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EVALUATION OF POSTGRADUATE ARCHITECT CANDIDATES' OPINIONS ON THE USE OF 3D PRINTERS

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ABSTRACT

Nowadays, when technology is developing at a rapid pace, new technological devices are being developed to become a part of both professional life and educational programs. One of these technological developments is the development of the development of three-dimensional printers. Recently, presentations have been presented in three dimensions and multimedia, allowing professionals to have better knowledge about these tools and their uses. 3D printers are rapidly becoming tools that support the production and creation process in small and medium-sized businesses. These printers are used not only for prototyping but also in many fields such as industrial planning, engineering, design, architecture, medicine, and scientific research. The aim of this study is to reveal the opinions of graduate architect candidates regarding the use of 3D printers within the scope of architectural education. The main reason for choosing graduate-level architects as the sample group is that they have reached a certain level by completing their undergraduate education and have a level of awareness in terms of increasing their competencies by continuing their education at the graduate level. In the study, data was collected using an opinion form with semi-structured questions. Participation in this study was provided on a voluntary basis. As a result of the study, it has been proven that the use of 3D printing will have an important place in the future of architecture, as will 3D representation and 3D models. This situation has revealed the awareness that future architects need to be supported and trained in this regard.

KEYWORDS

3D printer; 3D model; architectural education; education; additive manufacturing

1. INTRODUCTION

3D printers are additive manufacturing systems that produce objects from geometric models using digital fabrication technology. Therefore, it can also be called "additive manufacturing" or "additive manufacturing." While the concept of "3D printing" generally refers to individual and small-scale projects, "additive manufacturing" refers to larger-scale and professional work. (Shahrubudin, Lee, & Ramlan, 2019; Şahin & Turan, 2018; Villi et al., 2024). However, additive manufacturing technology is not a new phenomenon. When we look at its history, we see that this technology is quite old, and one of the first patents dates to 1902. Although its development has been proven since the 1970s, it remained limited until the early 2000s and

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was generally used for industrial prototyping purposes. Since the 1980s, it has progressed with the research and development activities of companies such as 3D Systems, Object Geometries and Stratasys (Chakraborty and Biswas, 2020; Şahin and Turan, 2018).

3D printing technology first emerged in the 1980s with the Stereolithography (SL) technology developed by 3D Systems. Following SL, various other 3D printing methods were developed and introduced to the commercial market by different companies in the early 1990s. These methods include Laminated Object Manufacturing (LOM) by Helysis, Fused Deposition Modeling (FDM) by Stratasys, Selective Laser Sintering (SLS) by DTM, Direct Metal Laser Sintering (DMLS) by EOS, Solid Substrate Curing (SGC) by Cubital, and Three-Dimensional Printing (3BP) by Soligen (Sürmen, 2019). In its simplest form, three-dimensional printers are devices that convert data stored in a computer environment into physical objects. This technology can produce geometries that are unattainable or difficult to obtain with traditional manufacturing methods. When we look at its history, the first examples emerged in the 1980s. In recent years, rapid prototyping has become widespread thanks to the increasing interest in the field and its practical availability (Şahin and Turan, 2018). 3D printers, which are considered an important component of Industry 4.0, have the potential to create radical changes in manufacturing business models. This technology allows for the reduction of material use, the lightness of products, and the design of multifunctional components. As additive manufacturing technologies develop, the production of new materials will be possible. Traditionally, designing for manufacturing means eliminating the difficulties and complexities of manufacturing, minimizing costs, and designing better products (Kökhan and Özcan, 2018). Additive manufacturing (AM) offers several important advantages, as well as major time and cost savings. Physical models that can be quickly obtained from CAD documents allow for form, fit, and function tests to be performed much earlier in the design process. In this way, errors resulting from misinterpretation of the design are minimized, and prototype iterations can be done much faster (Jafari et. al., 2021; Prakash et al., 2018; Zhou et al., 2024).

3D printing technology is a method of producing objects directly from a CAD model. The material is poured in layers by melting or in its own fluid state. Support structures can be removed after production, products can be sanded, shaped and painted. 3D printers can produce complex products with only 3D data files and raw materials. With these features, the production process is accelerated, and waste is reduced. The use of CAD files makes the design process efficient and provides businesses with the flexibility to develop prototypes and offer customized products. In addition, manufacturing only on demand reduces inventory costs for businesses. Today, 3D printers are of great interest in the development of mass-customized products in various sectors such as education, agriculture, health, automotive, aviation, electronics, architecture and sports (Demir and Ayranpınar, 2024).

Additive manufacturing has been recognized for its potential to offer various sustainability benefits. Among these are the reduction of waste during production, as it follows an additive rather than subtractive process; the ability to optimize designs and produce lightweight components, which not only minimizes material use in manufacturing but also lowers energy consumption during operation. Additionally, it can decrease transportation needs within supply chains and reduce inventory waste, as spare parts can be produced on demand (Ford and Despeisse 2016; Javaid et al. 2021). Furthermore, additive manufacturing is anticipated to emerge as a crucial manufacturing technology in the sustainable society of the future (Huang et al., 2013).

Additive manufacturing (AM) is an innovative technology with potential for application in various fields. This technology has the capacity to produce complex and large-scale components without the need for costly molds and intensive labor, which makes it a very interesting technology. However, its applications in building construction are still in the research and development stage (Van Woensel et al., 2018). Multilayer manufacturing can also be used in support structures and the production of lattice cells (Li et al., 2020). Some common functions of the support structure in the manufacturing process, such as supporting the protruding section, limiting model deformation or bending, and minimizing residual stress, can be met by joint manufacturing (Habib et al., 2017).

Part production with additive manufacturing (AM) consists of 8 steps: production of the CAD file, conversion to STL format, transfer of the file to the AM machine, adjustment of the AM machine, production, removal, final processing, and application (Gibson et al., 2021; Zeltmann et al., 2016). When black box and transparent box thinking systems are integrated into these steps, it is possible to carry out a production based on the process shown in figure 1. In this context, there are two basic feedback loops in the additive manufacturing process. The first feedback loop occurs between the CAD modeling and STL reading/machine settings stages. The main reason for the formation of this loop is that the material that the 3D printer will use or the technical features of the printer (size, nozzle thickness or number, temperature, etc.) function as two steps that feed each other until they reach the optimum level according to the desired result. The second feedback loop is the use of the output obtained as input in the system again to reach the desired final product. This process ensures continuous improvement of the product in order to increase production quality and minimize errors. In the additive manufacturing process, these bidirectional feedback loops contribute to optimizing production parameters and achieving desired results (Bayat et. al., 2023; Kim et. al., 2018).

In engineering, science, art and architecture, the black box is defined as a path, system or object that does not contain any information about the functioning of the thought structure and is evaluated only with inputs and outputs (Durmuş Öztürk, 2020); while the transparent box defines a systematic design process in which the designer is aware of what he does and why (Jones, 1970). As the steps in the design problem become more concrete, the black

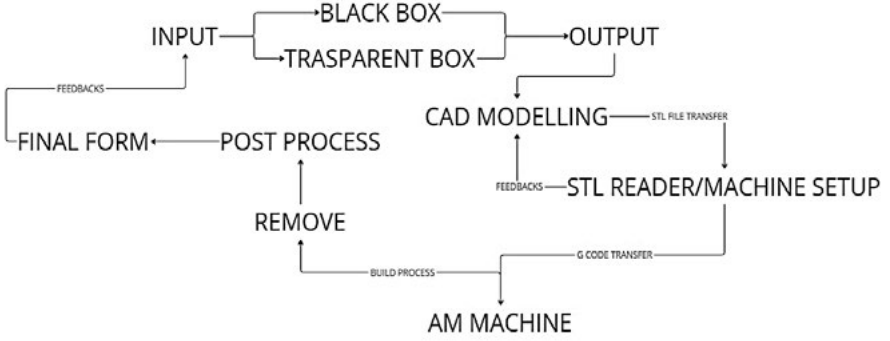

Figure 1. AM process. Source: (Authors)

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box process gives way to the transparent box (Oktan, 2021). In the transparent box process, the designer acts analytically like a computer. The inputs related to the design problem are handled with analysis, synthesis and evaluation steps, respectively. These steps are repeated in a cycle until the most accurate desired result is found (Jones, 1970). In this context, systematically designed and rational approaches-based 3D printer projects, thanks to the concretization of the data coming out of the final form cycle shown in figure 1 and returning to the input as feedback, ensure that the data becomes clearer and more optimized in each feedback cycle, allowing the final form to mature step by step and the system to operate more transparently. In this case, the data to be used enters the transparent box system instead of the black box and passes through there to progress towards the final form again. Thus, the development and concretization of data at each stage of the additive manufacturing process allows more conscious and rational decisions to be made in the design processes.

In recent years, it can be said that 3D printers have become even more strategically important, especially under the title of education, with the prevalence of 3D printers. The use of 3D printers in the field of education can offer an innovative approach that deepens students' learning processes. This technology provides students with a visual and tactile learning experience by concretizing abstract concepts. Especially in fields such as science, mathematics, and engineering, 3D printers allow the production of complex geometric shapes, scientific models, and prototypes. With these devices, students can not only learn theoretical knowledge but also turn their own designs into reality. In addition, by contributing to the development of problem-solving, creativity, and critical thinking skills, they provide students with an education equipped with future technologies.

2. MATERIAL AND METHOD

The purpose of this research is to reveal the views of postgraduate architect candidates on the use of 3D printers within the scope of architectural education. The main reason for choosing postgraduate architects as the sample group is that they have reached a certain level by completing their undergraduate education and have a level of awareness in terms of increasing their competence by continuing their postgraduate education. Data in the study was collected using an opinion form with semi-structured questions. Participation in this study was provided on a voluntary basis. The research was conducted based on the descriptive analysis method. Descriptive analysis is a form of analysis applied in cases where the theoretical framework of the research is determined in advance. In this approach, the main purpose is to convey the results of the interviews and observations to the reader in an organized and interpreted way (Yıldırım and Şimşek, 2011).

The data of this research were obtained using the "Postgraduate Architect Candidates' Opinions Form on the Use of 3D Printers" developed by the researchers. Before creating the form, the possible problems regarding the use of 3D printers by postgraduate architect candidates were examined and a literature review was conducted. After the literature review, a 16-question "Postgraduate Architect Candidates' Opinions on the Use of 3D Printers Form" was prepared for postgraduate students. The interview form includes 4 questions for the demographic characteristics of postgraduate architects, 3 questions regarding their aptitude for computer technologies, and 9 questions to determine their opinions on 3D printers, totaling 16 questions.

Within the scope of the research, an ethics committee approval dated 01/08/2024 and numbered 2024/284 was obtained from the Recep Tayyip Erdoğan University Social and Human Sciences Ethics Committee. To collect the data, a survey form was opened for filling out

via Google Form for a period of one month. In addition, contact information was obtained for the participation of faculty members continuing their postgraduate education via YÖK Academic and an informative email was sent.

3. FINDINGS AND RESULTS

26 people participated in the survey. The questions in the survey are basically divided into 3 parts. The first part aims to collect personal information of the participants; the second part aims to collect their relationship with 3D modeling; and the third part aims to collect data on additive manufacturing technology.

According to the questions in the first part of the survey, 69.2% (18) of the participants are female, 30.8% (8) are male, 3.8% (1) are 21-25 years old, 65.4% (17) are 26-30 years old, and 30.8% (8) are 31-35 years old. Of the participants who are required to have at least a postgraduate degree, 61.5% (16) are doctoral students, 15.4% (4) are master's students, and 23.1% (6) are master's graduates (table 1).

Participants were invited to participate in the survey considering the role played by the institutions they received education in Turkey's architectural education. However, since the study was based on volunteering, only a small number of people contacted

Demographic information		N	%
Sex	Female	18	69,2
	Male	8	30,8
Age	21-25	1	3,8
	26-30	17	65,4
	31-35	8	30,8
Level of education	Master's student	4	15,4
	Master's graduate	6	23,1
	PhD student	16	61,5

Table 1. Demographic characteristics of participants1. Source: (Authors)

University	N	%
Eskisehir Technical University	1	3,8
Gebze Technical University	4	15,41
Karadeniz Technical University	11	42,29
Istanbul Technical University	6	23,1
Yıldız Technical University	4	15,4

Table 2. Institutions where participants received training. Source: (Authors)

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to participate in the survey participated. The universities where the participants received education were Eskisehir Technical University, Gebze Technical University, Karadeniz Technical University, Istanbul Technical University and Yildiz Technical University (table 2).

According to the questions in the second part of the survey, the participants evaluated themselves with a score of 1-10 in terms of their aptitude for computer programs. As a result of the evaluation, the average value scored by the participants was measured as 7.5 and it was concluded that the participants were equipped with intermediate/advanced knowledge. figure 2 lists the architectural modeling programs that the participants used.

Based on the responses given by the participants, in the evaluation made on the effectiveness of the methods used in the transfer of information in architectural projects, it was seen that the virtual environment was preferred by 42.30% (11), models by 32.62% (9), renders by 19.23% (5), and two-dimensional drawings by 3.85% (1). These results reveal that virtual environments and physical three-dimensional objects are extremely important and effective in transferring project information. The low preference rate of two-dimensional drawings indicates that these methods are less effective in presenting project information. In this context, it is understood that both virtual and physical three-dimensional representation tools play a decisive role in presenting architectural projects in a more comprehensive and understandable way.

According to the questions given about 3D printer technologies in the third part of the survey, 61.5% (16) of the participants stated that they did not have any information about three-dimensional printers. 7.7% (2) stated that they received information in their undergraduate education and 26.9% (7) in their graduate education. The remaining participants stated that they had information from the internet or social media.

When participants were asked to define 3D printers, the answers given were evaluated under 6 headings and ranked according to frequency.

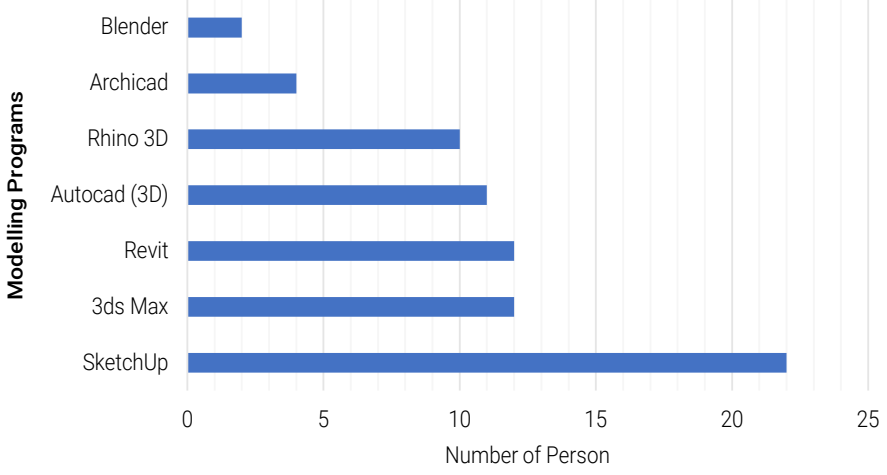

Figure 2. Software Programs Used by Participants for Modeling. Source: (Authors)

- Transformation from Virtual to Reality: Most answers emphasize that 3D printer technology transforms models designed in a virtual environment into physical objects. They claim that this technology enables digital designs to become tangible.
- Ease of Production and Speed: Many participants emphasize that 3D printer technology is a tool that accelerates and facilitates production. They stated that it highlights features such as the ability to produce even complex models at a simple level, and being fast and practical.
- Detail and Perfection: Some answers emphasize the ability of 3D printers to produce detailed and perfect models. They also stated that this technology is used to create the closest representations of designs to reality. • Architectural Applications: Especially in answers related to architecture, it is stated that 3D printers play an important role in architectural productions, model making, and better understanding of fullness-void relationships.
- Evolution and Potential of the Technology: Several responses indicate that this technology needs to be developed and popularized and that it is a creative and future-oriented technology despite being expensive.
- Lack of Technical Knowledge: Some participants state that they do not have sufficient technical knowledge to define 3D printer technology.

Based on these responses, it can be said that 3D printer technology is generally defined as a fast, detailed, and practical production method that enables virtual designs to be made tangible in the physical world. In addition, it is understood that it has an important place in the fields of architecture and engineering and is a technology that is expected to develop further in the future. Most participants have limited knowledge about the filaments used in 3D printers (figure 3).

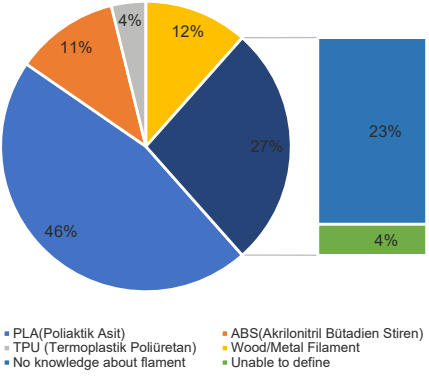

Figure 3. Knowledge about filaments. Source: (Authors)

12 participants stated that they know PLA (Polylactic Acid) filament. This shows that PLA is the most common and well-known filament type in the 3D printing process. Only 3 people know ABS (Acrylonitrile Butadiene Styrene) filament. This shows that this more durable and flexible filament is less known among students. TPU (thermoplastic polyurethane) is a filament type known for its flexibility, but it is only known by 1 person. Wood/metal filaments were only marked by 3 people, suggesting that these types of filaments are used for special and less common applications. In addition, 7 people stated that they have no information about filaments, indicating that there is generally insufficient awareness among students about filament types. This situation reveals that there is a need for more material and technological knowledge transfer in education, and in particular, different filament types and areas of use should be taught.

57.7% of those who responded to the survey stated that they have no experience with 3D printers. The programs used by experienced people to produce files in STL format are given in figure 4.

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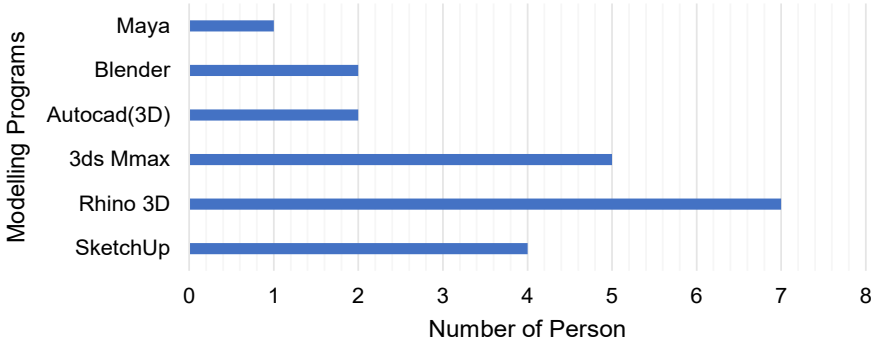

Figure 4. The software used to generate the STL format. Source: (Authors)

It was observed that the architectural design programs known by the participants were very different from the program used for the STL format. The change in the level of use of these programs, which can basically provide architectural scale modeling, while creating the STL format may be due to the difficulty of learning the program used and the fact that the program does not provide the desired level of convenience. This situation may create prejudices about 3D printers. When the participants were asked to score between complexity and comprehensibility (1 is the most complex; 10 is the most comprehensible), the average of the scores given was 6.38. The standard deviation of the score was calculated as 2.59. This situation can be said that the participants are far from agreement and are prejudiced against 3D printers. Despite this, when the participants were asked to score about the future place of 3D printers (1-I find it unnecessary; 10-it will have an extremely important place in the future), it was observed that the average was 8.00. The fact that the standard deviation in this score is 1.53 can be said that the participants are of the same opinion.

When the survey participants' views on the future of 3D printing technology are examined, it is seen that there is a strong consensus that this technology will gain an important place in production processes. It is thought that 3D printers will facilitate production, allow for flexible form designs, and provide great advantages in rapid prototyping processes, especially in the fields of construction and architecture. Participants predict that this technology will become widespread in terms of model making in architecture, production of complex geometries, and contributions to students in education processes. However, the future potential of 3D printers will not be limited to their current uses only but will also find a place in larger-scale projects with the use of different materials. However, some participants emphasize that this technology has certain limitations; factors such as limited material variety, high costs, and access difficulties are seen as obstacles to the widespread use of this technology. In addition, concerns are expressed that 3D printers may not completely replace traditional methods and may even lose their popularity in some cases. In addition, some participants stated that it is foreseeable that other technologies, such as holograms and virtual reality, will play an important role in design processes in the future and that physical production will therefore take a back seat. In conclusion, although the future role of 3D printing technology indicates great potential,

it is understood that this technology needs to be further developed and disseminated, while at the same time its current limitations should be taken into account.

4. CONCLUSION

3D printing technology impacts not only prototype production, building design, and construction processes in the field of architecture but also influences larger-scale themes. Particularly in urban planning, this technology can contribute to the sustainable development of urban areas by enabling the rapid and cost-effective production of buildings. Structures created with 3D printers produce less waste compared to traditional methods and offer significant advantages in terms of sustainability by utilizing construction waste and recyclable materials. Furthermore, the ethical dimensions of this technology are noteworthy. The potential future use of 3D printing to construct affordable housing in low-income areas of cities presents new opportunities for social justice and equity. Considering 3D printing technology from this broader perspective reveals its significant transformative potential in the field of architecture.

According to the survey results, it is possible to make several important inferences about both the current status and future potential of 3D printer technology. First of all, it is predicted that 3D printers are increasingly being used in the fields of architecture, design, and production, and that this technology will become even more widespread in the future and play a central role in production processes. Most of the participants stated that 3D printers will be an indispensable part of design and production processes in the future thanks to their superiority in flexibility, speed, and the production of complex forms. However, it is seen that this technology stands out as an important tool in architectural education and professional practices, offering great advantages to students and professionals, especially in areas such as model making, rapid prototyping, and enabling visual presentations. However, some participants also drew attention to the current limitations of 3D printer technology. In particular, limited material diversity, high costs, and access difficulties were evaluated as obstacles to the widespread use of this technology. In addition, some participants warned that with the development of other technologies, such as holograms and virtual reality, physical production may be replaced by digital solutions. In addition, it is also noteworthy that traditional model-making and building production techniques still hold an important place in architecture and design processes and that 3D printers may not be able to fully replace these traditional methods.

As a result, it is understood that 3D printer technology has great potential, especially in the fields of architecture and design, but that the technology needs to be further developed and popularized in order to fully realize this potential. It is envisaged that this technology will be integrated into design and production processes by combining it with innovative materials and production techniques in the future.

In today's world, where technological developments are rapidly progressing and becoming widespread, participants who have graduated from or are studying at important schools in Turkey realize the potential effects and importance of this innovative technology, even if they have not yet fully grasped it. In addition, this situation emphasizes how essential comprehensive education on future technologies, such as 3D printers, is in the education system and curriculum. The fact that students do not have sufficient knowledge on this subject clearly reveals the need for educational institutions to introduce this technology to students and provide them with practical experiences. Including more of these types of technologies in education will increase students' knowledge in this field and enable them to benefit from these technologies more effectively in their future professional lives.

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