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Model Making as a Creative Skill and Tool for Teaching-Learning Process in Architecture and Product Design

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Abstract In this paper, the study analyzes the necessity of model-making to comprehend and learn about architectural product design through a systematic literature review. Recent literature is identified from reputed peer-reviewed journals and a systematic appraisal is implemented. Through multitudes of instances mentioned in the reviewed literature, argumentation is carried out and summarized in the sections such as (a) design teaching-learning dimensions, (b) architectural product design, prototype, and manufacturing, and (c) investigation in the domain of design teaching-learning. Developing physical models while studying the fundamentals of architectural product design offers the opportunity to accomplish teaching-learning goals. Although the design was challenging to learn and even more challenging to teach, model-making greatly facilitates the process and offers opportunities for inducing creativity, innovation, and ability of thinking in a complex way, such as design concepts, and shared knowledge acquisition while trying to handle a design task communally learning by doing. The paper concludes with contributions of the literature appraisal on model-making as a creative tool for teaching-learning processes is explored in the context of the architecture and product design.

Keywords Model-Making, Teaching-Learning, Creative Tool, Architecture, Product Design

1. Introduction

Model making is significantly integral to architectural and product design pedagogy. Models can highlight a particularly interesting part of the building or display how the entire structure fits into the surrounding area without showcasing every detail. A segmental model can make the relationship between exterior design and interiors clearer. The scale of the model depends on the purpose for which it is made. Models are also made for the understanding of shape, size, and articulation of form.

With the advancement in information technology and development in gadgets along with software in the production of design, physical model making from the architectural and product design pedagogy is put aside increasingly gaining a secondary position. With the help of virtual models (3D CAD modeling), numerous options and experiments are possible, whereas there are few limitations through a physical model. However, physical model-making skill enhances the creative ability of novice students. And, it is a must in the initial phase of learning. Models and Prototypes stimulate innovative and creative ideas in the early ideation and idea development process. Thus, there is a need to investigate – how physical model-

making develops critical thinking ability in beginner students and, how this skill also develops creativity in students' responses and, the importance of model-making in the teaching-learning processes of design. Physical drawings and models are being replaced by 3D CAD models, mock-ups, and fly-through inside the offices of product design professionals. Laser-cutting cutting tools and 3D printers are increasingly used to complement the physical model-making process. This "authenticity" broadens the capacity of the structure culture by the graphic image at the expense of other methods of distinction. These tools have significantly improved presentation quality, manufacturing capability, and the capacity to identify complex geometries. However, they also fundamentally influence how we create and eventually result in architecture. As architects and industrial designers, we are interested in how individuals interact with the physical world, how they perceive different environments, and how those environments influence them. Making models is the first step toward comprehending this reality. Working with materials like card, plaster, stone, wood, steel, and glass helps one comprehend the building's structural presence. It is possible to "be there" and experience the atmosphere of the rooms we are trying to design with all of their own tactile and visual complexity by investigating the subtle unfurling of spaces and the play of light.

Through the literature review, this paper demonstrates the importance of using models when considering and learning about building architecture and product design. This same designer develops the skills necessary for the relative abundance of building structural elements and presents an appropriate argument for the target audience across various steps. The literature review's contributions are made in the paper's conclusion.

Recent literature is identified from reputed peer-reviewed journals and a systematic appraisal is implemented. While identification of this literature care is taken to include both the area of architecture and product design, including their dimensions, process (such as designing, prototype making, and manufacturing), and, inquiry in the domain of design educational objectives. The critical aspect of validating such qualitative research in such a designed teaching-learning context is also reviewed and adapted methods are presented in this paper. The terms and concepts used in this literature are mapped both horizontally and vertically to get a holistic perspective.

2. A Review on Model Making and Design Teaching-Learning

A literature review on model-making and design pedagogy was implemented to explore how model-making is a tool to induce problem-solving ability in learners. Multitudes of instances are reported in the literature wherein creative skill enhancement within students is found in the design of teaching-learning investigations and experiments. The following sections summarize this literature appraisal

2.1. Design Teaching-Learning Dimensions

There is a vast academic debate on teaching and developing creative skills in learners, and evaluation frameworks on whether the teaching-learning objective is fulfilled. Krathwohl [1] noted how to measure the educational objective by referring to Bloom's Taxonomy, Krathwohl [1] suggested overall framework of this is categorized into (a) Knowledge (b) Comprehension (c) Application (d) Analysis (e) Synthesis, and (f) Evaluation. Further, a detailed structure of the Taxonomy, cognitive processes, and dimensions are elaborated with a revision of the original taxonomy. The maximum level of learning inside the revised version has changed from evaluating to creating, with the former being the highest form of learning.

For example, the new Bloom's taxonomy spoke of the far more active Remember while the old one spoke of Knowledge. For ease of comparison, it is useful to look at the whole list of the six levels in Figure 1. Teachers who wish to inspire students to employ advanced critical thinking techniques might benefit from using Bloom's taxonomy. Former Bloom scholar Anderson modified and changed the taxonomy to make it more applicable to 21st-century century practices including learners and educators [1]. In three major areas nomenclature, organization, and focus, Anderson modified the taxonomy. Bloom's divisions were originally nouns, but Anderson changed them to verbs. Anderson changed the name of the understanding by employing the concepts of the taxonomy to direct their preparation, educators may focus on the goals of both organizations and individuals and make arrangements for their growth in the short, intermediate, and long periods.

While summarizing the knowledge dimension, a tabular matrix is proposed with components as shown in Table 1: (A) Factual Knowledge (B) Conceptual knowledge (C) Procedural Knowledge, and (D) Meta-cognitive Knowledge. In essence, taxonomy offers an organizational framework that gives teaching-learning objectives a generally accepted meaning. Bowers [2] presented research on the logic of annotated portfolios and elaborated on relevance in design thinking and practice.

The author proposed that the generative-inspirational design may take place through various descriptive intentions which may or may not be the theory behind it. Critical thinking in design education also develops to a great extent when a design task is handled collectively. Shared learning happens when worked together. Brandt et al. [3] presented their research on co-design. They reported that participants become knowledgeable in what they collaboratively worked on in the experiment. Accordingly, 'co-design' and 'making by doing' was integral to knowledge production. Design teaching-learning also

becomes possible when a task is experimented with by making a model. Koenigsberger's [4] 'Manual of Tropical Housing and Building' elaborates on the importance of model making and its use in the investigation of response to the climate. In the last section of this book, the author noted ways models can be used to design various devices. With several simple to complex scheme instances, various devices are suggested to simulate the sun-building relationship and to facilitate insulation and shading studies on models.

Table 1. The updated Bloom's Taxonomy includes the Knowledge and Cognitive Process Dimensions

	Remembering	**Understanding**	**Applying**	**Analyzing**	**Evaluating**	**Creative**
Factual Knowledge	List	Summarize	Classify	Order	Rank	Compile
Conceptual Knowledge	Describe	Interpret	Experiment	Explain	Assess	Plan
Procedural Knowledge	Tabulate	Predict	Calculate	Differentiate	Conclude	Compose
Meta-Cognitive Knowledge	Appropriate use	Execute	Construct	Achieve	Action	Actualize

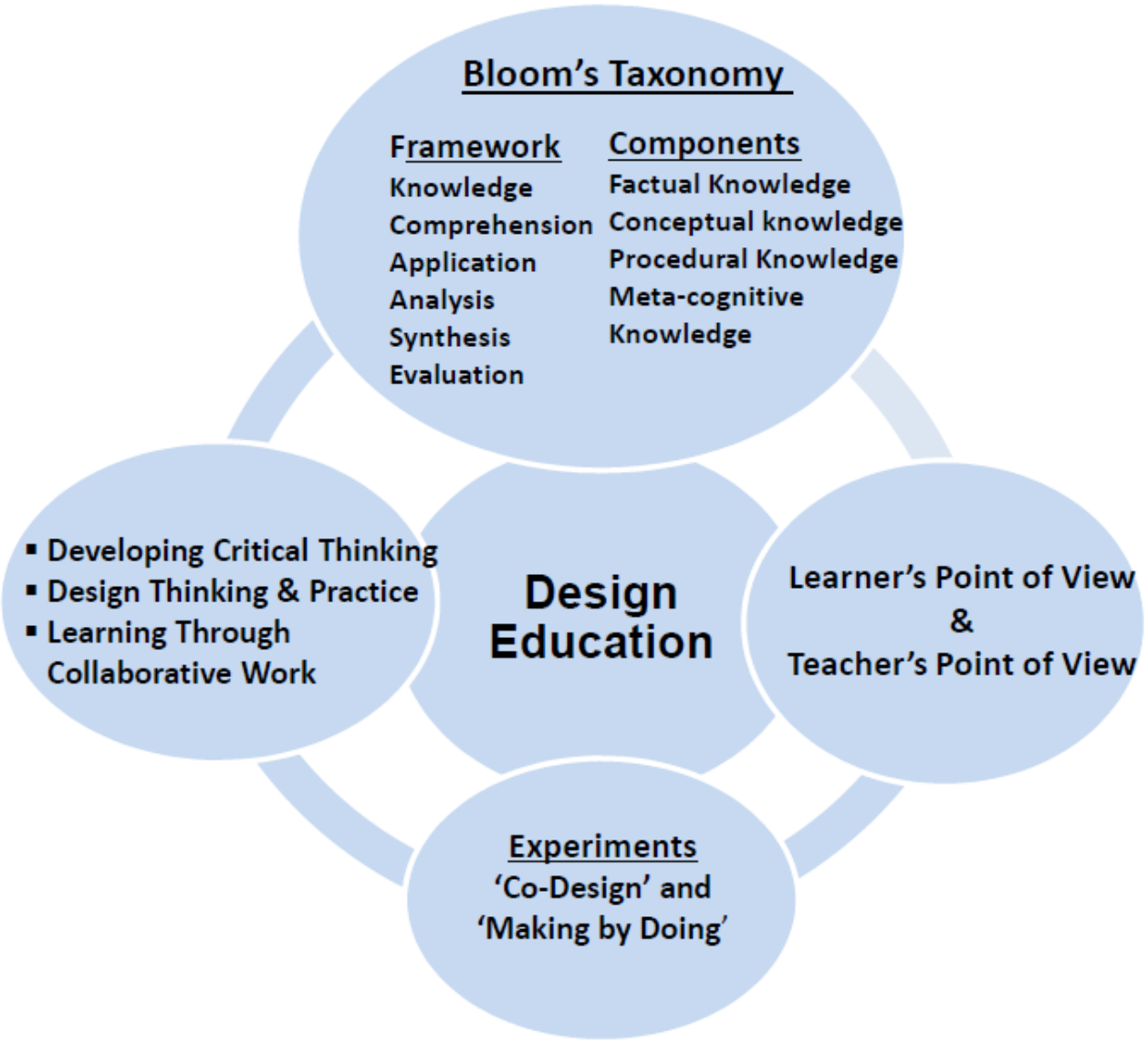

Figure 1. The design education cycle

In Figure 1, the design education is to let one design, and think creatively, innovatively, and in a complex way. Dym et al. [5] in their article noted several dimensions of design thinking and explained defining the studies on how effectively design thinking abilities are learned and why design is difficult to learn and even more difficult to teach. The article concludes with pedagogical improvement suggestions and recommended further research in enhancing design learning. In this context multitude of research is available, following either qualitative or quantitative or both methods. Such literature on experiments with subjects of different age groups and gender gives us a glimpse of its complex nature. For instance, in the research, the authors [6] experimented with children aged 10 to 12 and noted the idea-generation process. With an analytical lens, they observed the role of designers in creating a research plan and the children's role in participatory design. Further, they also noted events, engaging in play, field explorations, and design decisions taken by the children. Case study as a research method, an empirical inquiry was investigated within a real-life context. Haude and Hill [7] argued that both learning design and learning analytics require the making of a model. Dai used two lenses that are – (a) the importance of simplification of the design and, (b) further articulation of the design. The authors also noted the consequences from both the perspectives of the teacher and the learner. The research is a vital contribution to design pedagogy, variety management, and organization in the design process. Boucher and Gaver [8] researched on designing and making the Datacatchers. They reported that the design and making of the Datacatchers emerged, conceptualized, refined, and transformed throughout three different phases of development. Thus, the Datacatchers' complex ideas, imagination, and design evolved by making use of it. This reinforces the concept of developing critical thinking ability while 'making' and 'using' the product.

2.2. Architectural Product Design, Prototype, and Manufacturing

In Architecture and Product Design, the real test of creative skill comes when the design is put to manufacturing. And, that is why a vital phase in the design before manufacturing is 'prototype making. Architectural products such as precast and prefabricated building elements are common instances. Model-making stages are divided into four major parts- a) Trial model b) Mockups 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 behavioral) aspects. Figure 2 elaborates on various stages in model making. Through various examples, Giaccardi [9] elaborated, examined, and conceptualized the role of the prototype –skillful crafting and industrial design manufacturing.

In the research, she positions three key shifts namely the agential shift, the temporal shift, and, the infrastructural shift. Her research concluded that data technologies can provoke and provide scope for further design. Further, her research concluded that the interaction with things and the making of things triggers not only the scope for a new design but also helps build theories. In the prototype, making provides a platform not only for designers but users' point of view evaluation. It is a continuous evolution process, such as earlier design and problems therein become a reason for future design evolution. Cindy [10] et al. in their research elaborated that people not only purchase and use products but also design and innovate.

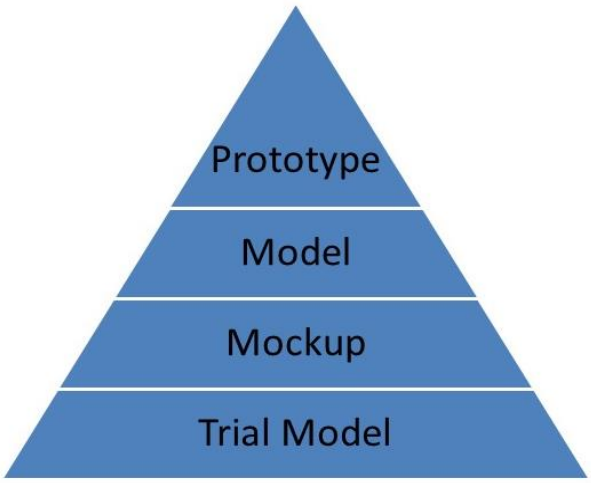

Figure 2. The different model-making stages

The 'designers' and 'users' roles in design and innovation are investigated with a focus on user participation, innovation, human factors, collaborative design, and how people manipulate technology and product design during use. The research concludes that more empirical and conceptual reasons are required to analyze active use and design engagement. Using a social scientific theory as a basis, Carlye et al. [11] investigated the role of designs in the interaction between six different stakeholders at a large footwear company. Based on the stakeholder interactions, they further explored – how designs can affect various social circumstances, such as trying to negotiate resources. In the present research context, such prototypes are the final phase of the model or a product. Carlye's research helps designers, design engineers, and others how prototypes can improve communication by highlighting their advantages and biases in real-world scenarios. Models/Prototypes can help students to solve many design problems during design studio/class and new product development process.

Das, et al. [12] arose the issues of students while developing physical models - the difficulty has come because of an absence of consideration of materials, creation shape/form correlation required for developing

prototypes/models, and the model-making processes. Das et al. [12] developed a tool for model making for making furniture design models based on material selection, related process selection, and, hand and power tools. Houde & Hill [7] stated that the prototypes are interactive artifacts. They demonstrated a variety of prototypes from actual projects, showed how well the prototype can be utilized to interact with their goals, and raised a few helpful ideas for designers. Prototypes bring together all the intended functions, look and feel, and applications of the artifact. It aids in balancing and resolving constraints that arise in various design dimensions as well as ensuring that the design is comprehensive and coherent.

2.3 Investigation in the Domain of Design Teaching-Learning

Research literature in this field mostly covers qualitative approaches. In their book "Architectural Research Methods," Groat and Wang [16] described the field of architectural research as well as offered seven possible research approaches. Out of these seven research strategies, a section on – 'qualitative research' helps understand the general characteristics of these types of research as shown in Figure 3.

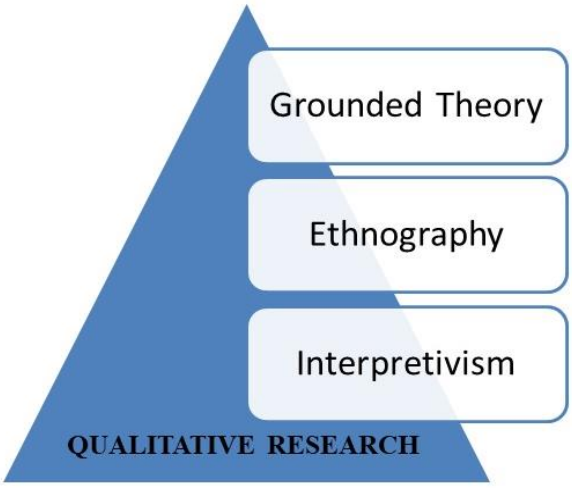

Figure 3. Pyramid of Qualitative Research - (I) Grounded Theory (Ii) Ethnography and, (Iii) Interpretivism

The authors further elaborate on three qualitative approaches – (i) grounded theory (ii) ethnography and, (iii) interpretivism. The last part of this section also highlights various tactics, giving an overview of data collection analysis, and interpretation. The strengths and weaknesses of qualitative research methods are also explained. This section is useful to understand how to implement such research while working on questions such as teaching-learning, inducing creative skills, the effectiveness of the teaching methods, and so forth. Several investigations through workshops and experiments therein are also reported. For instance, Valerie [13] and her co-authors researched scenario-based design, wherein they conducted test workshops. These workshops also focused on participatory architects and clients' potential future design developments. This scenario-based design similar to "model making" was concluded as an integrated approach that supported architects in designing.

The effectiveness of the physical or virtual model-making method (using some software) over the traditional method of teaching with the help of graphic forms is reported. Daalhuizen [14], with expertise in design theory and methodology and, innovation processes, elaborated 'design tool' as any piece of software or hardware (the model in the context of the present review) that allows practitioners to execute their tasks or extends their aptitude to do so. According to Griffiths [17], design tools directly influence the form and appearance of the outcome of a design activity. Similar to this, from his research one can say that model-making 'medium' and 'material' also influence design activity.

3. Analysis and Discussion

As noted in the literature review, model making in architectural and product design pedagogy when evaluated with Bloom's Taxonomy framework, clearly fulfilled the teaching-learning objective. Making models is a skill that will aid students in understanding the actual mechanisms of interfaces and deformation, material combinations, the impact of shape and color, and other topics that are considered to be fundamental architectural learning components. A proportionate model can give the learner an idea about the structural existence of the building or a product in actuality. Therefore, students are concerned with practical design rather than drawing some hypothetical ordered elements in drawing sheets. Making models increases one's ability for imagination and eliminates design phobia. (as they are concerned with the surface treatment and structural combination), and makes students bold to think better about design.

Literature concerning architectural product design, prototypes, and manufacturing also pointed out the inducement of critical thinking among students. Models are frequently constructed at a massive scale as creations are developed, giving the user a true sense of infecting the design. This may even include full-size concepts of individual elements, which allow for the comparison of proportions to the shape of a hand or body. When using a CAD drawing, which requires architects to spend a significant amount of time on their individual computers, models assist the designer in trying to make design issues noticeable to all parties involved most concretely. The model offers a common area of discourse for design in a way that encourages engagement with the chaotic, physical, imaginative process of creating the world as well as communication and the sharing of ideas. Thus, the reviewed literature reinforced the research question and

recommended physical model-making in enhancing creativity, innovation, and thinking ability in a complex way.

The reviewed literature also tested the hypothesis of model making as a creative tool enhancing design skills within learners through qualitative research approaches such as experiments with subjects (designers and users) (of different age groups, such as children and architects), responses in the workshop, use of models in climate-responsive buildings, and, so forth. A holistic multidisciplinary approach in the research thus covered all details validating the question under investigation.

The use of modern information technology gadgets and software are reported as supplementing tools in the design exploration processes at advanced stages, whereas in the initial stage of design teaching-learning physical model-making is certainly a necessary giving opportunity for the designer not only for his engagement but for acting practically [17]. As noted in the reviewed literature, design is ever-evolving practice and can be better learned by doing (where there is users' active design engagement) instead of mere thinking, which helps communicate with stakeholders. Alongside, learners when designing in a virtual mode directly, that is, without exploration of the physical model, are often found with difficulty related to scale, texture, ergonomic concerns, and so forth. Alternatively, physical model-making provides more opportunities for co-working, discussion, debates, idea sharing, and ease of participation.

The physical model making, although a conventional method of teaching-learning design, is referred to as vital in the initial stage of design learning as it is elaborated in recent research as well. Through this literature review (research literature of the academician, practitioner professionals, manufacturers, and so on), the significance of physical model-making in teaching-learning specifically in architecture and product design is revealed with instances from different contexts.

4. Conclusions

A systematic review of identified recent literature from reputed peer-reviewed journals including both the area of architecture and product design is implemented to explore model making as a creative tool to undertake teaching-learning processes. through countless instances cited in the review, argumentation is carried out as summarized in the sections such as (a) design teaching-learning dimensions, (b) architectural product design, prototype and manufacturing, and, (c) investigation in the domain of design teaching-learning. The following are the contributions of the literature appraisal:

(i) Physical model making in the initial stage of learning architectural product design, provides opportunities in fulfilling teaching-learning objectives. though the design is hard to learn and harder still to teach, to a great extent model making eases the process and provides opportunities such as participatory design, shared learning while handling a design task collectively (that is, co-design), learning by doing, developing critical thinking ability while 'making' and 'using' the product] for inducing creativity, innovation, and thinking in a complex way.

(ii) Several benefits of prototype and manufacturing instances are presented. The interaction with physical models and the making of models trigger not only the scope for a new design but also help in building theories. Through prototypes, the designer and design of the model communicate with stakeholders' groups influencing different social situations including negotiating resources (benefits, biases, understanding of materials, product shape/form, and so forth) and contributing to the designer in managing the project. The prototypes are interactive artifacts manifesting design in aspects of their application, purpose, and appearance.

(iii) Intricacies in qualitative approaches in the exploration of physical as well as virtual model making as a creative tool enhancing teaching-learning in architectural product design are presented. arguments are presented highlighting 'designers' and 'users' roles with experiments instances of participants of different age groups (such as children, architects, clients, stakeholders, and so forth) and gender and, design decisions taken by them in participants' participatory experiments and scenario-based design workshops (wherein they used different 'medium' and 'material' in making models).

We may share these spatial experiences with others using physical models, such as teammates, end users, and experts. Design is a multidisciplinary process. Everyone may participate in the creation of spaces while adding to the process of creativity by discussing design models. Models allow us to make design challenges accessible to all parties involved in the most tangible way possible, which is critical because CAD drafting requires designers to spend a lot of leisure time at a personal computer. The concept provides a common focus for design conversation in a way that encourages communication, exchange of thoughts, and participation in the messy, tactile, creative process of design. The additional benefit of physical models is that they assist designers in communicating their concepts with various stakeholders where insights must be gathered and choices must be made.

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