Exploring the Potential of 3D Printing Technology

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**Abstract:** The emergence of 3D printing technology has led to its exploration across various domains, including landscape design. However, its potential in the context of landscape design and education has been relatively overlooked. This study aims to investigate the implications of 3D printing technology for landscape design education and practice. Our investigation encompassed an exhaustive examination of the available literature, coupled with an in-depth analysis of the present status of 3D printing technology. Moreover, we executed empirical studies involving students in secondary education and professionals in landscape architecture, aimed at evaluating the tangible application of this technology. The interactive sessions conducted with secondary school students utilizing 3D-printed prototypes yielded favorable results, such as heightened engagement, amplified involvement, and enhanced comprehension. Furthermore, semi-structured interviews with landscape practitioners confirmed certain limitations of 3D printing, such as cost, delivery time, scale, and level of detail.

**Keywords:** digital fabrication technology; 3D printing; landscape design; landscape architecture education; landscape practitioners

# Introduction

3D printing technology, referred to as digital fabrication, rapid prototyping, and solid freeform fabrication, has found extensive application among engineers and industrial designers for creating physical prototypes to visualize and test novel design concepts [1]. The growing popularity of 3D printing is anticipated to bring significant transformations across various industries. In manufacturing, for instance, the adoption of small-quantity production systems enables the customization of goods according to consumer preferences, leading to substantial economic advantages [2]. Moreover, the relationship between 3D printing and design is gaining increased attention [2].

Due to its adaptability, 3D printing has garnered attention in the planning and design industry. Various sectors, including automobile, fashion, architecture design, and more, have actively implemented 3D printing technology [3]. As 3D printers continue to evolve, their applications are expanding to fields like arts, medicine, aerospace, and design, making this technology relevant across industries [3]. 3D printing offers significant advantages, enabling the production of complex designs with reduced time and cost compared to other methods [3]. It allows for the creation of early-stage prototypes, facilitating market assessment and small-quantity batch production to enhance the manufacturing system [3]. Consequently, 3D printing is expected to foster further developments in the design industry.

Within the realm of education, the integration of 3D printing spans a diverse array of fields, encompassing architecture, computer science, ergonomic studies, human factors, and medical applications. Universities are proactively incorporating 3D printing into their academic programs, notably in areas such as computer graphics, engineering design, medical innovation, and product/industrial design, as documented in reference [4]. Additionally, the efficacy of 3D printing extends to enhancing students' comprehension of geological formations—a feat not attainable solely through 3D visualizations [5]. The production of 3D models through printing facilitates an improved grasp of topographical concepts, as highlighted in references [6] and [7]. This technology further contributes to a heightened spatial perception, facilitated by tactile and observational interactions with physical models, as evidenced in references [8] and [9].

Interdisciplinary education extensively embraces 3D printing technology, as outlined by Eisenberg in reference [8]. Its pragmatic utility transcends IT, art and design, science, engineering, robotics, mathematics, and the humanities. A notable instance is a secondary school in Australia [10], where seamless integration of 3D printing into the curriculum has garnered favor among students, educators, and parents. The institution employs 3D printers for an assortment of projects encompassing playground designs, character crafting for stop-motion films and digital books, as well as assorted constructions. This incorporation of 3D printing has yielded cross-disciplinary advantages across all subjects taught at the school. Similarly, the UK's Department for Education funded a 3D printing initiative spanning 2012 to 2013, aimed at enhancing instruction in science, technology, engineering, mathematics, and design disciplines. Educational institutions were encouraged to explore inventive methodologies in leveraging 3D printing technology to convey intricate scientific and mathematical principles, as referenced in [11].

The utilization of 3D printing technology within education has yielded favorable outcomes. To illustrate, a particular study showcased enhancements in students' verbal communication proficiencies attributed to educational integration of 3D printing [12]. Educators have conveyed that the adoption of 3D printing technology not only engenders student motivation but also fosters a student-centric learning environment, as documented in references [13] and [14]. Additionally, within the domain of landscape architectural planning and design, the educational arena stands to gain by assimilating 3D printing technology into design workshops, procedural phases, and participatory community workshops. This stands in contrast to a sole reliance on final outputs, as outlined in reference [14]. This application of 3D printing can further enhance the learning experience and engagement of students in landscape design education.

# As previously emphasized, the realm of education and diverse sectors presents a multitude of potential applications for 3D printing technology. Nonetheless, the discourse surrounding the practical implementation of 3D printing technology in education within the landscape architecture domain remains constrained, as underscored by reference [15]. Nonetheless, with the expected decrease in 3D printing technology costs and the anticipated advancements in its tools and efficiency, opportunities for its implementation in other fields are likely to emerge. Nevertheless, it is essential to assess these opportunities carefully to avoid inappropriate applications.

# The lead author, with experience in visualizations, Landscape Visual Impact Assessments, and computer graphics, undertakes this study to explore the existing literature on 3D printing and landscape architecture. Furthermore, an in-depth examination of 3D printing's role in education, coupled with interviews involving professionals in landscape architecture, has been undertaken to establish the foundational framework for potential integration of 3D printing within the landscape architectural sphere. The objective is to uncover the prospective trajectory of 3D printing technology's advancement. This study evaluates the literature on 3D printing and landscape architecture, along with the insights gained from the case study and interviews with landscape architects, to prepare the basis for the future application of 3D printing technology in landscape architecture.

# Literature Review

In the traditional landscape architectural design and planning procedures, the utilization of sketches and visual depictions is prevalent, as documented in references [16–19]. These methods centered around visual representations facilitate essential contrasts between the initial and envisioned states of a design. However, there has been some skepticism surrounding the practicality of using visualizations [20–23]. Unlike computerized visualizations, which often lead to discrepancies between stakeholders' expectations and actual outcomes, physical models are considered to be more credible and interactive. Three-dimensional models offer an accurate representation of the eventual construction outcome. Navigating through the landscape architectural design process can pose challenges, particularly in the realm of design decision-making. Grasping the planning implications frequently involves intricacies and subjectivity due to the involvement of diverse stakeholders, as discussed in reference [16].

Traditional methods, such as drawings and plans, are primarily tailored for trained personnel or experts, and they have limitations in terms of effectively communicating information. For instance, users without sufficient training or familiarity with maps might find it challenging to interpret the visual variables presented in them. In contrast, physical models, such as 3D models, can overcome these limitations and provide a more accessible and tangible representation of the design, facilitating better communication and decision-making in the landscape architectural planning process.

Physical models have the potential to overcome the limitations of 2D visualization. Over the last 50 years, physical models have found applications in various fields and have become increasingly versatile [24]. Instances include shipbuilders, automobile manufacturers, and aerospace engineers, who have employed tangible 3D models to depict their designs. Such models serve diverse objectives, encompassing educational, testing, and sales facets within the scope of development ventures. Physical prototypes hold significant efficacy as they convey objects in three dimensions, preserving vital details that might be compromised in two-dimensional portrayals such as maps, as indicated in reference [24].

Differing from two-dimensional technologies like images and videos, which are limited to visual interpretation, physical models offer distinct advantages over 2D sketches. Viewers can observe various facets of the model with simple adjustments in head or body position, effectively revealing aspects potentially obstructed from a direct line of sight, such as elevated structures or foreground mountains. Consequently, 3D models furnish a more authentic portrayal of the design concept, simplifying evaluation, aiding in pinpointing design imperfections, and enhancing communication between clients and planners, as elaborated in reference [15].

In the field of landscape architecture, 3D computer graphics are often used to overcome the limitations of explaining a design solely with a 2D plan. However, in many cases, 3D models are preferred due to their ability to provide a more comprehensive and tangible representation of the design proposal [15].

Physical models offer additional sensory experiences that contribute to the growing interest in 3D printing [25]. 3D-printed models allow for multi-sensory experiences, which is a significant factor behind their increasing popularity [26]. Furthermore, in scenarios necessitating haptic communication, traditional mediums prove inadequate in enabling engagement among the various participants engaged in landscape planning and design endeavors. Effective interaction between stakeholders, including the community, planners, and designers, frequently hinges on the utilization of drawings and computer-generated visual representations. As mentioned earlier, physical models are specifically designed for communication, and they play a crucial role in public debates concerning alternative futures in landscape architecture [27].

In the context of landscape modeling, we explored the potential of 3D printing technology as a valuable tool to create physical models, which are widely used in landscape design practices. Traditional physical models in civil engineering and architecture are typically crafted by hand using materials like clay, cardboard, foam, or wood. This manual assembly process is time-consuming and can lead to inaccuracies, especially when dealing with complex topographic terrain [24].

By leveraging 3D printing technology, these challenges can be addressed more efficiently and accurately. Compared to conventional physical modeling, 3D printing offers advantages such as faster production, greater precision, and the ability to create intricate geometries. With 3D printing, the process of building physical models can be streamlined, reducing time and effort while ensuring higher accuracy in representing complex landscapes.

Nevertheless, even with its design-oriented benefits, the comprehensive integration of 3D printing technology into landscape architectural planning and design remains relatively unexplored. This state of affairs can be attributed to various factors and limitations.

The realm of landscape architectural planning and design revolves around the integration of organic elements, including vegetation, and frequently encompasses expansive regions. Current 3D printing technology faces limitations in supporting such cases due to cost and size constraints. Studies have pointed out that the speed of 3D printing, particularly for large-scale models, is one of the limitations that hinder its widespread application across various fields [28,29]. Additionally, researchers like Neumüller et al. [26] have highlighted that despite rapid developments, 3D printing technology still has limitations in terms of color expression and the range of applicable materials, which presents challenges when attempting to print complex landscape architectural models. As stated by Ervin in reference [27], the term 'landscape' can encapsulate a range of interpretations, encompassing intricate cultural constructions, elemental arrangements like landforms, water bodies, and foliage, or the dynamic interplay of influences across varying temporal spans, spanning from seconds to centuries. From a modeling vantage point, landscapes manifest as intricate formations extending over substantial expanses. In the tangible landscape, pivotal factors governing its visual aspect comprise topography, flora, fauna, aquatic elements, human-made structures, atmospheric conditions, and lighting, as elucidated in reference [30].

Steinhilp and Kias [15] conducted a comprehensive examination of various 3D printing technologies to identify an appropriate option for the field of landscape architecture. They underscored the significance of prioritizing speed and affordability over supreme precision, particularly when employing 3D printed models to depict the overarching site rather than aiming for absolute exactitude. This approach resonates with the customary role of physical models in landscape architecture. Depending on the specific planning or design quandary and the nature of the landscape in question, a landscape architectural depiction need not necessarily encompass all constituents, nor must every element be rendered with exceptional intricacy. Nevertheless, each element can present a substantial challenge when aiming for a portrayal characterized by a high level of authenticity [30]. As an example, authentic vegetation inherently boasts complexity, encompassing numerous components such as leaves, flowers, and branches, and the assorted characteristics of vegetation across a landscape can introduce additional complexities [30]. Given the intricacy inherent to landscapes, the creation of landscape architectural 3D prints can indeed prove to be a formidable undertaking.

However, it is essential to acknowledge that omitting real landscape details from a virtual representation might result in a certain lack of richness [31], and overly abstract representations may not be suitable for accurately determining landscape aesthetic and scenic beauty values [32].

# To recapitulate, the integration of 3D printing technology into landscape architectural planning and design entails a number of critical factors to be taken into account: degree of intricacy, manufacturing expenses, production duration, and scale. To gain a comprehensive understanding of these factors and their interrelations, our study adopted a holistic research approach. This approach was inspired by the way landscape practitioners tackle problem-solving, synthesizing various elements into a cohesive whole without requiring detailed knowledge of each part. The approach utilized a descriptive framework and a storytelling technique to provide a better overview and comprehension of how 3D printing technology is applied in real-life landscape projects. The framework focused on four dimensions of implementation: cost, level of detail, time, and scale. By employing different tools and models based on this framework, we aimed to analyze the factors influencing the utilization of 3D printing technology in landscape planning and design, effectively operationalizing the connections between the design process and 3D printing technology [33].

# Notably, while the significance of boundary work and interactive design has been acknowledged in the context of industrial design, it has been relatively overlooked in landscape planning and design implementation. In our research, we aimed to bridge this gap by integrating insights from the literature on 3D printing technology with the findings from interviews with landscape practitioners. This unique approach shed light on the potential of 3D printing to enhance communication and participation in landscape design.

# Methodology

Considering the potential benefits and drawbacks of 3D printing technology, this research aims to explore its applicability in the landscape architectural planning and design process, with a focus on enhancing communication within the industry and fostering overall development. Additionally, the study seeks to investigate the integration of 3D printing into the landscape architectural education curriculum.

To achieve these objectives, a qualitative research methodology and case study approach are adopted. The data collection process involves conducting semi-structured interviews with landscape practitioners and surveys with secondary students. This combination of methods ensures the validity of the qualitative study, following the recommendations by Yin [34]. Through these interviews and surveys, the study analyzes the advantages and disadvantages of 3D printing technology and explores potential strategies to address challenges associated with this innovative technology.

The research detailed in this paper originates from a landscape architectural design workshop that engaged secondary school students. Spanning from 2016 to 2019, each year saw the enrollment of 50 students to partake in the Major Experience program. The workshop's objective was to offer secondary school students a preview of the curriculum encountered in a university landscape architecture major, fostering an enhanced grasp of the subject matter. The program consisted of three sessions: an introductory lecture on landscape architecture, an experiential workshop that included a design activity utilizing 3D-printed models, and an opportunity to engage in conversations with senior students. This initiative was undertaken to cater to the needs of secondary school students who were on the verge of choosing their college majors and enhance their understanding of landscape architecture.

Experimental 3D printed models were developed for the workshops, utilizing a simplified geometric approach with "lollipop-like" tree formations created from modular toy blocks on 30 cm x 30 cm square boards. Due to limited time and budget, the models were restricted to two types of trees, broadleaved and conifers, using a Da Vinci 1.0 AiO 3D printer. These models were employed within a landscape design workshop specifically designed for secondary school students who were engaging in a landscape course experience. The workshop aimed to explore the usability of 3D printing in education, with students using the modular 3D-printed models to design and install gardens based on assigned themes.

Following the workshop, a brief survey was conducted to collect feedback from the participants. The survey included questions about their understanding of the subject of landscape architecture with the aid of 3D models, as well as the satisfaction level with the training processes. The questionnaire used a 5-point Likert scale for responses. Two main question groups were included: the participants' most preferred program among lecturing, workshop, and talk sessions with current students, and how helpful the overall program was in understanding the subject of landscape design. The survey results from 177 participants were analyzed, excluding any responses with omitted values (Table 1).

# The semi-structured interviews conducted for this study involved six practitioners with field experience ranging from two to thirty years in various sectors, including construction companies, multi-disciplinary practices, design studios, and the public sector. The interviews aimed to gather insights into their experiences with 3D printing in the landscape design field and to explore the pros and cons of implementing this technology, along with their recommendations.

# The interviews were divided into five question groups as follows:

# Experiences in 3D printing in the landscape design field.

# Description of any previous experience using 3D printing technology.

# Evaluation of the advantages and disadvantages of implementing 3D printing technology and any recommendations.

# Explanation of their knowledge about the technology and its potential for implementation in their field.

# Review of tradeoffs in 3D printing technology, including cost, scale, time, and level of detail.

# Each interview lasted between one and two hours, starting with general background questions about the interviewees' experience and previous use of 3D printing technology. The interviewees were then shown samples of 3D printed technology and encouraged to explore and provide their opinions on the technology. The discussions covered the strengths, weaknesses, and potential applications of 3D printing technology in landscape architectural planning and design.

# Thematic analysis was employed to analyze the interview data. Each author independently conducted the thematic analysis, focusing on four interconnected issues: cost, size, time, and level of detail. The study's analysis was based on these four themes (Section 4.2).

# Case Study Results: 3D Printing in Landscape Architectural Education andLandscape Design

To explore the capabilities of 3D printing technology, we initiated a case study built upon project-based encounters. In response to inquiries regarding participants' preferences among the three conducted sessions, hands-on experiential workshops emerged as the favored choice at 83.1%. General introductions to the major garnered 10.2%, while dialogues with senior students accounted for 6.8% (Table 3).

Most preferred session.

|  |  |  |
| --- | --- | --- |
| **Sessions** | n | Ratio (%) |
| Total | 1  7  7 | 100 |
| Lecture for introducing the major | 1  8 | 10.2 |
| Experiential workshop | 1  4  7 | 83.1 |
| Conversation with senior students | 1  2 | 6.8 |

The students mentioned that they chose the preferred session because they enjoyed the hands-on experience of creating something themselves. They found the activity of designing a park with 3D models to be engaging and allowed them to showcase their creativity. Some students expressed that they appreciated the opportunity to do practical work and apply what they had learned, which was different from the traditional lecture classes.

They also mentioned that the workshop provided a unique experience that they couldn't find elsewhere, and they liked the variety of activities offered during the major experience sessions. They found the park-designing workshop to be enjoyable, but they felt it was too short, and they found one-sided lecture classes to be boring in comparison.

Several students who participated in the workshop expressed that they enjoyed collaborating and discussing ideas with other participants. They found it fun to work together as a team and appreciated the opportunity to present their park designs using 3D printing technology.

Moreover, when queried about the efficacy of the major experience workshop in enhancing their comprehension of the landscape architecture major, a substantial 94.35% of the students responded affirmatively (Yes or Very much). Respondents highlighted that their understanding of the major had markedly advanced due to the workshop.

Did the workshop contribute to a broader understanding of the major?

|  |  |  |
| --- | --- | --- |
| **Division** | **n** | Ratio (%) |
| Total | 17  7 | 100 |
| Not at all | 1 | 0.56 |
| No | 0 | 0 |
| Neither helpful nor unhelpful | 9 | 5.08 |
| Yes | 84 | 47.46 |
| Very much | 83 | 46.89 |

The feedback from the participants highlighted the positive impact of the garden and park design practice during the workshop. Students expressed that the experience allowed them to gain a practical understanding of landscape architecture and made the subject more approachable and enjoyable.

One student mentioned that the workshop helped them realize their career aspirations, as it aligned with their interest in designing and decorating cities based on their surrounding environments.

Moreover, the design workshop that involved 3D models was perceived as easier to understand compared to the CAD workshop that focused on 2D design drawings. The students found the 3D design workshop more straightforward in terms of planning and designing, while they faced challenges with the 2D CAD workshop and needed more assistance from senior students.

The findings from the workshop align with previous research that indicates students can gain deeper knowledge and understanding through hands-on experiences, such as creating actual 3D printing models. The use of multiple sensory processing methods in the workshop also contributed to enhancing learning ability.

Feedback from students indicated that while most of the programs were enjoyable, the CAD program proved challenging for some due to its complexity. However, the guidance and assistance provided by senior students were appreciated.

Based on the positive outcomes of the workshop, 3D printing technology was recognized as having the potential to improve the landscape design process. Although academic studies have demonstrated the potential of this technology, its widespread implementation in practice would require careful consideration and planning. To explore the implementation of 3D printing technology in landscape design further, semi-structured interviews were conducted with experienced landscape practitioners.

In the landscape planning and design field, computer visualization technology is commonly used, but there have been efforts to enhance its credibility and interactivity. While the potential of 3D printing technology to enhance interactivity and authenticity is acknowledged, its adoption remains limited among landscape practitioners in South Korea. This is the case even when such technology might be solicited by developers and governmental bodies following consultation with relevant experts. Physical 3D models are seen as an auxiliary technique, and their utilization in planning authorization procedures is infrequent. Instead, computer-generated graphics are the more prevalent choice. The integration of 3D printing technology is frequently perceived as a technical endeavor that centers on textual portrayals of developmental ramifications.

During the interviews with landscape professionals, it was found that the majority of them had not yet used 3D printing technology in their own projects. Several reasons were cited for this, some of which are as follows:

"It is quite challenging to use 3D printers, and the cost is a significant concern." (Interviewee D)

"In my company, we don't have a 3D printer." (Interviewee C)

"I don't see a compelling need to use 3D printers in my work." (Interviewee E)

Based on the responses from the interviews, several constraints for the implementation of 3D printing technology in landscape planning and design can be identified. These constraints include high cost, size limitations, and relevance to the work. An interviewee, possessing three decades of professional expertise, disclosed utilizing 3D printed models for a lakeside project's decking design back in 2016. The resultant model exhibited satisfactory quality and garnered a positive response from the client. This interviewee expressed interest in using a variety of materials and highlighted the usefulness of a technology that could easily print larger items.

Another interviewee, a street furniture designer, acknowledged having knowledge of 3D printing from news sources but stated that they were not the decision-maker for its usage. However, they mentioned that implementing 3D printing technology in the street furniture industry could be successful. For instance, using a 3D printer for prototype fabrication before manufacturing could save time and money.

Regarding the value of implementing 3D printing technology, one interviewee emphasized its usefulness in aiding client understanding during consultation for smaller items such as benches, entrances, and art features. They suggested that while there are various 3D modeling software programs available, having physical models to see and touch would be more beneficial.

In terms of cost issues, the interviewees expressed their opinions despite their lack of actual experience with 3D printing. One interviewee expressed a desire to see higher-durability materials, such as metal, for 3D model production. Another interviewee mentioned that the cost of 3D printing could be a concern and that for it to be feasible in the field, 3D models should be produced more cheaply than physical 3D models. They also noted that smaller firms might find it challenging to acquire 3D printing facilities.

Furthermore, an interviewee with experience in street furniture manufacturing stated that 3D printing technology could be useful in the prototype fabrication stage. However, they pointed out that the final quality of street furniture heavily relies on the manufacturer's ability. While 3D printing might enable less skilled manufacturers to produce final items, skilled personnel would still be required for the 3D printing process.

In comparing current computer graphics and physical 3D modeling methods in the design process, one interviewee emphasized the price competitiveness of 3D printing technology compared to computer graphics. They mentioned that average architecture and landscape architecture firms typically pay around 500 to 700 USD per image for computer graphics, making 3D printing a potentially cost-effective alternative.

The size of 3D printed models was identified as a critical factor during the interviews. At the time of the interviews, 3D printed models were limited to dimensions of 20 cm x 20 cm x 20 cm, which posed challenges for larger-scale applications. Interviewees linked size to cost issues and expressed the need for larger-scale 3D printing to be feasible for widespread use in landscape architecture.

However, one interviewee argued that size was not a major concern, as size limitations are encountered not only in 3D printing but in other design media, such as computer graphics presented on monitors or paper.

Although the deliberations addressed limitations regarding size, recommendations for suitable 3D printing dimensions were proposed concerning landscape planning and design. An interviewee indicated that the size choice would hinge on the intended purpose, noting that smaller formats like A3 or A2 could prove more effective as design aids in comparison to larger sizes.

Manufacturing time emerged as another key issue in the study. Participants acknowledged the long production time of 3D printing as a significant drawback. They compared it to the production of hand-made physical models and expressed the need for 3D printing to be faster and more efficient to compete effectively. One interviewee pointed out the challenge of reflecting design changes quickly in 3D models, which is essential in landscape design.

The significance of the detail level accommodated by 3D printing technology emerged as a pivotal consideration. Unlike architectural designs, landscapes encompass numerous organic shapes, necessitating 3D printers to be capable of reproducing these natural forms effectively for feasible integration within the industry. The use of various materials and textures, such as vegetation and hardscapes, was highlighted as essential for creating realistic landscape designs using 3D printing.

The issues of detail, cost, and time were interrelated. More intricate details would require longer manufacturing times and could increase costs. This observation underscores the need for finding a balance between detail and practicality in implementing 3D printing technology in landscape architectural planning and design.

Some landscape architectural practitioners viewed 3D printing technology as just another tool with its own strengths and weaknesses. However, two interviewees recognized the potential for significant changes in current practices, especially in street furniture design, indicating that technology can drive transformative shifts in the industry.

Based on the case study's findings and the interviews, the study aimed to identify the relationships between the four main issues: cost, size, time, and level of detail, and their implications for the implementation of 3D printing technology in landscape design.

# Conclusions

3D printing technology has been widely recognized for its potential in planning, design, and education literature. However, in the context of landscape architecture, it has been relatively neglected. The objective of this research was to close this disparity by merging insights from technological literature with input garnered from interviews with landscape practitioners. This amalgamation aimed to delve into the prospective benefits of 3D printing in augmenting the landscape design process. Specifically, the study looked into how 3D printing could contribute to improving the level of detail, cost, scale, and time in landscape planning and design. Additionally, it investigated how 3D printing could facilitate the translation of scientific and technical understanding into the policy arena and improve communication, understanding, and negotiation among key stakeholders.

A design workshop conducted for secondary students in this study provided positive results, confirming the applicability of 3D printing in the current landscape architecture curricula. The workshop, which utilized 3D models, helped students grasp 3D design concepts effectively and sparked their interest, encouraging active participation. The 3D models were found to be valuable tools for explaining and discussing design ideas.

During the interviews with practitioners, the importance of credibility and interactivity was emphasized. However, this focus on methodology and justification might limit the potential impact of 3D printing in practice. Implementing a secure methodology could restrict the model to features that can be supported by recognized sources and extrapolation methods, leaving out potentially important elements. On the other hand, laypeople and clients often require more detailed and realistic impressions of landscape planning and design, where a more game-like apparent realism could be more effective.

In conclusion, the study highlights the promising prospects of 3D printing in the landscape architecture field, both in educational settings and in professional practice. It emphasizes the need to strike a balance between a secure methodology and the desire for more realistic and immersive representations to effectively communicate design ideas to various stakeholders.

However, the effective integration of 3D printing technology into landscape architectural design procedures necessitates addressing various critical concerns. These encompass the technology's proficiency in managing intricacy, cost, timing, and production dimensions. These concerns were observed to be closely intertwined. Significantly, 3D printing technology displays promising potential in the streamlined creation of diminutive landscape design elements, such as urban furniture. Yet, the present study couldn't comprehensively dissect each interrelation between intricacy, timing, cost, and scale within the context of landscape architecture. Further investigation is warranted to individually scrutinize these relationships, delving into aspects such as cost-to-intricacy, intricacy-to-size, size-to-timing, and timing-to-cost quandaries with greater depth.

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