli, M., Stadler, P. C., French, L. E., & Reinholz, M. "3D printing and silicone models of

primary skin lesions for dermatological education as remote learning tool", JDDG: Journal der Deutschen Dermatologischen Gesellschaft, Vol. 20, Issue 2, Pages 177-183, 2022.

94. Levin, L., & Verner, I. M., "Teachers Uncover the Potential of 3D Printing Activities to Promote Analytical and Applied Mathematical Skills" International Journal of Engineering Pedagogy, Vol 11, Issue 3, Pages 39-52, 2021.

95. Gülburnu, M., "Secondary School Students' Views on Geometry Teaching via Three-Dimensional Dynamic Geometry Software Cabri 3D: Solid Volume Measurement", International Journal of Curriculum and Instruction, Vol. 14, Issue 1, Pages, 1088-1105, 2022.

96. Kumar, N., Ramakrishnan, S. A., Lopez, K. G., Chin, B. Z., Devyapriya, S., Kumar, L., & Anantharajan, S. K. "Current trends and future scope in 3D printing for surgical management of spine pathologies", Bioprinting, Pages 00197, 2022.

97. Novak, J. I., Maclachlan, L. R., Desselle, M. R., Haskell, N., Fitzgerald, K., & Redmond, M. "What qualities are important for 3D printed neurosurgical training models? A survey of clinicians and other health professionals following an interactive exhibition", Annals of 3D Printed Medicine, Vol. 6, Pages 100060, 2022.

98. Ebrahim, A. M. S., & Fahem, M. M., The Future of 3D Printing in Medicine. *Exploratory Research and Hypothesis in Medicine*, 2022.

99. Isdianti, M. , Nasrudin, H. & Erman, E., "The effectiveness of STEM based inquiry learning packages to improving students' critical thinking skill", Journal for the Education of Gifted Young Scientists, Vol. 9 Issue 3, Pages 223-232, 2021.

100. Wu, C., & Li, W., August). Application of 3D Printing Technology in Practical Teaching of Environmental Design. International Journal of Physics: Conference Series, Vol. 1992, No. 2, Pages 221-66. IOP Publishing, August 2021.

101. Karimov, O. "The ımportance of the use of 3d prınters ın the fıeld of technologıcal educatıon," Mental Enlightenment Scientific-Methodological Journal, Vol. 2021, Issue 1, Pages 20, 2021.

102. Eisenberg, M., "3D printing for children: What to build next?", International Journal of Child-Computer Interaction, Vol. 1, Issue 1, Pages 7-13, 2013.

103. Blauch, D. N., & Carroll, F. A., "3D printers can provide an added dimension for teaching structure–energy relationships", Journal of Chemical Education, Vol. 91, Issue 8, Pages 1254–1256, 2014.

104. Demir, K., Demir, E. B. K., Çaka, C., Tuğtekin, U., İslamoğlu, H., & Kuzu, A., "Üç boyutlu yazdırma teknolojilerinin eğitim alanında kullanımı: Türkiye'deki uygulamalar", Ege Eğitim Dergisi, Vol. 17, Issue 2, Pages 481-503, 2016.

105. Love, T. S., & Roy, K., "3D printing: what's the harm?", Technology and Engineering Teacher, Vol. 76, Issue 1, Pages 36, 2016.

106. Denisco, A., "Fab Labs: Using Technology to Make (Almost) Anything!" District Administration, Vol. 48, Issue 11, Pages 34-37, 2012.

107. Jo, W., Hee I.J., Harianto, R.A., So, J.H., Lee, H., Lee, H.J., & Moon, M. "Introduction of 3D Printing Technology in the Classroom for Visually Impaired Students", Journal of Visual Impairment & Blindness, Vol. 110 Issue 2, Pages 115-121, 2016.

108. Özsoy, K., Duman, B., "Eklemeli imalat (3 boyutlu baskı) teknolojilerinin eğitimde kullanılabilirliği", International Journal of 3D Printing Technologies and Digital Industry, Vol. 1, Issue 1, Pages 36-48, 2017.

109. Çallı, L. ve Taşkın, K., 3D yazıcı endüstrisinin oluşturacağı yeni pazarlar ve pazarlama uygulamaları. ICEB 2015. Uluslararası Vizyon Üniversitesi, Gostivar, Makedonya.

110. Patton, M., Qualitative Research and Evaluation Methods, 3rd edn.Thousand Oaks, CA:Sage, 2002.

111. Stone, P.J., Dunphy, D.C., & Smith, M.S., The general inquirer: A computer approach to content analysis. The M.I.T. Press, Massachusetts, 1966.

112. Cohen, L., Manion, L., & Morrison, K., Research Methods in Education (6th ed.). London and New York, NY: Routledge Falmer, 2007.

113. Esteban-Munız, G., "Additive manufacturing and 3D printing technologies in the EC", Workshop Fabrication additive pour Telectronique, CNRS, Paris, 2016.

114. Petch, M., Terry Wohlers gives 3D Printing Industry further insights into the Wohlers Report, , https://3dprintingindustry.com/news/terry-wohlers-gives-3d-printingindustry-insights-wohlers-report-110196, April 6, 2017

115. Coyne, I. T., Sampling in qualitative research. Purposeful and theoretical sampling; merging or clear boundaries?.*Journal of advanced nursing*, Vol *26.* Issue 3, Pages 623-630, 1997.