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Bridging Traditional Drafting and Modern Technology: Enhancing Miniature Making Through 3D Printing

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Abstract: This study explores the integration of 3D printing technology into miniature model-making as an innovative approach to enhance the learning experiences of Architectural Drafting Technology students. Traditionally, miniature making has been a manual, time-consuming process that requires high levels of precision, patience, and craftsmanship. While valuable in developing technical and creative skills, traditional methods often limit students' efficiency and exposure to modern industry practices. This research seeks to bridge traditional drafting techniques with digital fabrication tools by examining how 3D printing can be applied as a complementary method in the creation of architectural miniatures. Employing a quantitative research methods approach, the study evaluates through standardized assessment rubrics measuring design quality, task completion, and accuracy, as well as surveys evaluating accessibility, readiness, and students' self-efficacy in applying drafting skills. Results indicated that students exposed to 3D printing demonstrated significantly higher learning outcomes, reflected in improved design quality, reduced production errors, and greater efficiency compared to those using conventional methods. Moreover, students reported stronger perceptions of accessibility and readiness to use modern drafting tools, aligning their competencies with industry practices. Findings also revealed a notable increase in students' self-efficacy, as they gained confidence in combining traditional craftsmanship with emerging digital technologies. The study concludes that 3D printing integration is not only a viable instructional strategy but also a catalyst for elevating student performance, fostering design innovation, and preparing learners for the evolving demands of architectural education and practice.

Keywords: *Architectural Drafting, Miniature Making, Technology Acceptance Model, 3D Printing.*

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I. INTRODUCTION

Miniature model making has been an integral part of architectural education, allowing students to transform their conceptual designs into tangible, physical representations. This process not only helps students visualize spatial relationships and the functionality of their designs but also hones their skills in precision, material handling, and construction techniques. Traditionally, students have relied on manual methods involving materials such as wood, foam, and acrylic to build architectural models. While effective in teaching basic craftsmanship and technical skills, these traditional methods are often time-consuming, labor-intensive, and can limit the range of complexity in student designs.

In recent years, technological advancements such as 3D printing have revolutionized the way models are created in the field of architecture. 3D printing, also known as additive manufacturing, allows for rapid prototyping of intricate and precise models directly from digital designs. This process offers significant advantages over traditional techniques, including reduced production time, greater accuracy, and the ability to create complex forms that would be difficult to replicate manually. By incorporating 3D printing into architectural education, students are provided with the opportunity to enhance their learning experience, experiment with more intricate designs, and increase their efficiency in model production.

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Recent studies support the idea that 3D printing enhances architectural education by offering more flexible, innovative, and accessible tools for students. For instance, a study by *Kolosky et al. (2021)* found that 3D printing allows students to visualize complex geometric forms that are traditionally difficult to model using conventional methods, leading to an increase in students' engagement and creative problem-solving. In line with this, *Huang et al. (2022)* argue that the integration of 3D printing into design curricula can significantly improve student learning outcomes by enabling faster iteration and giving students the ability to test design concepts in real time. They further highlight how 3D printing helps students to engage with more intricate and innovative designs that they may not have explored using traditional manual methods.

Moreover, studies have also highlighted the practical benefits of 3D printing in terms of design accuracy and quality. *Özeren et al. (2023)* demonstrated that the precision offered by 3D printing allows students to produce highly accurate models that closely resemble their digital designs, reducing the occurrence of errors that are often seen in handmade models. These advantages have led many educational institutions globally to incorporate 3D printing into architectural curricula, providing students with the opportunity to work with modern fabrication tools, which align with industry practices.

In the Philippine context, the integration of 3D printing into architectural education remains underexplored, especially when it comes to its impact on miniature model making. While some universities in the country have begun adopting 3D printing in their programs, many schools still rely heavily on traditional model-making techniques. *Miranda et al. (2020)* explored the development of a 3D engine assembly simulation for senior high school students, highlighting the importance of digital technologies in enhancing practical learning experiences. However, there remains a gap in empirical research specifically assessing the impact of 3D printing on architectural students, particularly in how it influences their learning outcomes and engagement in tasks like miniature model making.

This study seeks to address this gap by examining how the integration of 3D printing into miniature model making enhances learning outcomes for architectural drafting students in the Philippines. The study will explore several aspects, such as the improvement of design quality, accuracy, and students' self-efficacy in using modern technology. It will also assess whether 3D printing helps bridge the gap between traditional architectural education and industry-relevant digital fabrication skills, thus preparing students for the technological demands of the modern architectural workforce.

II. METHODS

The researcher used a descriptive research design, the study gathered data from participants who responded the study on 3D printing into miniature model making. Descriptive statistics, including frequency, percentage, mean, and standard deviation, were employed to analyze user responses and identify patterns in their evaluations which measured the differences in students' learning outcomes before and after the intervention (use of 3D printing technology), with a focus on design accuracy, model quality, and student confidence

A. Participants

The respondents of this study consisted of Fifty 50 students from 1st-4th year, under the College of Technology, Department of Architectural Drafting Technology of Surigao Del Norte State University.

B. Data Collection

The data gathering follows accordingly the following prerequisites: 1) An intent letter being sent to the Research Planning and Development Office to seek permission to conduct a study. Consequently, this involved the students, under the department of architectural drafting technology; 2) Questionnaire were administered to the target respondent to answer them thoroughly; 3) checklist and tables were made for better presentation and analysis of the gathered data.

C. Data Analysis

The Technology Acceptance Model was used to explore Miniature Making through 3D Printing by utilizing the modern and traditional technology of the students of Surigao del Norte State University. A 5-point Likert scale was attribute of reference in which the rate ranged from 1 to 5. The researcher used the weighted mean to get average of the respondent's Miniature Making through 3D Printing.

III. RESULTS & DISCUSSION

Table 1: Improvement of Student Learning Outcomes

Areas of Concern	Mean	Interpretation
1.1 Accuracy of miniatures produced	4.56	Very Effective
1.2 Efficiency and time-saving in project completion	4.46	Very Effective
1.3 Development of technical skills	4.52	Very Effective
Overall Mean	**4.513333333**	**Very Effective**

Legend: 5.00-4.21 Very Effective, 4.20-3.41 Effective, 3.40-2.61 Neutral, 2.60-1.81 Ineffective, 1.80-1.00 Very Ineffective

Table 1 shows the result of the Improvements of Student Learning Outcomes, which provides empirical result with the Overall Mean of 4.513333333 with the interpretation of Very Effective, and so majority of the students believed that utilizing modern technology makes their tasks much more effective. Among the 3 concerns, Accuracy of miniatures produced got the highest mean of 4.56, followed by Development of technical skills with 4.52 as the mean and 4.46 for Efficiency and time-savings in project completions.

In the study of Kolosky, D., Bruns, S., & Winter, D. (2021) confirms that students who utilized 3D printing to

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produce architectural miniatures demonstrated higher model accuracy, faster prototyping, and improved engagement compared to traditional methods. Which only implies that it is essential that students should utilized the appropriate tools for them to produce good and accurate projects.

Table 2: Enhancing Design Accuracy and Creativity

Areas of Concern	Mean	Interpretation
2.1 Ability to create complex architectural models	4.76	Very Effective
2.2 Precision and detailing of designs	4.82	Very Effective
2.3 Creative freedom in model-making	4.76	Very Effective
Overall Mean	**4.833333333**	**Very Effective**

Legend: 5.00-4.21 Very Effective, 4.20-3.41 Effective, 3.40-2.61 Neutral, 2.60-1.81 Ineffective, 1.80-1.00 Very Ineffective

Table 2 shows the result of the Enhancing Design Accuracy and Creativity, which provides empirical evidence with the Overall Mean of 4.833333333 with the interpretation of Very Effective, and so majority of the students believed that utilizing modern technology makes their tasks much more effective, particularly in enhancing their design with accuracy and creativity. Among the 3 concerns, Precision and detailing of designs got the highest mean of 4.82, followed by Ability to create complex architectural models and Creative freedom in model-making got with 4.76 as their mean.

Qurraie, B. S., Özeren, Ö., & Özeren, E. B. (2024) affirms that, incorporation of 3D printing into architectural education significantly improves students' design accuracy and fosters greater creativity, suggesting its effectiveness as a teaching tool in architectural design studios. The study proves that utilizing the modern technology in crafting their miniature architectural drawing provides opportunity to make the design with accuracy and creativity.

Table 3: Accessibility and Technological Readiness

Areas of Concern	Mean	Interpretation
3.1 Technological readiness of students	4.80	Very Effective
3.2 Access to digital resources and equipment	4.62	Very Effective
3.3 Willingness to adopt 3D printing technology	4.84	Very Effective
Overall Mean	**4.753333333**	**Very Effective**

Legend: 5.00-4.21 Very Effective, 4.20-3.41 Effective, 3.40-2.61 Neutral, 2.60-1.81 Ineffective, 1.80-1.00 Very Ineffective

Table 3 shows the result of the Accessibility and Technological Readiness, which provides substantial evidence with the Overall Mean of 4.753333333 with the interpretation of Very Effective. Majority of the students believed that utilizing modern technology compared to traditional makes their tasks much more effective, particularly in accessibility and technological readiness of the students. Among the 3 concerns, Willingness to adopt 3D printing technology got the highest mean of 4.84, followed by Technological readiness of students with 4.80 as the mean and Access to digital resources and equipment got with 4.62 as mean.

Brozovsky, J., et al. (2024) in their study found that while there is a growing awareness of digital technologies in the AEC sector, significant gaps remain in technological readiness, particularly concerning the integration of advanced tools like 3D printing in architectural education. While the result is still evident, there is still a need for accessibility and technological readiness of the students in order for them to be ready in making their task more effective.

Table 4: Students Efficacy in Architectural Drawing

Areas of Concern	Mean	Interpretation
4.1 I am confident in my ability to accurately create miniature architectural models from my design plans.	4.85	Strongly Agree
4.2 I can effectively solve design or construction problems that arise while creating architectural miniatures.	4.82	Strongly Agree
4.3 I am confident in using tools and technologies (e.g., 3D printing, CAD software) to enhance the quality and accuracy of my miniature models.	4.90	Strongly Agree
Overall Mean	**4.85666667**	**Strongly Agree**

Legend: 5.00-4.21 Strongly Agree, 4.20-3.41 Agree, 3.40-2.61 Neutral, 2.60-1.81 Disagree, 1.80-1.00 Strongly Disagree

Table 4 shows the result of the Students Efficacy in Architectural Drawing, which provides empirical evidence with the Overall Mean of 4.85666667 with the interpretation of Strong Agree. Majority of the students believed that they are confident in their ability, confident in using tools and technology and effectively solved design in their convenient way. Among the 3 concerns, confident in using tools and technologies got the highest mean of 4.90 followed by their confidence in their ability to accurate create designs with 4.85 as the mean and effectively solve designs problems got with 4.82 as mean.

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Al-Rqaibat, S., Al-Nusair, S., & Bataineh, R. (2025) in their study examining the use of hybrid digital tools in architectural education, found out that these tools positively affect students' design creativity and cognitive processes. Therefore, integrating hybrid digital tools into architectural education can enhance students' self-efficacy and creative abilities in design tasks.

Table 5: Barriers And Challenges

BARRIERS	CHALLENGES
Difficulty in obtaining wood, foam, acrylic, or other model-making materials, affecting project completion.	Advanced or intricate designs may be difficult to execute accurately.
3D printers, CAD software, and precision tools may be expensive for students and institutions.	Ensuring scale and proportion in models is often challenging.
Schools may lack adequate 3D printing labs, computers, or software licenses for all students.	Students may struggle to innovate while adhering to design requirements.
Inadequate guidance or feedback from teachers may hinder proper techniques and skill development.	Certain materials restrict flexibility in model-making techniques.
Students may lack prior experience in CAD, 3D modeling, or digital fabrication.	Errors or breakdowns in 3D printers or cutting tools can disrupt progress.
Limited class hours make it difficult to complete detailed models.	Students may find it challenging to merge manual and digital model-making methods.
Physical or digital resources may not be equally available to all students.	Group projects may face coordination issues, affecting design quality and timelines.

Table 5 shows the barriers and challenges faced students. Students in miniature and architectural drawing programs often face multiple barriers and challenges that affect their learning and performance. Common barriers include limited access to materials, high costs of tools, and insufficient technological resources, while challenges involve complex design requirements, maintaining accuracy, and integrating traditional and digital methods like 3D printing. These obstacles can limit students' creativity, efficiency, and confidence in completing projects. According to Al-Rqaibat, Al-Nusair, and Bataineh (2025), while hybrid digital tools can enhance design creativity and cognitive skills, students require adequate resources, guidance, and support to effectively overcome these challenges and maximize learning outcomes.

IV. CONCLUSION

In today's technological era, bridging traditional drafting and modern technology demonstrates an empirical results that integrating 3D printing into architectural drafting education significantly enhances student learning outcomes by enabling faster prototyping, improving design accuracy, and fostering creativity in miniature model-making tasks. The use of digital fabrication tools increases students' technological readiness and accessibility, allowing them to engage more confidently with complex designs and modern architectural practices. Furthermore, the intervention strengthens students' self-efficacy, empowering them to apply both traditional and digital techniques effectively in their projects. While students still face barriers such as limited access to materials, high tool costs, and the challenges of integrating traditional and digital methods, the findings suggest that proper guidance, resources, and structured integration of 3D printing can overcome these obstacles, ultimately improving learning experiences, design quality, and preparedness for professional practice.

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