Civil Engineering and Architecture 11(4): 2231-2239, 2023
DOI: 10.13189/cea.2023.110440 http://www.hrpub.org

Exploring the Potential of Model Making as a Tool for Designing Sustainable Buildings

Rupesh Surwade[1], Kanwaljit Singh Khas[1], Smruti Raghani[2], Mohammad Arif Kamal[3,*]

[1]Lovely School of Architecture and Design, Lovely Professional University, India
[2]Symbiosis Institute of Design, Symbiosis International University, India
[3]Architecture Section, Aligarh Muslim University, India

Received February 7, 2023; Revised March 25, 2023; Accepted April 16, 2023

Cite This Paper in the Following Citation Styles

(a): *[1] Rupesh Surwade, Kanwaljit Singh Khas, Smruti Raghani, Mohammad Arif Kamal , "Exploring the Potential of Model Making as a Tool for Designing Sustainable Buildings," Civil Engineering and Architecture, Vol. 11, No. 4, pp. 2231 - 2239, 2023. DOI: 10.13189/cea.2023.110440.*

(b): *Rupesh Surwade, Kanwaljit Singh Khas, Smruti Raghani, Mohammad Arif Kamal (2023). Exploring the Potential of Model Making as a Tool for Designing Sustainable Buildings. Civil Engineering and Architecture, 11(4), 2231 - 2239. DOI: 10.13189/cea.2023.110440.*

Abstract Model-making plays an important role in architectural design projects. Models can depict how a building fits into its surroundings without revealing every detail, or they might highlight a particular feature of the structure. Model making is important to better understand how the architectural design adopts the energy efficiency of a structure. Active learning through the Modelmaking method has been useful to learners in developing their conceptual design using three modes: a) Observations b) By doing c) Problem-solving. When the beginners start their project, it has been observed that they are unable to understand the three-dimensional form and find it difficult to study climate-responsive architecture / sustainable building design. Physical model making is an extremely versatile tool for the design process, conducting research, and introducing three-dimensional designs. It may assist the process used to explore different forms in Architectural design. It also refers to an educational strategy that uses engaging learning processes tailored to the learners' requirements and interests. Model making is a vast domain, and there are many aspects about how to be understood in relation to its use, presentation, experimentation, testing (prototype), etc. The research underlines how the assumptions and accessibility of a technology education design process may give learners many opportunities to learn about models and modeling.

Keywords Model Making, Design Tool, Sustainability, Climate, Building Design

1. Introduction

Model-making is a fine-looking and skillful technique, and architectural model-making is a very important part of the building design process [1]. Models are made by novice students/designers to the understand shape, size, and articulation of form [2]. Model making is a significant learning tool to improve the basic design skills of a new learner, which can lead to their visualization and creativity development. Beginners in their 1st attempt were not able to understand three-dimensional forms, the selection of material, and model making process [3]. Novice designers (students) have difficulty with the study of climate-responsive architecture / sustainable building design [4]. The architectural model is often the first time that a building is visualized in three-dimensional forms and the climate parameters that influence the building fabric are solar radiation, temperature, relative humidity, wind, and precipitation [5,6]. Fabric membranes can affect the condition in the given circumstance as a result of internal surface temperature and the amount of thermal radiation directed into the spaces. Through the physical model making, the learners have understood the sustainable building design. Several studies were explored below.

1.1. Model Studies

Koenigsberger has observed that the models are really

essential for beginners and contribute to observation, imagination, and ingenuity [4,7]. A few devices have been created to simulate solar geometry and permit the investigation of concealing utilizing building models. The inference of these devices as design tools is fairly dubious, however, they are absolutely valuable as learning tools, or for checking the presentation of gadgets designed, or for the reasons for the show, conceivably by photographs of the model with shadows cast on various dates and times. Such photographs are very helpful in some dubious building license applications, for introduction to customers.

i) Drawings, two - dimensional (2D) portrayals of three-dimensional items (3D)
ii) For a precise explanation, physical models, and reduced size ages of objects, may be delegated:

The perspective on using, such a model falls into two general classes:

a) First is design tools which are built devices that do not need any assumptions or hypotheses, but instead display the thing or strategy by evaluation using the model, such as the forward assessment system update process.
b) Checking tools for situations where it's essential to make assumptions about future changes – for example, 'backward analysis. The stereographic sun-path diagrams (solar charts) and related protectors and overlays provide a detailed and easy-to-use range of design aids for the prediction of isolation and shading. These can be thought of as 'models' that fix the sun-building relationship in a realistic structure. They can be used as testing tools for planned conformity, but they are mostly designed as design tools. Various systems have been constructed to mimic the relationship between the sun and the building and to facilitate model isolation and concealment. In the context of a complicated structure, where just a few key points have really been decided analytically (determining all information with all possible outcomes will be too time-consuming), it is necessary to analyze the actions of the entire complex as well as the proposed details. As an instructional medium or to aid in visualizing the sun-building connection, it needs reduced description rather than graphic approaches.

2. Significance of Model Making in Architectural Design Pedagogy

For novice designers, the presentation of new ideas is critical in any construction field, but it is especially important in design, where we sometimes see the final product, i.e., the architecture before the designing process is finished [6,8] The preliminary idea was developed from side to side that enables the students to examine, revise, and review process thoughts in increasing features awaiting such a spot that the project's design is suitably consolidated to be constructed [7]. Models are created by students as a means of testing and improving designs in 3D forms. Models have a number of benefits, including their permanence, which allows them to communicate concepts about textures, form, texture, patterns, size, and color in a quick and simple manner.[7,11] The size required at various stages of construction creation determines the volume of either a concept to a certain extent, given those models can demonstrate a design development in relative to a city framework, or a landscape, since a remodeling otherwise adds together to an accessible building, or is capable of even being constructed as full-scale versions, normally referred to as 'prototypes'. All over history, individual forms of models have also been widely used to address perceptual knowledge deficits [8,13]. This is for the reason that models know how to be very stimulating in an immediate entry to every part of a model, and to complete as well as on the whole views. A model's flaws need to be addressed. Model making and prototyping are among the most well-known approved methods designers use to convey and visualize their design ideas [9,18].

2.1. Types of Architecture Models

a) Physical models: Physical model making gives tremendous understanding to novice students rather than trying to visualize the three-dimensional image, and the model allows one to view it [3,10]. This mostly encourages the transmitter - including a beginner or an engineer - to refine and update the concept in the future, but it also helps the listener - such as the teacher, the customer, or the general public - to communicate more effectively. This short introduction seeks to demonstrate the significance of models not only as aids in the decision-making process but also as a means of generating, searching, and investigating creative impulses. The models depict the internal design, materials, colours, decor, and aesthetics of a building. The models of landscape design are representations of elements including pavement, sidewalks, walls, balconies, and trees in landscape architecture and extension. Models of urban design are generally designed on a far smaller scale (beginning at 1:500 yet fewer, 1:7000, 1:800, 1:1200, 1:1500, 1:20 000), as well as reflect many city blocks, a huge resort, building, manufacturing facility, airfield, and so forth. For town/city planning and growth, urban models are essential [1,10].
b) Compute Aided Design (CAD) or Virtual Modeling: Initially understanding the Computer Aided Design model making through climate response architecture was found to be quite difficult for novice students, these observations were found in the first-year studio. It is observed that CAD model making for senior students is increasingly used in architectural design. Digital modeling is used to include the placement of imaginary lines as well as points in the virtual world,

mostly for the purpose of producing scientific drawings [10,12,18].

2.2 Research Gap

It was discovered that the novice students do not understand how architectural design incorporates the structural design, climatic design and energy efficiency into their design projects. After completing the technical drawings, the first-year students are unsure of the design idea and building form of their design projects. They are often unable to evaluate and develop the design in 3D form in terms of building orientation, daylighting solar radiation, and other climatic conditions. The study of physical model with reference to climatic design has not been carried out earlier.

3. Research Methods: Active Learning through Model Making (ALTM)

In this method (ALTM) we developed the active learning approach as shown below in Figure 1.

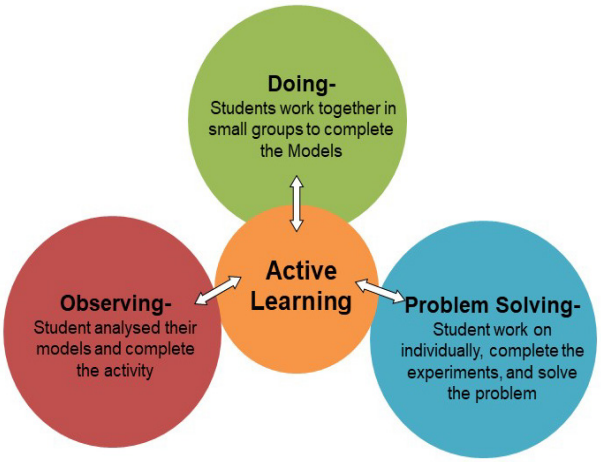

Figure 1. Active Learning through Model Making (ALTM)

ALTM- helps learners to develop their design project using three approaches – a) Observations, b) By doing and c) Problem-solving. ALTM is an educational technique that uses engaging learning processes that are adapted to the student's needs and interests. Models are used as a means of concept communication to compensate for certain flaws. Models are very adaptable methods for use in the design process, investigation, and creating and introducing designs in three dimensions and students are supposed to be able to articulate themselves creatively with ease [13-15]. Architectural education, as one of the most distinctive branches of education, requires creative capabilities [19,20]. With the exploration of form in design through physical model making, students' critical thinking ability has been developed as shown in Figure 2.

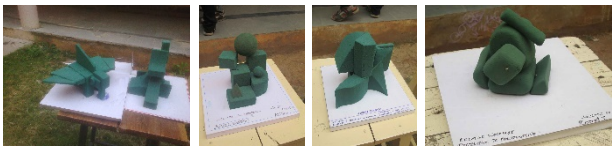

Figure 2. From Exploration through Model Making.

3.1. Solar Radiation

Beginners developed their physical models for the study of solar radiation. The reflective energy obtained from the sun is known as solar radiation. The student studied that the energy source processes can be carried out by observing the action of an architectural model under natural light with suitable cardinal alignments (Figure 3).

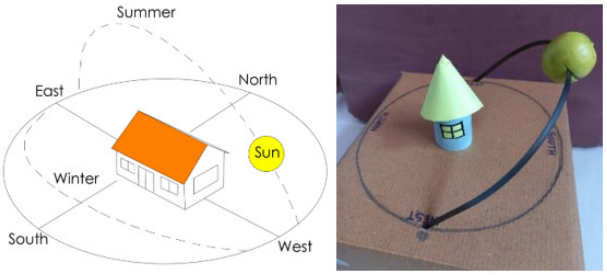

Figure 3. Solar Radiation Study through Model Making

The amount of radiant energy on the ground varies based on its geographical region season, a time during the day, and weather patterns are all factors to consider.

3.2. Study of Passive Solar Design Methods and Techniques

Thermodynamics of that same house, direct-gain, inverse, ventilation, daylighting, solar radiation, thermal containment walls, insulation, including windows strategies of applying energy efficient methods will be included in the Passive Solar Building Techniques course [16,17]. For the purposes of this analysis, the houses are presumed to be in the temperate zone, with the majority of solar radiation south and east.

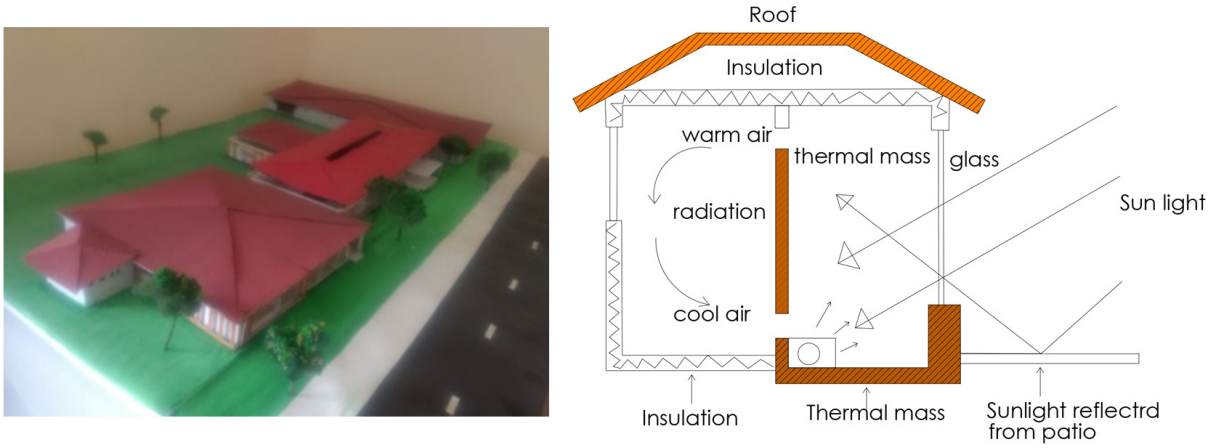

Figure 4. Passive solar Building Techniques.

The learners studied the passive solar building techniques through model making for their better understanding of climate-responsive building in the studio (Figure 4).

3.3. Study of Climatology through Model Making

3.3.1. Heliodon

The study of climate-responsive architecture / green building design is proving it challenging for novice designers (students). Students did the study that has quite a model table that tilts and rotates (for latitude as well as hour changes, to between them), as well as a lamp that slides upwards on such a longitudinal rail at a length. The advantages of simplicity and table model should be fixed so that it cannot be tilted to picture the sun's and buildings' relative sizes (Figure 5).

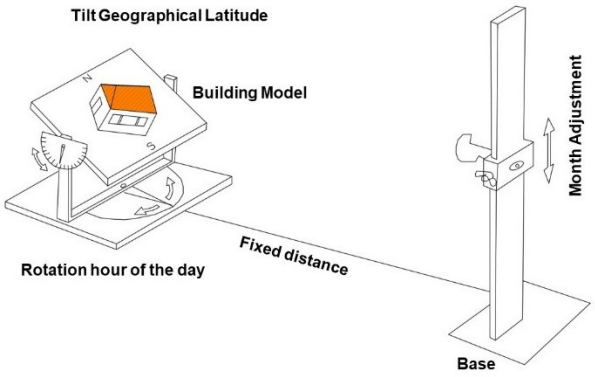

Figure 5. Heliodon shows the Demonstration through Students' Design Models in Climatology Lab.

3.3.2. Solarscope 'A'

A flat table and then a light (or mirror) fixed there at down after a long arm with three-way rotation make up the Solarscope 'A'. Advantages: The table stays flat, big versions can be accommodated and parts can also be left loose of minimal modification (Figure 6).

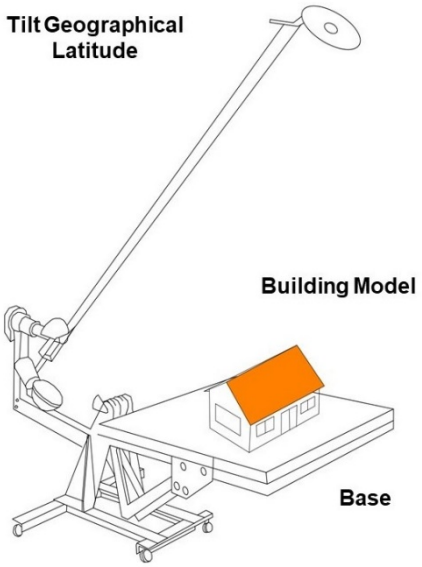

Figure 6. The Solarscope'A'

The Solarscope 'B': It has four- circular wide radius rail that shows the sun's direction, as well as a slanting (latitude) and longitudinal (time of year) rotation under which light moves to show the hours of the day. The advantage of Solarscope B is that, as previously said, the entire sun path is still indicated by the train, making it easy to recognize (Figure 7).

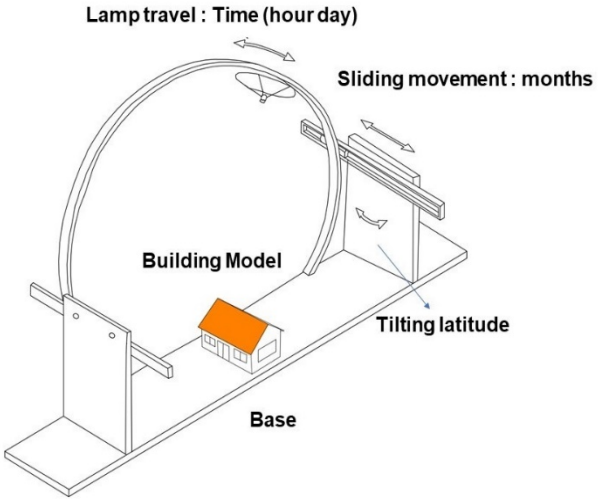

Figure 7. Arrangement Diagram Solar Scope B.

A graphical model from a whole community of structures can be evaluated in many of these devices to predict the time and scale of shading of an open environment by buildings including buildings that shade each other. For testing the output of a shading system, a larger-size mock-up of such a unified platform with a portion of the area it corresponds to is optimal. It is sometimes used as a constructive modeling tool for loose parts to decide the best shape and location for a system. In hot dry regions, methodology of building construction is becoming uniform. Traditional housing methods are seldom suited in urban areas since the constructions have to be very less in maintenance, and durable methods and materials are valued in urban areas [12, 14]. Traditional building forms in that particular area may include sound solutions to climatic problems [13]. Designing a residence is a complex process involving many designs and decision makes criteria

3.4. Climatic Factors

The students as a beginner (First year) have provided the exterior treatment to the building in terms of temperature with the aid of models and studies. Central Building Research Institute has developed an effective method for making thatch roofs fire-resistant and water-repellent [20].

The following factors are explained in detail on further pages which are very important to study the climatic problems from the model by students' design projects.

1. Roof Form
2. Orientation
3. Aligning of buildings.
4. Fenestration
5. Openings

3.4.1. Roof Form

The roof form can increase or decrease the scope of natural ventilation (Figure 8 and Figure 9).

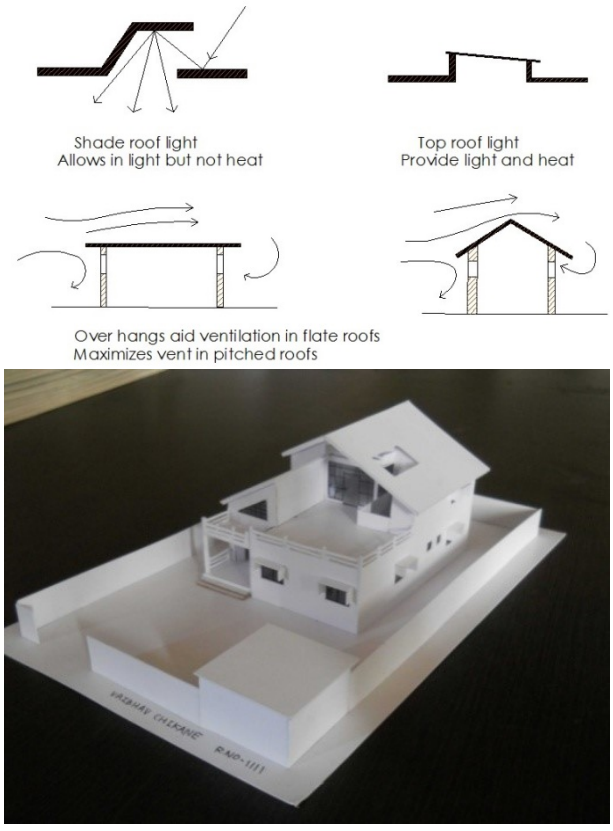

Figure 8. Different types of roof form s and a study model done by students.

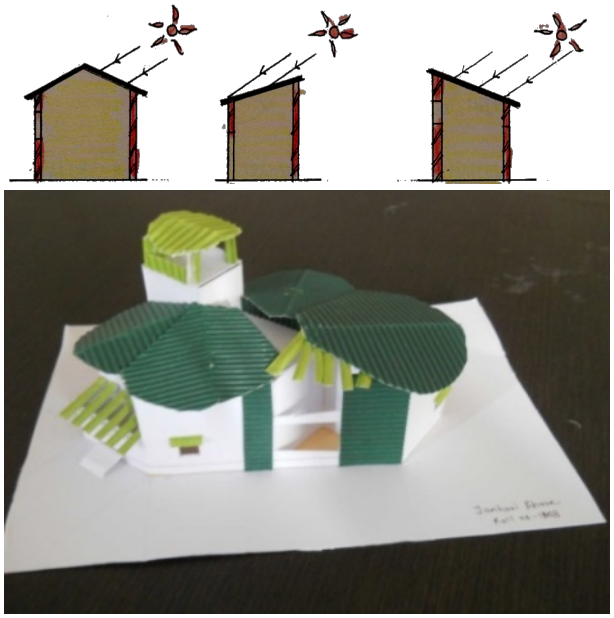

Figure 9. Study Model done by students showing inclined roof forms

3.4.2. Orientation

Building orientation and form pattern are studied by the student with the help of Model Making in their design studio. The amount of surface area exposed to the sun needs to be as low as possible [22]. Since these elevations reduce the total solar heat through solar radiation, sites with broad measurements can face southern and northern (Figure 10).

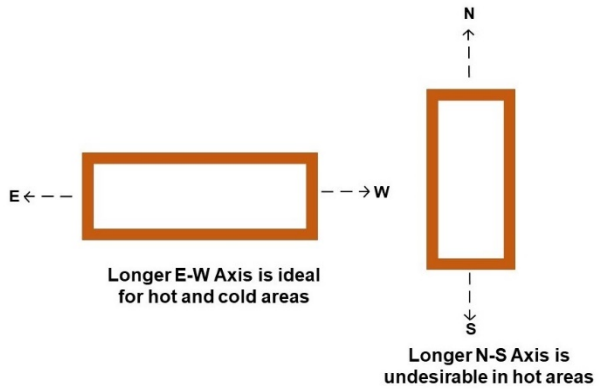

Figure 10. The orientation of the building.

3.4.3. Aligning of Buildings

Mutual shading reduces heat gain on exterior walls by aligning buildings close to one another and, particularly if eastern and western walls are held near each other [22].

3.4.4. Fenestration

Any light-transmitting gap in a structure, wall, or roof is referred to as fenestration. The aim of fenestration is to:

1. Visual communication
2. Admittance of solar radiation to provide heat and light in winter
3. Admittance of outdoor air and breeze.

Pattern and configuration involve the area, shape, location and relative position of window. This would affect the air movement, daylight, glare indoors (Figure 11).

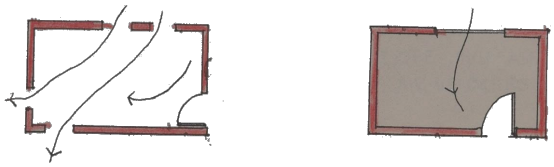

Figure 11. The two different opening spaces.

3.4.5. Openings

Learners explore the opening's orientation in the different building forms with the help of physical model making as shown in Figure 12.

Two considerations influence the opening's orientation:

1) Towards the predominant wind during the hot season to take advantage of the cooling influence.
2) Toward this sun in the winter to take advantage of the temperature increase of the sun's rays touching the windows.

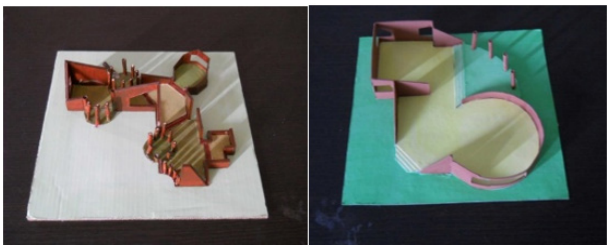

Figure 12. Models of two different opening spaces.

4. The Participants Feedback

A model-making survey was conducted in the design studio and it is pragmatic. The following points are shown below in Table 1.

Table 1. Results of model-making survey in the design studio

S. No.	Survey Questions	Rating of Participants (Total no of Participants = 80) Note: Rating is 1 to 10 numbers.									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	Rate the Model making in the Design Project	1	1	2	2	3	3	14	19	20	15
2	How much you enjoyed the Model Making work in the design development process?	1	0	1	1	6	4	10	16	21	19
3	What is your level of satisfaction with developing the Physical model for the Design Project?	1	1	2	5	11	6	13	12	13	16
4	As per the answer to the above question no.4, why do you most like this Model Making type?	1) 70% towards Physical Model making because of easy to understand Form/shape and hands-on experiences 2) 30% towards CAD Model making because of time-consuming less physical efforts.									
5	How much you were pleased with the time for discussion during class?	3	1	0	1	7	18	11	15	12	12
6	Are you get confused to select the material and process for the model making of the Design Project	Yes = 51.2 % No = 20 % Maybe = 28.7 %									
7	How would you rate the Physical Model Making of this Design Project	1	1	5	4	6	4	11	19	16	13
8	How would you rate the CAD Model Making of this Design Project?	0	0	4	4	3	4	13	17	19	16
9	Which Model Making type you would like to adopt in your future Design Assignments?	Physical Model making				CAD Model making					
	Participants Rating in Percentage =	76%				24%					
10	As a beginner, which Model Making type do you most like in your Design Project	Physical Model making				CAD Model making					
	Student Rating in Percentage:	63.7%				36.3%					

5. Results and Discussion

The observations in Table 1 have been summarized as below:

1. According to the study, there is a direct link between learners' development toward model-making, particularly during the concept generation stage, and their ability to achieve the desired learning outcomes in design projects.
2. From the preliminary design way to the end of the second presentation, the physical models must proceed to be used in the creative process.
3. 70% of learners throughout favor create physical models due to simple Form/Shape and practical experiences.
4. The participants stated that creating physical model making and learning through experience gave them new ideas and helped them come up with unconventional solutions to design issues that participants intended to solve.
5. Most of the participants specified that physical Model Making will be adopted in their future Design Assignments/projects.
6. As per ANOVA, a statistical Analysis in Social Science (SPSS) software, it was found that the physical models are likely to be more effective than Computer Aided Design (CAD) models. The summary of the results between physical model making and CAD model making has been mentioned in Table 2 and the variances between different groups have been summarized in Table 3.

Table 2. Summary of ANOVA single factor (one-way)

Groups	Count	Sum	Average	Variance
Physical Model Making (Column 1)	80	51	0.6375	0.234018987
CAD Model Making Column 2	80	33	0.4125	0.245411392

Table 3. Variation in different groups using ANOVA single factor (one-way)

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2.025	1	2.025	8.447524752	0.004180848	3.900988556
Within Groups	37.875	158	0.23971519	-	-	-
Total	39.9	159	-	-	-	-

(Column-1 represents the Physical model making and Column 2 represents the CAD model making) The P-value of 0.0041 indicates that there is a strong evidence to reject the null hypothesis. It means there was a statistically significant difference between the two types of models and that the physical models are likely to be more effective than the CAD models.

6. Conclusions

The Model making in the architectural curriculum, if taken and taught seriously to the architecture students may help the students and clients better understand the architectural design, climatic design and sustainability of the buildings. Faculty members who want to encourage students to use advanced critical thinking skills might benefit from adopting Bloom's taxonomy [21]. There is also a lot of scope for technological companies to create technologies that enable people to test passive and active structures in environmentally sustainable buildings. Often consider how effective the building is in terms of natural daylight and ventilation, as well as the impact of solar panels and a green roof upon the architectural composition of something like the façade. Even today novice students can strengthen their basic design knowledge by using the old famous climatic: instrument in the practice order through physical model making. The term model is utilized here from a nonexclusive perspective, which means the portrayal of one framework by another, which is comparable to with it structure of the given perspective. For beginner students, the physical model is a valuable artifact for the interaction of all design types, and for senior students, CAD modeling is very beneficial to their design projects. The physical modeling tools have evolved into a separate discipline as well as an art practice with its own materials, instruments, and techniques.

REFERENCES

[1] M. Driscoll. Model Making for Architects, Crowood, 2013.

[2] D. Griffiths. The use of models in learning design and learning analytics, Interaction Design and Architecture Journal (IxD and A Journal), 2017, 33, p.113- 133.

[3] S. Das and A. K. Das. Tool for Teaching Physical Model Making in Product Design, Materials Science and Engineering, in IOP Conference Series, 2019.

[4] O. Koenigsberger, J. S. Millar and J. Costopolous. Window and Ventilator Openings in Warm and Humid Climates, Architectural Science Review, 1959, 2(2), p. 82-96.

[5] V. Baweja,. A Pre-history of Green Architecture: Otto Koenigsberger and Tropical Architecture, from Princely Mysore to Post-colonial London (Doctoral Dissertation)," The University of Michigan, 2008.

[6] N. Dunn. Architectural Model making, Second Edition, Hachette, UK., 2014.

[7] C. B. Mills. Designing with models: a studio guide to architectural process models. John Wiley and Sons, 2011.

[8] A. Schilling. Architecture and Model building: Concepts, Methods, Materials. Birkhäuser., 2018.

[9] T. Kelley. Prototyping is the shorthand of innovation. Design Management Journal (Former Series), 2001, 12(3), p. 35-42.

[10] C. Cannaerts. Models of/models for architecture: Physical and digital modelling in early design stages, 2009.

[11] H. M. N. Afify, M. A. Alhefnawi, M. J. Istanbouli, A. H. Alsayed, and Z Elmoghazy. 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, 2021, 12(1), p. 1123-1132.

[12] A Kirimtat, B. K. Koyunbaba, I. Chatzikonstantinou and S. Sariyildiz. Review of simulation modelling for shading devices in buildings." Renewable and Sustainable Energy Reviews, 2016 p. 23-49.

[13] P. Littlefair. Passive solar urban design: ensuring the penetration of solar energy into the city. Renewable and Sustainable Energy Reviews, 1998, 2(3), p. 303-326.

[14] B. A. Hallgrimsson. A Model for Every Purpose: a Study on Traditional Versus, March, 2012.

[15] D. Neat, Model-making: Materials and Methods, Crowood., 2013.

[16] K. Y. Kondratyev. General Climatology, AGU Publications, 1984.

[17] H. Lansdown. Digital Model making: Laser Cutting, 3D Printing and Reverse Engineering, The Crowood Press., 2019.

[18] A. Velásquez-Posada. Model Making Techniques as a Teaching Tool in Product Design Engineering in Crossing Design Boundaries, in Proceedings of the 3rd Engineering and Product Design Education International Conference 15-16 September 2005, Edinburgh, UK.

[19] A. Salama, New trends in architectural education: Designing the design studio, Arti-arch., 1995.

[20] P. Sambare, R. Bongirwar, S. Sinhal and M. Tiwari, Post

earthquake housing construction using low cost building materials., in Proceedings of International Conference on Advances in Architecture and Civil Engineering 2012, 21, p. 848.

[21] D. R. Krathwohl, A revision of Bloom's taxonomy: An overview, 2002. Online available from https://www.depauw.edu/files/resources/krathwohl.pdf

[22] O. H. Koenigsberger, Ingerscoll, Mayhew, Szokoyal, Manual of tropical housing and building., Orient Longman Pvt. Ltd., 1975.