Journal of Design and Built Environment
E-ISSN: 2232-1500 |Print ISSN: 1823-4208
https://ejournal.um.edu.my/index.php/jdbe
Volume 25, Issue 03, 2025, 01-17

Evaluating the Efficiency of Different Model-Making Techniques in the Academic Architectural Design Schools

Raghad Mourad[1*], Firas Noori[1] and Nadeen Abd Yashoaa[1]

[1]Department of Architecture, College of Architecture, Art and Design, Ajman University, UAE.

*Corresponding author: r.murad@ajman.ac.ae

Article Info:

Submission date: 14th June 2024
Acceptance date: 20th June 2025

Keywords:

architectural, design, laser-cutting, model-making, traditional, 3D printing

Abstract

This paper investigates current model-making techniques and evaluates each method by demonstrating and measuring architectural students' acceptance and reliance during the design phases. The study evaluates the three approaches used in making architectural models (traditional, laser-cutting, and 3D printing) using criteria such as quality, completion speed, cost, availability of technology, materials, and software requirements. These criteria will be presented in the form of questions to a selected group of students to find out their preference rate for each method and measure the efficiency of each method for each stage of the architectural study on the one hand and its suitability for the type of the selected architectural project and its degree of complexity on the other hand. A test group completes a detailed questionnaire to assess the advantages and disadvantages of each method. The collected data has been analysed to formulate conclusions and recommendations. The results explain to both students and professors when and why each model-making method should be used, and what the barriers and limitations are for each method. It was found from this research that applying the 3D printing model technique is the preferred one, especially for the final product presentation, but applying that method of model making faces many challenges in terms of the applicability and the used software and the research has concluded a list of solutions and recommendations for the addressed issues.

1.0 INTRODUCTION

Architectural model-making has long served as a critical pedagogical tool, bridging the gap between abstract design concepts and tangible spatial comprehension (Surwade et al., 2023). As Dunn (2014) asserts that models function as provocative instruments that facilitate instantaneous perceptual engagement, offering simultaneous access to detail and holistic views of architectural ideas. Within academic design studios, physical and digital models not only aid in visualizing form and scale but also foster iterative experimentation, material understanding, and collaborative communication (Bermudez & King, 2000). However, the rapid evolution of fabrication technologies, from traditional handcrafted techniques to advanced methods like laser cutting and 3D printing, has introduced both opportunities and challenges in architectural education. While these innovations enable precision and complexity previously unattainable (Delikanlı, 2020), their integration into curricula remains uneven, often constrained by cost, accessibility, and disparities in student technical proficiency (Hmoud, 2018).

Throughout history, models have been used extensively to convey knowledge due to their provocative nature and ability to facilitate understanding as a communication tool (Friedman et al., 2008; Schmitt et al., 2014). Our perception provides instant access to any part of a model, and detailed as well as overall views (Dunn, 2014). In architecture education, model-making has been integrated as a powerful tool for experimentation, spatial understanding and interactive development (Afify et al., 2021). The use of model making has experienced gradual changes and major development in terms of the methods, materials and application (Zalloom, 2024).

This study examines how effective three common model-making methods are in academic architectural training: traditional handmade, laser-cut, and 3D-printed. A significant gap in the literature is filled by the research, which assesses factors like cost, time, quality, and pedagogical outcomes at various stages of the design process. Although earlier research has highlighted the geometric flexibility of digital tools (Ceylan et al., 2020) or the cognitive advantages of physical modelling (Afify et al., 2021), few offer a comparative framework to direct method selection based on project-specific requirements and student skill levels. This paper discusses, in depth the major model-making methods in terms of challenges, applicability and results. Which will lead to recommendations and suggestions for improving the role of model making in the architectural schools.

2.0 LITERATURE REVIEW

A study conducted at Imam Abdulrahman bin Faisal University examined the effectiveness of using physical models in architecture education, focusing first-year design studios. It contrasts conventional sketch-based instruction (no model-making teaching) with methods that use physical (manual or hand-made) modelling all along the way in the design learning process. The study suggests that model-making enhances knowledge, creativity, and communication in architectural design education. The study uses a questionnaire to gauge student perceptions and measure their interaction with the design learning process. The study highlights enhanced student performance and engagement and suggests a hybrid method of teaching that combines sketching and model-making (Afify, 2021). Although this study did not compare the different methods of model-making and their effects on architectural education, it states clearly the importance of model-making and that it crucially enhances the learning process, especially for those students with less academic skills, and mainly within the first year. The study recommends more investigation into the blending of digital and physical modelling methods to keep raising student achievement in architectural design education, which will be evaluated in this paper by comparing physical models built manually with others that came straight from a digital base, either by using laser cutting or 3D printing technologies.

Another article investigates model-making's role in architectural design, looking at how it affects creativity and form in design studio education. It looks into the interaction between manual and digital model-making methods, how they affect architectural form, and how they could affect architecture education pedagogically. The study's conclusion draws attention to three areas: a lack of resources for encouraging student creativity in model creation, the way computer-related curricula and design class material are related, and how students' ability to create models affects the resulting form of architecture. Combining the manual and digital model-making approaches could improve the educational process by fostering creative thinking in architectural design and offering a thorough grasp of design principles. The students' form morphing skills are higher and more mature when using digital methods than hand-made ones. Regardless of the syllabus's ineptitude between architectural schools, the study found that students' expressive ability during the model-making process and their accumulated skills and knowledge greatly influence the architectural final product (Hmoud, 2018)

Like Hmoud's work, Delikanlı's paper addresses how architectural models have changed throughout design education, focusing on how advances in information and communication technologies (ICT) have led to a shift from analog to digital modelling. The paper emphasizes that digital tools will provide new avenues for creativity and intricate geometries; the palpable component of physical modelling is still vital, yet it is not easy to create non-Euclidean geometries. In order to improve the educational value of digital model-making in architectural design, future research is recommended to compare the effects of physical and digital modelling methodologies on variable-level student results (Delikanlı, 2020). Both Hmoud and Delikanlı's work stated the importance of hand-made as a tangible method and pointed out that digital modelling is more suitable for creating complicated and advanced designs. The two studies encouraged a broader investigation of students at various levels to measure and better understand the challenges and benefits of digital modelling and compare them to traditional model-making in architectural education.

Another research conducted at Gdańsk University of Technology, Poland, discusses the value of traditional model-making in the early phases of architecture education. It highlights how it helps students develop their technical proficiency, inventiveness, and comprehension of spatial concepts. It makes the case that conventional physical models, which enable direct engagement with materials and forms, offer unique educational benefits even in the face of the growing popularity of digital modelling. Students were surveyed as part of the study, and the results showed that they preferred traditional approaches for conceptual understanding and idea presentation. The conclusion promotes a well-rounded strategy for architectural education that combines traditional and digital methods (Szuta, 2020). The research used only fourteen students to build parts of the results; a higher number will give more reliability to the results. Although the research stated clearly that it targets students at earlier stages, yet it is hard to deny that only targeting students at earlier stages, which have less knowledge in digital modelling and 3D Printing skills, renders their opinion less accurate as they need more time practicing to understand the full benefits of digital modelling and 3D Printing. A broader study that includes more students at higher levels with more extended digital practice and 3D printing experience will help better understand which model-making methods are more suitable for each architectural design type.

Roslina Sharif & Shafizal Maarof, in their paper, “Model Making as a Cognitive Tool for the Beginners” fifteen junior students (first-year students) were tasked with developing conceptual models based on their initial thoughts to assess the use of models. Students moved on to the next design development phase once their instructors assessed these models and gave them feedback. Several further study models were created before arriving at the ultimate design. The study shows how (students) designers think, what knowledge they possess, how they solve challenges, and what kind of thinking is needed for the design. The several research models being created demonstrate how their thought and cognitive processes are documented and mirrored in the designs created step by step (Sharif, 2014). According to the paper, models can facilitate the process of creatively visualizing three-dimensional spaces. Also, a model usually performs better than drawings since it aids in the understanding of intricate visual linkages.

Benay Gursoy and Mine Ozkar did another study to look at whether physical and digital models can be counted among ambiguous design tools. Three architecture graduate students with comparable work experience and proficiency in creating digital and physical models participated in the investigation. Three architectural design projects were presented to the participants; these tasks were similar in contextual, functional, and programmatic complexity and scale. The participants were required to use three different media, freehand sketches, physical models, and digital models, to address the assigned design difficulties. The research focused on identifying ambiguity factors in model-making rather than concerning the generic characteristics of its medium alone (Gursoy & Ozkar, 2010).

The research authors concluded that despite the immense number of cognitive studies on freehand sketching, there are very few cognitive studies concerning physical and digital models. Further research can be done to compare the design productivity of these media in the way that Goldschmidt defines it. We find it challenging to discuss the sketchy aspects of physical and digital models on that level (Gursoy & Ozkar, 2010). It is worth mentioning here that comparing three different architectural projects in terms of complexity, context, and scale cannot be accurate from a scientific point of view, and this aspect was the fundamental point of that paper.

This paper will build and develop from the knowledge gained from the literature review and start concentrating on comparing different model-making techniques, i.e., manual, laser cutting, and 3D printed models, as summarized in Table 1. It will survey 72 students from various levels to build a comprehensive understanding of different level audiences. Furthermore, it will evaluate each model technique as a tool for the final presentation of the architectural projects, not only for the architectural project development process.

Table 1. Summarizes key findings regarding handmade, laser-cut, and 3D printing techniques in terms of cost, speed, quality, and student preferences.

S.no	The Method	Cost	Speed	Quality	Student Preferences
1	Handmade	Relatively Low	Low	High	Low
2	Laser Cutting	Medium	Medium	Medium	High
3	3D Printing	High	High	High	Medium

3.0 RESEARCH AIM AND OBJECTIVES

The research aims to evaluate the efficiency of the three primary model-making techniques (traditional, laser-cutting, and 3D printing) used in architectural education. This goal can be achieved via three main objectives: evaluating the quality of three model-making techniques through the design process; second, measuring the satisfaction of the students with the model-making result; third, assessing the effect of the selected software and knowledge and experience of the students on the model-making techniques and their results.

4.0 RESEARCH METHODOLOGY

The methodology comprises four steps:

i. **Step One**: The research will critique the previous relevant literature and identify the most important criteria that need to be evaluated concerning the three previous objectives.

ii. **Step Two**: Create an online survey based on the SurveyMonkey website (SurveyMonkey, 2025) that enables data to be gathered from each audience member in a unique way, depending on how they answer each question (Grover et al., 2006). The questionnaire will present the required criteria embodied in different questions. In order to avoid bias, the questions were designed to be neutral and clear, no jargons were used. Also, they were randomized in order. The survey ensured anonymity and used a balanced rating scale (Baker, 1991). The questionnaire consists of 28 questions. See Table 2.

Table 2. Shows the questionnaire provided to the sample population to evaluate the efficiency of the three model-making techniques.

1	What is your institution affiliation?	15	How many times have you made a handmade model? (less than 5 times, 5 to 10 times, 10 – 20 times, more than 20 times)
2	Status? (Second year students, Third year student, Fourth year student, Fifth year Student)	16	How many times have you made a laser-cut model? (less than 5 times, 5 to 10 times, 10 – 20 times, more than 20 times)
3	Which method for model-making have you used the most during your study (the one you find fast, reliable, or cheap)?	17	How many times have you made a 3D Printed model? (less than 5 times, 5 to 10 times, 10 – 20 times, more than 20 times)
4	What method do you prefer for making your model (The one you think it gets the best results! Not because of the price or speed)? (Hand-made, Laser-Cut, 3D Printing)	18	Which of the following do you believe is the reason for NOT using 3D Printing method widely through the design course (Choose more than one if required): a. Lack of the experience in the modelling software required for the process b. Lack of the experience in the 3D Printing software and converting the 3D Model into a proper 3D Print model. c. Lack of the places that provide the service d. High cost e. Requires long time f. None of the above (I am using 3D Printers without any problems)
5	What method do you prefer for making your model (The one you think it gets the best results! Not because of the price or speed)?	19	Are you able to design and model complex/organic geometries using handmade models? (Yes, No)
6	What is the name of the software that you used in your model-making?	20	Have you ever failed to express a design idea because you were not able to physically model it? (Yes, No)
7	(AutoCAD, 3Ds Max, Rhino, Grasshopper, Revit, Dynamo, Maya, Sketchup, Others, None)	21	Do you prefer adding a new dedicated physical and digital model-making course to the current curriculum
8	How do you rate your knowledge of the most used software? (Beginner, Intermediate, Professional)	22	Does your college provide sufficient 3D Printers? (Yes, No)
9	Can you arrange the model-making methods according to their speed from the fastest to the slowest (Handmade, Laser-Cut, 3D Printing)?	23	Do you believe that your college has provided sufficient laser cutters?
10	Can you arrange the model-making methods according to the cost from the most expensive to the cheapest (Hand-made, Laser-Cut, 3D Printing)?	24	Do you think there are any material limitations related to the hand-made model-making?
11	Please explain your choice in the previous question	25	(Hard-to-find, expensive, fail or break during the modelling, hard to work with, difficult to adhere, combine and assemble)
12	Do you have good skills required for running the 3D Printer?	26	Do you think there are any material limitations related to the laser-cut model-making?
13	Are you using different model making method for each design phase? (Yes, No)	27	(Hard-to-find, expensive, fail or break during the modelling, hard to work with, difficult to adhere, combine and assemble)
14	If you chose Yes for the previous question, provide the best mode-making method for each design phase.	28	Do you think there are any material limitations related to the 3D Printing model-making?

iii. **Step Three**: Determine the study sample from the Ajman University bachelor's and master's degree architecture student categories. The total number of sample participants was 72 students.

This research utilizes the Accidental Sample method, where participants are chosen based on the information the authors can gather. Despite the absence of explicit limitations, the rapidity and user-friendliness of this sampling technique assist researchers and facilitate convenient evaluation of the sample population (Etikan et al., 2017). According to the methodological literature, the use of probability-sampling techniques enhances the likelihood that a representative sample will be obtained (Ziegel & Lohr, 2000). Thus, from a statistical perspective, methods such as simple random, stratified and cluster sampling are preferable because they are more likely to produce representative samples and enable estimates of the sample's accuracy (De Vaus & De Vaus, 2013). Here are the characteristics of the survey sample:

Population	**:** 72
Age	**:** 18- 35
Educational Level	**:** Architectural students and Master's holders.
Geographic Area	**:** Immediate geographical area.

iv. **Step Four:** Analyse the collected data to generate the conclusions and recommendations from all previous steps.

4.1 Architectural Model-Making Function

The architectural sector and associated fields find various applications for model making. In the educational field, the most important application is the one that falls under the design process, since it is crucial for the students to get sufficient comprehension of the design stages and the architectural product development. The representation of creative ideas is of primary importance within any design-based discipline, and is particularly relevant in architecture, where we often do not get to see the finished result, i.e. the building, until the very end of the design process (Dunn, 2014).

Throughout the design process, architects and students can explore spatial relationships, express ideas, and physically represent their architectural designs using an architectural model. For that reason, architectural models are essential for several reasons that fall into three main categories:

i. Inventiveness and Trials

The conceptual model is the initial kind of model. This is used to create and experiment with possible forms and shapes early in the design process, since architectural modelling “is not a ‘neutral’ means for the conveyance of ideas but is in fact the medium and mechanism through which concepts and designs are developed” (Dunn, 2014).

ii. Progress

The second method involves using the architectural model as a guide to create the working model of a design. This kind of model is used to generate ideas and work on solutions, but it is not visible to the client or the general public.

iii. Final presentation

The presentation model is what architects use to show the client or general audience the finished design concepts. Model-making stages are divided into four major parts, shown in Figure 1(a) Trial model, b) Mock-ups c) Detailed Model d) Prototype. In the initial stage, one should first work on a trial model (for the development of random forms/surfaces and mock-ups). And, in the final stage, the prototypes are prepared for testing of the product and its functional (or behavioural) aspects (Surwade et al., 2023).

4.2 Types of Architectural Models

4.2.1 Physical Models in the architectural education (Traditional, Laser-Cut, 3D Printing)

Physical models are essential to architectural education since they provide a physical and spatial understanding of architectural principles that are not always possible to grasp using digital tools alone. The following are some major points from studies on the value of physical models in architecture education:

i. Tangible Learning and Spatial Understanding

Tangible engagement with materials enhances spatial thinking and problem-solving in architectural design in the educational process since the students can engage with their designs hands-on with physical models, which helps them grasp scale, proportion, and spatial relationships. Physical models, as opposed to digital ones, appeal to more senses, which makes them perfect for conceptual development and early design exploration (Bermudez & King, 2000).

ii. *Materiality and Craftsmanship*

Students learn about the characteristics of materials how they behave, bend, break, and can be worked by physical models. Gaining a sense of physicality and craftsmanship skills that are frequently overlooked in solely digital design requires having this practical experience.

iii. Design Process

Students can readily edit, improve, or recreate their models through the iterative thought process that comes with creating a physical model by hand or any other method. This iterative approach facilitates the rapid exploration of many design possibilities, which also develops creativity and critical thinking.

iv. Communication and Design Results

Physical models are an effective means of communication for both students and non-architects. They facilitate the communication of complicated design concepts, particularly to stakeholders or clients who might not be familiar with digital models or architectural drawings. Even though digital technologies are now required in architecture education, research indicates that physical models still have some benefits that digital models cannot match. It is more difficult to get a direct, intuitive sense of scale and proportion using computer interfaces than with hand-made models (Griffin & Carter, 2015).

4.2.2 Digital Model-Making and Their Software in the Architectural Education

One of the most popular forms of representation and communication during the design process is architectural models (Delikanlı, 2020) Integrating digital tools, mainly 3D software specialized in modelling, has significantly transformed the academic education environment especially in the field of architectural model-making. These digital tools allowed the creation of digital architectural models which offer a range of advantages, including detailed analysis, enhanced precision, efficiency, and the ability to visualize complex geometries that are challenging to replicate manually (Ceylan et al., 2020). In addition, creating architecture models are becoming quickly digitalized by current technical advancements. Design students are drawn to digital settings because of their advantages, which hastened this shift. Non-Euclidean models need significant effort and are considered complex if traditional model-making methods are used. On the other hand, using digital and computational design software, these geometries can be easily digitally made and then physically 3D Printed or laser cut into accurate architectural models quickly (Delikanlı, 2020).

Studies have shown that 3D modelling software enables students to explore a broader spectrum of design possibilities, fostering creativity and innovation in their work (Ceylan et al., 2020). These software does not need any real built material like cardboard; you can almost model endlessly as the built materials are not going to finish. These digital models do not comply with real-life physics, which allows them to be the perfect environment to increase the creativity and fasten the design learning process as students will be able to make more models faster and cheaper. They also allow rendering enhancements to create a super realistic image that can be considered the closest to the real results (Delikanlı, 2020). Although digital software provides a wide range of benefits to the architectural model-making process, they require significant effort to keep both students and architectural schools updated with rapid and endless changes (Hmoud et al., 2018).

Software like Revit, Rhino and 3Ds Max are good examples of these digital modelling tools, combined with CNC and 3D Printers architectural students are now able to physically model what they learnt quickly and easily (Liu et al., 2006), which will help to bridge the gap between physical and digital existence (Aktaş, 2014). In addition to the previous digital traditional tools, a new set of computational and generative design platforms, like Dynamo and Grasshopper, allowed the designers to develop new complex architectural forms using visual algorithms, which later facilitates an advanced fabricating process to create complex models (Noori et al., 2023).

4.3 Theoretical Framework

The research creates a theoretical module based on the literature review study to achieve the research aim. This module depends on connecting the research objectives with the extracted values of the architectural models' types and their criteria, which will be presented within the questionnaire to the sample population to collect their responses. See Table 3.

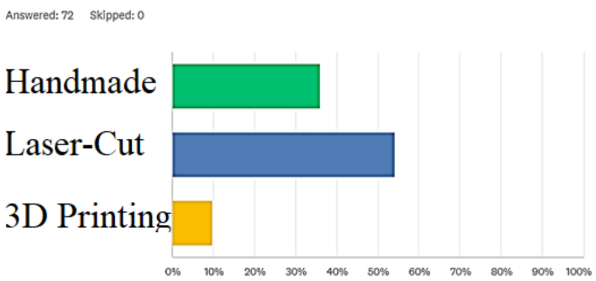
Table 3. Shows the research theoretical framework work which is the suggested module that connects each one of the research objectives with the selected values and criteria to evaluate the efficiency of the different model-making techniques.

S.no	Objectives	Values	Criteria	Questions
1	Design Process	Materiality and Craftsmanship, Tangible Learning & Design Process	Dependable	Q3
			Speed	Q3, Q8
			Cost-effective method	Q3, Q9
			Frequency	Q3
			Material Availability	Q22 to Q26
			Model-Making Consistency (using the same technique through the design phases)	Q13, Q14
			Time Consuming	Q3
2	Software	Digital Model-Making	Distinguishing between 3D Model for visualization and 3D Printing	Q10, Q11
			Software Selection	Q6
			Software Proficiency	Q7
			Time to Practice	Q15, Q16, Q17
3	Final Result	Communication & Design Results	Creativity: managed to achieved the required goals	Q5
			Complexity: The model-making technique allows the creation of complex architectural concepts	Q19
			Quality: accuracy, cleanliness, and matching the documentation	Q20
			Knowledge required to achieve the final model	Q12, Q18, Q21
			Experience	Q4, Q18

5.0 DISCUSSION AND RESULTS

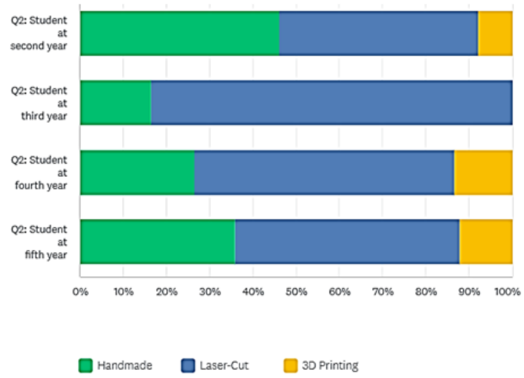
The research indicates that over half of the participants utilized the Laser-Cut modelling technique, deeming it the most efficient, fast, dependable, and cost-effective method for the design process. The Handmade modelling technique was the second most preferred, selected by 36% of the participants. In contrast, 3D Printing was the least favoured method, chosen by only 9% of the participants. See Figure 1(a) (Q3). To gain deeper insights into the previous findings, this research also examines students' preferences in model-making techniques across different academic levels. Notably, 80% of third-year students selected laser-cut as their preferred method, citing its speed, reliability, and cost-effectiveness. Interestingly, no students favoured 3D Printing by this group. 60% of fourth-year students expressed a preference for laser-cut, while only 26% preferred the handmade. Among second and fifth-year students, approximately 45% also favoured laser cutting as their technique of choice, with a higher preference compared to the previous groups. 3D Printing was the least preferred choice for all students. For a visual representation of these trends, see Figure 1(b).

The research indicates that Laser-Cut modelling, chosen by over half of the participants, is the most preferred method for achieving the best result (as the quality of the end product). Following closely, the 3D printing modelling technique, selected by 38% of the participants, is gaining popularity. Conversely, Handmade, chosen by only 6% of the participants, is the least favoured method. See Figure 2(a) (Q4). The research further explores preferences by students for model-making techniques across different academic levels. Notably, more than half of second, third, and fourth-year students chose Laser-Cut modelling as their preferred method, citing it as the most effective for achieving desired outcomes. Interestingly, the 3D Printing technique was secondly favoured by the participants. 48% of the fifth-year students preferred 3D printing, and 44% favoured laser cutting. Among all the selected levels of students, the least preferred was handmade modelling, with 13% to 0%, see Figure 2(b).



ANSWER CHOICES	RESPONSES	
Handmade	36.11%	26
Laser-Cut	54.17%	39
3D Printing	9.72%	7
TOTAL		72

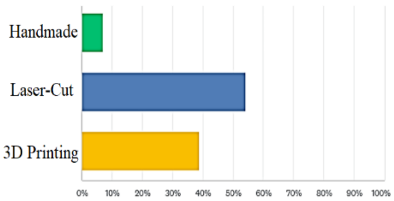
(a)



	HANDMADE	LASER-CUT	3D PRINTING	TOTAL
Q2: Student at second year	46.15% 12	46.15% 12	7.69% 2	36.11% 26
Q2: Student at third year	16.67% 1	83.33% 5	0.00% 0	8.33% 6
Q2: Student at fourth year	26.67% 4	60.00% 9	13.33% 2	20.83% 15
Q2: Student at fifth year	36.00% 9	52.00% 13	12.00% 3	34.72% 25
Total Respondents	26	39	7	72

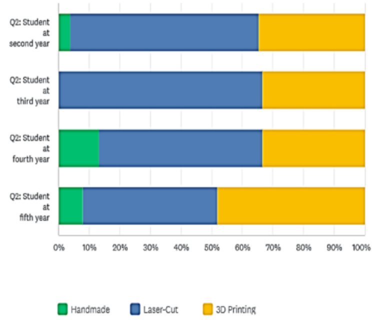
(b)

Figure 1. (a) Shows the population response to most preferred model-making techniques based on the speed, reliability and cost (b) Shows the students' responses, categorized by their academic levels, to the most preferred model-making techniques based on the speed, reliability, and cost.



ANSWER CHOICES	RESPONSES	
Handmade	6.94%	5
Laser-Cut	54.17%	39
3D Printing	38.89%	25
TOTAL		72

(a)



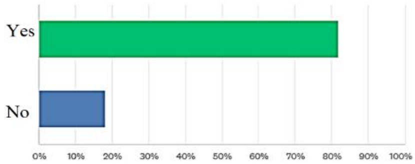
	HANDMADE	LASER-CUT	3D PRINTING	TOTAL
Q2: Student at second year	3.85% 1	61.54% 16	34.62% 9	36.11% 26
Q2: Student at third year	0.00% 0	66.67% 4	33.33% 2	8.33% 6
Q2: Student at fourth year	13.33% 2	53.33% 8	33.33% 5	20.83% 15
Q2: Student at fifth year	8.00% 2	44.00% 11	48.00% 12	34.72% 25
Total Respondents	5	39	28	72

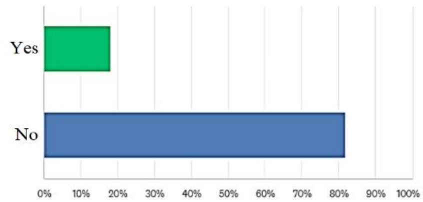
(b)

Figure 2. (a) Shows the population response to the most preferred model-making techniques based on the best results gained, (b) Shows the students' responses, categorized by their academic levels, based on the best results gained.

The research reveals that 81% of the participants agree that the Handmade modelling technique has an impact, limiting design creativity by affecting the resulting forms negatively. See Figure 3(a) (Q5).

The research indicates that 81% of all the participants lacked the knowledge required to run 3D printers. This supports the findings stated in conclusion number one (Q12). When each level of students was examined separately, interestingly, all fourth-level students lacked the required skills to work on 3D Printers, while 19% of the second-level students claimed that they had the required knowledge. Third-level students are only 16%, and fifth-level students are 28%. See Figure 3(b) and Figure 3(c).



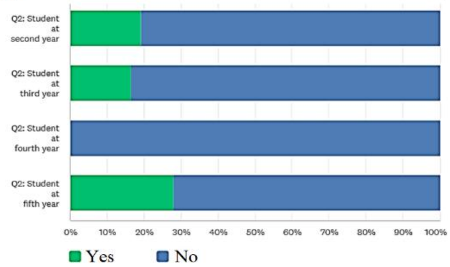


ANSWER CHOICES	RESPONSES	
Yes	81.94%	59
No	18.06%	13
TOTAL		72

(a)

ANSWER CHOICES	RESPONSES	
Yes	18.06%	13
No	81.94%	59
TOTAL		72

(b)



(c)

	Yes	No	Total
Q2: Student at second year	19.23% 5	80.77% 21	36.11% 26
Q2: Student at third year	16.67% 1	83.33% 5	8.33% 6
Q2: Student at fourth year	0.00% 0	100.00% 15	20.83% 15
Q2: Student at fifth year	28.00% 7	72.00% 18	34.72% 25
Total Respondents	13	59	72

Figure 3. (a) Shows the population ratio that believe that the handmade model-making limits design creativity by affecting the resulting forms negatively (b) Shows the population ratio that has the required skill to run a 3D Printer (c) Shows the students' responses, categorized by their academic levels, expressing their knowledge of operating a 3D Printer

The research finds that the audience considers 3D printing the most expensive model-making method, followed by Laser-Cut Modelling as their second choice. The Handmade modelling technique is the cheapest (Q9). The research finds that handmade models are the most frequently used technique, followed by Laser-Cut modelling and 3D Printing (Q15, Q16 and Q17). Using the students' responses shown in Figure 4, the numbers of students who chose "More than 20 times" has been added to a new table, see Table 4, then their values have been added with the "10 – 20 times" values to get a new bar titled "More than 10 times" to gain the percentage of the population who used this method more than 10. Finally, the previously found bar "More than 10 times" will be added to the "5 to 10 times" to gain a new bar titled "More than 5 times" to gain the population percentage that used each method more than 5 times. See Table 4.

ANSWER CHOICES	RESPONSES	
Less than 5 times	12.50%	9
5 to 10 times	37.50%	27
10 - 20 times	30.56%	22
More than 20 times	19.44%	14
TOTAL		72

a. Handmade

ANSWER CHOICES	RESPONSES	
Less than 5 times	48.61%	35
5 to 10 times	29.17%	21
10 - 20 times	15.28%	11
More than 20 times	6.94%	5
TOTAL		72

b. Laser-cut

ANSWER CHOICES	RESPONSES	
Less than 5 times	93.06%	67
5 to 10 times	2.78%	2
10 - 20 times	1.39%	1
More than 20 times	2.78%	2
TOTAL		72

c. 3D Printing

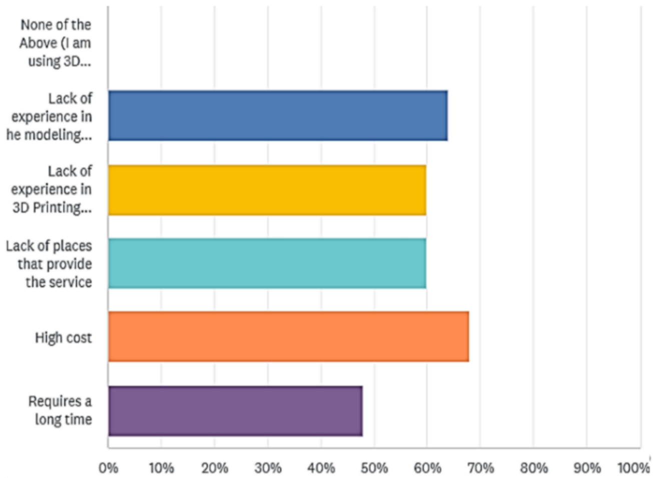
Figure 4. Shows the frequency of the population using each modelling technique

Table 4. Shows the modelling technique and the frequency of its use compared to the others

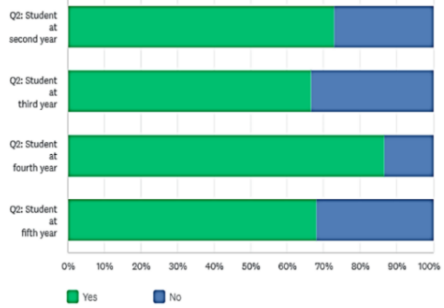
	Less than 5	**More than 5 times**	**More than 10 times**	**More than 20 times**
handmade	12%	88%	50%	19%
Laser-cut	48%	52%	22%	7%
3D Printing	93%	6%	3%	2%

The authors found that there are several reasons for the infrequent use of 3D printing. The main obstacle is the high cost of this method and the lack of local service providers near the students. Students reported that they lack the experience required to prepare and operate a 3D printing device (Q18). See Figure 5(a).

Nearly 73% of respondents indicated that their limited knowledge of model-making hindered their ability to physically articulate their design ideas (Q20). The research further examines this issue across different academic levels, revealing that 66% to 73% of second, third, and fifth-year students reported similar challenges in expressing their designs due to a lack of model-making skills. Notably, 87% of fourth-year students identified this as a significant obstacle, the highest percentage within the department. See Figure 5(b).



(a)

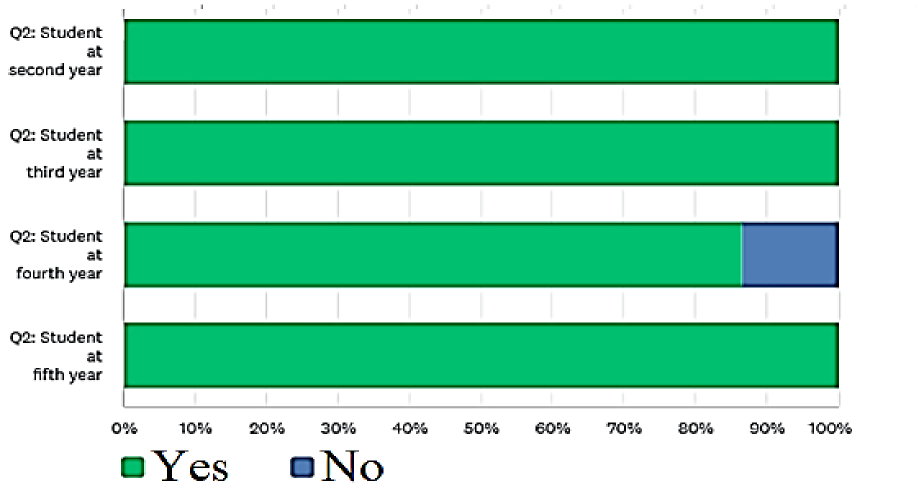


	YES	NO	TOTAL
Q2: Student at second year	73.08% 19	26.92% 7	36.11% 26
Q2: Student at third year	66.67% 4	33.33% 2	8.33% 6
Q2: Student at fourth year	86.67% 13	13.33% 2	20.83% 15
Q2: Student at fifth year	68.00% 17	32.00% 8	34.72% 25
Total Respondents	53	19	72

(b)

Figure 5. (a) Shows the population response to the main reasons for the infrequent use of 3D Printing (b) Shows the students' responses, categorized by their academic levels, stating that their lack of knowledge effects on express their design idea.

Almost 97% of the students stated that they need a dedicated course in their current curriculum to teach model-making methods and to allow more practice (Q21). The research further examines this issue across different academic levels, revealing that all of the second, third, and fifth-year students reported that they need extra dedicated courses to enhance their model-making skills. Notably, only 13% of the fourth-year students believe they do not need such extra courses. See Figure 6.



	YES	NO	TOTAL
Q2: Student at second year	100.00% 26	0.00% 0	36.11% 26
Q2: Student at third year	100.00% 6	0.00% 0	8.33% 6
Q2: Student at fourth year	86.67% 13	13.33% 2	20.83% 15
Q2: Student at fifth year	100.00% 25	0.00% 0	34.72% 25
Total Respondents	70	2	72

Figure 6. Shows the students' responses, categorized by their academic levels, stating their need for an extra course to enhance their model-making knowledge.

The results of the limitation factors in terms of the used materials, which affect model making according to the sample, can be briefly summarized in Table 5 as follows:

Table 5. The results of the limitation factors in terms of the used materials, which affect model making

Aspect	Hand-Made Model-Making	Laser-cut Model-Making	3D Printing Model-Making
Hard to find	43%	33%	47%
Expensive	26%	50%	84%
Fail or break during the modelling	47%	25%	11%
Hard to work with	43%	16%	19%
Difficult to adhere, combine, and assemble	55%	23%	4%

The Table 5 shows that 3D Printing Model-Making is the most effective method in terms of the materials assembling, combining, and also the preferred one by the population as it is not easy to break during the modelling process (Q24 to Q26) It is also found to be the most expansive and the material required for it is very hard to find compared to other techniques (Q24 to Q26). Notably, the research indicates that 55% of the population stated that the hand-made model-making technique is the most difficult to adhere, combine, and assemble. It also has the most potential to fail or break during, and it is also found the hardest to work with compared to all other types of model-making (Q24 to Q26). The research finds that 41% of the participants need to learn the difference between the 3D models required to 3D print their designs and the 3D model needed for presentation purposes. This is a critical issue of software implication deficiency within both empirical and educational levels. See Figure 7(a) (Q10).

The majority of the participants preferred using specific software for architecture design model-making. These most preferred applications are Autodesk Revit Architecture, followed by Autodesk AutoCAD, and 3Ds Max. The students have shown less interest in most of the other software available currently, such as, Autodesk Dynamo, Grasshopper, Rhino and SketchUp (Q6). See Figure 7(b).

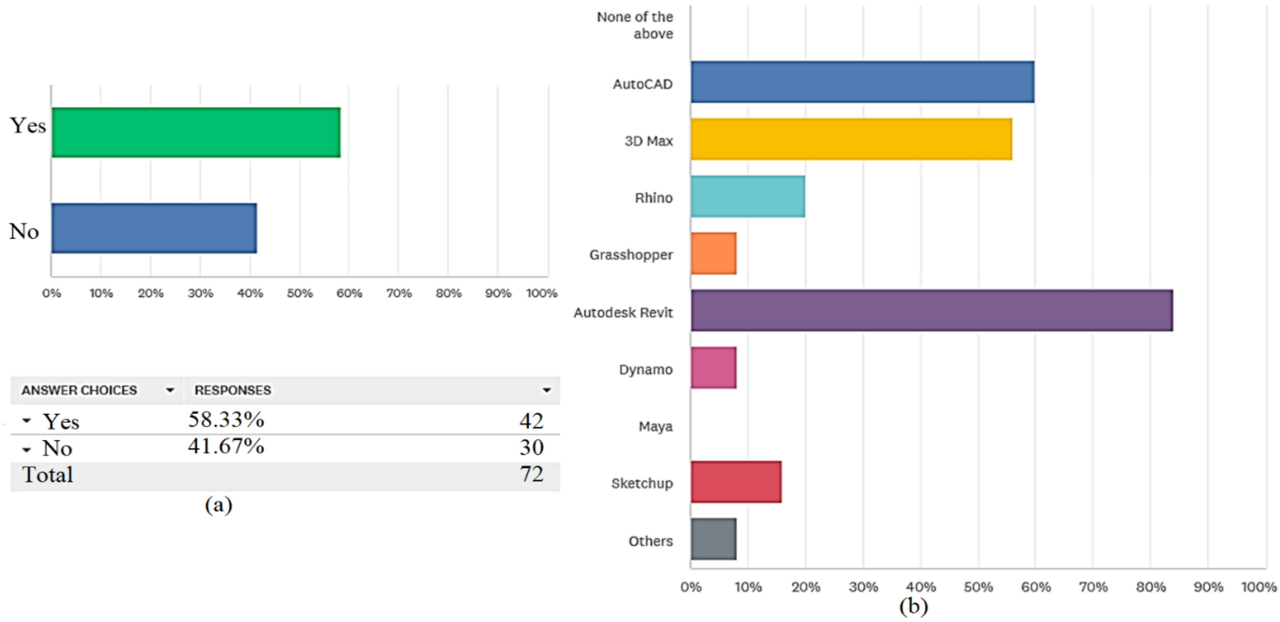
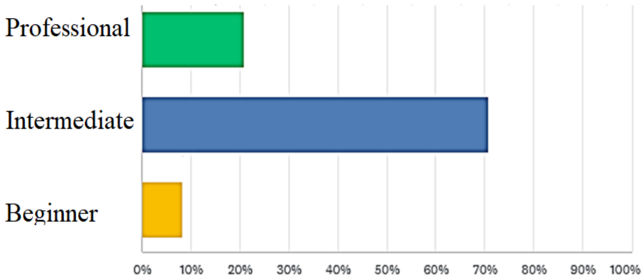


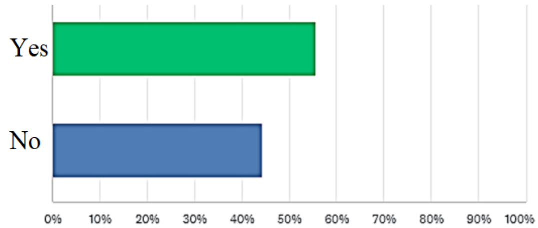
Figure 7. (a) Shows the population ratio that needs to learn the difference between the 3D models required to presentation and to print (b) Shows the population's response to the most preferred software used in model-making.

Although 20% of the students ensured their knowledge of available architectural design software, over 70% of the population acknowledged that they were still at an intermediate level when it came to applying the software knowledge in model-making. See Figure 8(a) (Q7). The research finds that 55% of the participants use different modelling-making methods through the different design phases. They prefer using the hand-made model making in the earlier conceptual design phase, since it is the cheapest and the easiest to be modified as the conceptual phase requires lots of amendments, while they prefer presenting the final projects using laser-cut or 3D Printing models since they are usually more precise and elegant (Q13). See Figure 8(b).



ANSWER CHOICES	RESPONSES	
Professional	20.83%	15
Intermediate	70.83%	51
Beginner	8.33%	6
Total		**72**

(a)



ANSWER CHOICES	RESPONSES	
Yes	55.56%	40
No	44.44%	32
Total		**72**

(b)

Figure 8. (a) Shows the population's knowledge self-assessment of using and applying software in model-making (b) Shows the population's response to whether they use different model-making methods for each design phase.

The research indicates that participants expressed that they need more time to practice Modelling-Making Knowledge, especially 3D Printing, and more supervision on applying their design idea to the model-making technique they chose (Q27). The research results are aligned with the previous similar research, which were discussed in the literature review; they agreed on the importance of the model making in the architectural educational process, and also on the lack of students' experience in 3D model making related software. However, this research has a wider sample range than the one that has been discussed in the literature review; the survey sample of 72 students from various levels was selected to build a comprehensive understanding of different level audiences. Furthermore, it evaluated each model technique as a tool for the final presentation of the architectural projects, not only for the architectural project development process.

6.0 CONCLUSIONS

Architectural education faces a critical juncture aimed profound environmental, cultural and societal transformation, and due to that rapid juncture, addressing challenges that limit adaptive, situated design, and creative design approaches is essential.

The research findings offer valuable insights into preferences and challenges of students regarding model-making techniques in architectural studies. Laser-Cut modelling emerged as the most widely used and preferred method, chosen by over half of the participants due to its efficiency, speed, and cost-effectiveness. It was especially popular among third and fourth-year students, while 3D Printing was least favoured, primarily due to its complexity and higher cost. Handmade models, while frequently used, ranked low in preference for final product quality but were valued for their affordability and ease during early design phases.

Interestingly, while 3D Printing gained some traction for achieving high-quality final models, particularly among fifth-year students, it remained less favoured overall due to the participants' limited knowledge and experience with the technique. Most students lacked the necessary skills to operate 3D printers, and this gap was especially prominent among fourth-year students. Despite this, students recognized 3D Printing's advantages in terms of material durability and assembly ease, though the method was considered expensive and materials difficult to source.

Handmade modelling, though cheap and frequently used in conceptual phases, was perceived as difficult to assemble and prone to failure, with a significant portion of participants reporting that it hindered their creativity. Furthermore, most students acknowledged their limited knowledge of model-making techniques, which affected their ability to effectively communicate design ideas. Over 97% of students expressed a need for dedicated courses to improve their skills in model-making methods, particularly 3D Printing.

The research also identified software proficiency as a significant concern, with only 20% of participants reporting confidence in using architectural design software. Despite a preference for applications like Autodesk Revit and AutoCAD, students felt they were at an intermediate level in applying software knowledge to model-making.

Overall, the findings suggest a strong need for enhanced training and curriculum adjustments to equip students with the skills and knowledge necessary for mastering various model-making techniques. This includes more focused supervision, increased practice time, and specialized courses to ensure students are better prepared to use modern technologies such as 3D printing effectively.

7.0 RECOMMENDATIONS

According to the research, many points can be suggested and recommended to assist architectural students to convey their design ideas in the most effective, simple and up-to-date method. The recommendations are:

i. Applying the 3D printing model technique should be enhanced by a solid teaching background for the software used; the research advises teaching students the proper software earlier within the academic curriculum.

ii. The design instructors should recommend the most suitable model-making method to students since it varies according to the project design, shape, nature, and each student's ability. The instructors should also supervise students’ progress and provide the technical help required to ensure that model-making learning and implementation are correctly developing and achieve both technical and design representation goals.

iii. The research recommends having a specific course related to model-making different methods and techniques in the early stage of the architecture study plan, to build a comprehensive background about each model making method and its requirement and limitations, this will lead students to select carefully the most effective and suitable method during their study years.

iv. Even though 3D Printing Model-Making is the most up-to-date method, it is not a one-size-fits-all method for all architectural projects. Many factors should be considered in selecting the proper model-making method for each project case. Therefore, the design instructor should advise students, especially in the early academic years, regarding the feasibility of using 3D Printers.

v. The architectural school should be provided with 3D printers and well-trained supervisors who can assist the students in the process of making their 3D printed projects.

vi. The research recommends adding a compulsory workshop every year where the students will be provided with a fully detailed 3D Model used in a previous presentation. They will be guided through a step-by-step hands-on tutorial to ensure their ability to amend the presentation models, simplify them, and remove any unnecessary parts to facilitate an elaborate and accurate 3D printing job. This initiative will reduce the lack of knowledge in differentiating between 3D printing and visualization models and increase students' confidence to apply their academic knowledge in a practical environment.

vii. The research recommends that teaching assistants within the architecture design courses dedicate some time to ensuring the correct selection of the model-making techniques for each student and provide the required extra time and supervision for the students to practice their model-making knowledge on their design projects to ensure a one-to-one empirical educational process on their own real-life projects.

viii. The process of each model-making method is a key factor for achieving the best final result, for example, clean cut and working in layers are recommended for hand-made models, using vector files for cutting and raster files for engraving is recommended for the lase-cut method, while Ensuring models are manifold with no holes and properly oriented is recommended for the 3D- Printing models.

ix. Students should be guided toward the best software that fits the selected model-making technique. This should be an integrated process between design studios and digital courses.

x. The research results can be considered during the process of re-designing the architectural curriculum since they provide clear evidence of the importance of integrating courses that enhance the students' abilities to apply 3D printing efficiently.

xi. Knowledge of 3D printing is a must not only within architecture education but also afterward in architecture practice. 3D printing is important not only for final product presentation and advertisement but also for reducing manufacturing risks. Product designers can test product prototypes using 3D printing technology before making potentially disastrous large manufacturing investments.

xii. The research recommends that the best model results can be achieved via both proper model implementation and proper method selection. Each one of them has its success factor; see Figure 9 for more details.

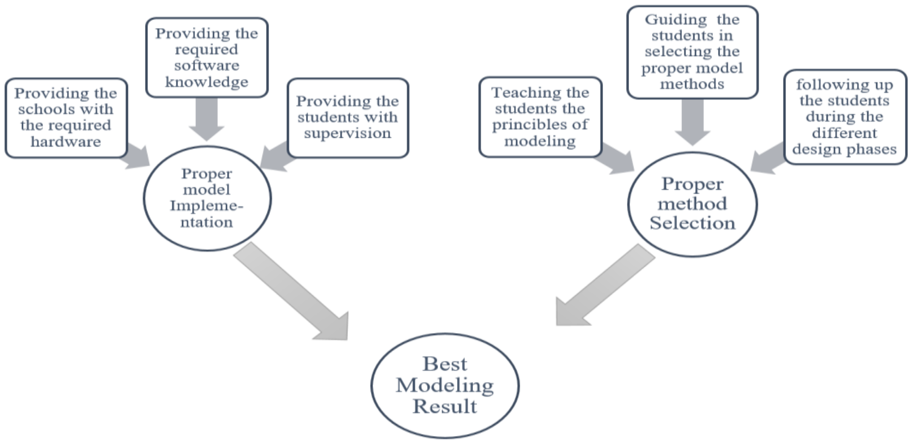


Figure 9. Recommendation map for achieving the best modelling result (Authors)

ACKNOWLEDGEMENT

The authors have no conflict of interest.

8.0 REFERENCES

Afify, H. M. N., Alhefnawi, M. A., Istanbouli, M. J., Alsayed, A. H., & Elmoghazy, Z. A. A. E (2021). An Evaluation of Physical Model-Making as a Teaching Method in the Architectural Design Studio–A Case Study at Imam Abdulrahman Bin Faisal University. Ain Shams Engineering Journal, 12(1), 1123-1132.

Baker, M.J (1991). Data collection — questionnaire design. In: Research for Marketing. Palgrave, London. https://doi.org/10.1007/978-1-349-21230-9_7

Bermudez, J., & King, K (2000). "Media interaction and design process: Establishing a knowledge base" - This paper discusses how tactile engagement with materials enhances spatial thinking and problem-solving in architectural design.

Cannaerts, C (2009). Models of/models for architecture. In eCAADe (Vol. 27, pp. 781-786).

Delikanlı, B (2020). The role of digital model-making for design education. Architectural Models as Learning Tools, 14-21.

De Vaus, D., & De Vaus, D (2013). Surveys in social research. In Routledge eBooks. https://doi.org/10.4324/9780203519196

Dunn, N (2014). Architectural Modelmaking Second Edition. Hachette UK.

Etikan, I., & Bala, K (2017). Sampling and Sampling Methods. Biometrics & Biostatistics International Journal, 5(6), 00149.

Friedman, L. W., Friedman, H. H., & Pollack, S. *The role of modelling in scientific disciplines: a taxonomy. Rev. Bus. 29 (1), 61–67 (2008)*.

Griffin, C., & Carter, D (2015). "Exploring the Benefits of Traditional and Digital Model-Making in Architectural Design".

Grover, R., & Vriens, M (Eds.) (2006). The handbook of marketing research: uses, misuses, and future advances. Sage.

Gursoy, B., & Ozkar, M (2010). Is Model-Making Sketching in Design?

Hmoud, S. M., & Ibrahim, N. M (2018). The Effect of Modelling Forming the Architectural Products (The Products of Architects Student in Iraq as Case Study).

Schmitt Olabisi, L., Blythe, S., Ligmann-Zielinska, A., & Marquart-Pyatt, S. (2014). Modelling as a tool for cross-disciplinary communication in solving environmental problems. *Enhancing communication & collaboration in interdisciplinary research*, 271-290.

Sharif, R., Maarof, S., & Rahim, A (2014). Model Making as a Cognitive Tool for the Beginners. *Stedex, 6*, 117-122.

SurveyMonkey (2025, March 25). 3 survey bias types to avoid (and why). SurveyMonkey. https://www.surveymonkey.com/learn/survey-best-practices/how-to-avoid-common-types-survey-bias/

Surwade, R., Khas, K. S., & Bangre, A. Model-Making and Its Practices Improve Design Process for Beginners Students of Architecture & Product Design. *Journal for Re Attach Therapy and Developmental Diversities, 6*(1), 1312-1319. https://doi.org/10.53555/jrtdd.v6i1.2602

Surwade, R., Khas, K. S., Raghani, S., & Kamal, M. A. (2023). Model making as a creative skill and tool for teaching-learning process in architecture and product design. *Civil Engineering and Architecture*, *11*(6), 3278-3284.

Szuta, A., & Taraszkiewicz, A (2020). The role of traditional architectural models in the first stages of education. *World Transactions on Engineering and Technology Education, 18*, 177-182.

The world's most popular free online survey tool (2024) SurveyMonkey. Available at: https://www.surveymonkey.com/ (Accessed: 23 August 2024).

Zalloom, B. (2024). From Concept to Reality: How 3D Printing Transforms Architectural Model-Making. *The Eurasia Proceedings of Science Technology Engineering and Mathematics*, *32*, 568-574.

Ziegel, E. R., & Lohr, S. L (2000). Sampling: Design and analysis. *Technometrics,* 42(2), 223. https://doi.org/10.2307/1271491