ARCHITECTURAL FORM CREATION IN THE DESIGN STUDIO: PHYSICAL MODELING AS AN EFFECTIVE DESIGN TOOL

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Abstract
This research paper attempts to shed more light on an area of the design studio which concerns with the use of physical modeling as a design medium in architectural form creation. An experiment has been carried out during an architectural design studio in order to not only investigate physical modeling as a tool of form creation but also improve visual design thinking that students employ while using this manual tool. To achieve the research objective, a method was proposed and applied to track form creation processes, based upon three types of operation, namely: sketching transformations, divergent physical-modeling transformations, and convergent physical-modeling transformations. The method helps record the innovative transitions of form during conceptual designing in a simple way. Investigating form creation processes and activities associated with visual design thinking enables the research to conclude to general results of the role of physical modeling in the conceptual phase of designing, and to specific results of the methods used in this architectural design studio experiment.

Keywords
Form making; physical modelling; design studio.

Introduction
Digital tools facilitate the processes to generate record, interpret, and manipulate tentative forms designers have in mind while designing. These potentials have completely revolutionized ethos that governs the design process. The high-end digital techniques incorporated in designing have the potential to integrate themselves in the architectural designing. Digital methods of designing, therefore, are considered among fields that have an important impact on the form creation process.

Sketching indeed is another mean of communication for what are happening inside the designer's mind. Many activities and processes such as, conception, perception, evaluation, decision making, representation, etc. occur during conceptual designing. Ferguson (1992) stated that using sketches is to evaluate new design ideas, and to capture and record 'fleeting ideas' on paper. Many researchers (for example, Schon, 1983; Geol, 1995) highlight the inevitable role of sketching in conceptual designing. Having the same bases, Ferguson, (1992) classified the act of sketching into different types according to their
role in conceptual designing.

Architects employing their individual design thinking and personal design capabilities through manual and digital methods in various design techniques. Each designer, therefore, has his/her individual design thinking being associated with own unique uses of media. In other words, this personal design thinking is different from one designer to another even in the same design case and with the same medium use. Many areas and factors affect the form creation process, whereas designing is influenced by: 1) architects’ knowledge - design, environmental factors, structure, etc. - and 2) architects’ capabilities - decision making, evaluation, representation, etc. - (Rowe, 1987). However, the research paper is not concerned with the foregoing different areas and factors, and their effects, focusing on the opportunities and paths potentially offered by physical modeling.

**Methodology**

This study aims to monitor and record different kinds of students’ conceptual designs. In another path, the architectural design studio attempts to highlight the benefit of using physical modeling. The study, also, has benefited from previous researches focused on the act of sketching in conceptual designing. Geol (1995), in his study of the act of sketching in conceptual design, identified two types of operation occurring between successive sketches, namely lateral transformations and vertical transformations. The two types reflect the kinds of changes occurred in the design path and the ways of thinking performed. The designer, in form creation process, may proceed further to add some details to finalize the form, or may go back for more modifications and even main shifts (Geol, 1995). Rodgers, Green and McGown benefiting from Geol’s classification of sketches described another technique based upon three types of operation, namely lateral transformations, vertical transformations and duplication (Rodgers, et. al, Green and McGown, 2000). In Geol’s work, no measure of the degree of transformation was proposed. Applying a different methodology from Geol’s method, Rodgers, Green, and McGown proposed a measure that would be useful in helping to track design progress. In this measure, the most simple of sketches is rated a ‘one’ and the most complex a ‘five’ (Rodgers, Green and McGown, 2000). Although this measure helps judge the level of design development, the research paper chose another method whereas the research concern is the transformation kind and direction, rather than level and rate. The level and rate of sketches, transformations as a result, are related to many factors and areas previously stated at the introduction section. The research concern does not cover the transformation level and rate, nor the areas and factors related to the transformation process. The methodology background can be described into the following statement, the back and forth movement in visual design thinking processes reflect both the direction of form transformation, and the number of form transformation processes. Both the direction and the number of transformation are related to the medium effectiveness.

The direction of transformation is either to modify the form to another, or to add more details to the one at hand. The study, therefore,
introduces a simple methodology through recording the different transformations in form creation processes to provide insight into the student’s made of thinking. The transformations of form creation were classified and recorded based upon three types of operation, namely: sketching transformations, divergent physical-modeling transformations – from one to slightly different, and convergent physical-modeling transformations – from one to more detail.

Architectural Design Studio

Design studio is routinely referred to as the center of architectural education. The pedagogical content of this design studio was to provide a means for investigating the effectiveness of physical modeling as a design medium, and to highlight for the students the effect of this medium. This main goal was illustrated to the students to understand the methodology and procedures being applied to their design work. Students were asked to identify the difference, if any, in their visual design thinking while using physical modeling in form development. The design studio aims at improving students’ visual design thinking employed in physical modeling and manual design techniques. Questions related to conceptual designing and visual design thinking were discussed in the design studio for example, what design medium, at what design situation, and with what design ideas.

Objectives

The design studio used a consciously planned sequence to record the students’ design ideas development in response to form creation. The primary modes were various kinds of sketching to develop and construct their design ideas into architectural composition and proposition, and in later stages, various methods of physical modeling to explore and modify tentative architectural forms.

The students were asked to provide self-records of each explicit stages, actions and reasoning. These explicit sequences records with the supplementation of students’ textual explanations were used during presentations for criticizing and evaluating by the students themselves. This reveal of conceptual designing steps different from one design case to another was highly beneficial for students through the exposure to different styles of visual design thinking, to different medium uses, and to different design solutions.

Procedures

During the design processes of students, basic form modifications were developed through using the following methods: sketching transformations, divergent physical-modeling transformations, and convergent physical-modeling transformations.

Starting by discussing the goal, objectives and procedures, the design studio continued with various presentations and instructions in order to show the students how to record their design steps and how to benefit from this process. Few examples were presented to explain the steps of solving the creative design problem. In another path, there was no time limitation as many students preferred to work on their designs in and out the studio. The time and place of work therefore were not restricted for students. This freedom was to overcome and neglect their fluency in using manual design tools, sketching and physical modeling. The students’
levels of visual design thinking and creativity are not included in the research concern. There were no intermediary submissions, only a final completion date. The conceptual design period was set to cover a total of twelve weeks of the design studio in order to provide enough time for students to apply the required methods. Two weeks followed this conceptual stage for students to finalize their designs in any design medium they choose.

Subjects and techniques
The subjects, nineteen senior architecture students, were asked not to use any computational power in conceptual designing. They depended on their raw imagination and manual methods of designing in the processes of design-ideas generation and exploration. Using physical modeling in the conceptual design phase was a new method to all students who used to employ this medium during their first design studios in which manual media were solely used. In intermediate design studios, the subjects were allowed to use computer while the physical modeling use was at the final representational stage, not in conceptual designing phase.

Subjects were requested to formulate explicit representational sketches at the beginning, then through physical modeling in the processes of constructing tentative forms. The subjects kept recording each graphical manipulation and rationale throughout the design studio.

Therefore, the representational structures of sketching and physical modeling employed in reasoning and visual design thinking were identified and recorded. Each change or modification in the form creation processes was classified into one of the three types of operation, previously explained.

Content
The architectural design studio introduced two design projects, elementary school and health center, for the subjects to freely select one. The two program requirements were defined including the architectural components and their required areas after investigations and researches made by the subjects. The two architectural programs were equal in the required areas, number of zones and components, functional relation complexity and two site conditions. The site of each project did not have any limitation in terms of area.

The required projects were intentionally kept only two in order for the subjects to limitedly have freedom in selection, and for the instructor/researcher to easily track and evaluate transformational steps of the decision-making rationale and the reasoning. The design studio was divided into three stages in response to design medium employed - sketching for two weeks, physical modeling for ten weeks, and any design medium based on students' selection for two weeks. The third stage was to finalize the plans, sections and facades.

Subjects start designing through various kinds of sketches that fit their techniques and potentials. After performing the initial designing tasks of problem definition, site analysis, concept articulation and form composition and proposition through sketching, Figure 1, they were encouraged to explore and develop their tentative forms by using physical modeling. In this stage, methods of physical modeling had the priority to methods of sketching. No
certain materials or techniques in modeling were assigned; subjects were free to select their materials and techniques. After sketching stage, most physical models did not have complicated forms. In other words, the formal compositions and propositions were in abstract levels. A part of this observation resulted from the new process used by students, (see figure 2). The complicated formal compositions appeared in later stages, (see figure 3).

Form Creation: Analysis of Students’ Work

The subjects’ sketching activities were initially grouped. This selection is intended to identify a range of thinking activity and rationale. Each drawing/sketch was numbered in sequence by subjects. This stage was set to two weeks. Drawings were analyzed to identify transformations in form creation processes. A week by week record of the transformation progress of each subject’s sketching activity was identified.

The next stage was set to employ physical modeling. The instructor, at the beginning, helped subjects to identify the transformation kind, divergent and convergent, in their work. This step was to ensure that subjects completely comprehended and were familiar with the method applied.

Quantitative analysis resulted from the subjects’ sketches and models were analyzed in figures and tables. Qualitative observations and analysis were necessary to explain both trends.
and contradictions in quantitative results. The students worked on a wide range of products in both levels: sketching and physical modeling, which varied in many ways.

**Sketching Episodes**
The sketches made by each subject were various in numbers and types comparing to others’. The reason behind this variety is the differences of each subject’s design thinking, sketching skills, and rationale. Although these areas are not of the research concern, they were discussed in the studio presentations to explain this observation, and to understand the different individual uses of one medium. Figure 4 shows the relation between the times used in sketching stage and the transformations occurred in form creation processes. The design studio had two sessions per week, but the time unit of X scale was set to one day as there were many sketches made in/out the studio. In many design cases, subjects made a large number of sketches even per a day. The changes in form therefore were accumulatively calculated to be scaled per one day. The changes in form presented in Y scale were set for each divergent transformation to be ‘-1’, and for each convergent transformation to ‘+1’. Three cases shown in figure 4 were chosen to present the range of form transformation in subjects’ work. The design of case 2 presented in Figure 3, and of case 3 presented in Figure 2.

Some designs were developed by more sketches than other designs. The back-forth movement varied from one design case to another, reflecting the difference of visual design thinking processes for each subject. The back-forth movement also was more dynamic in cases of having more fluency in employing sketching, for example case 2 and 3. The effectiveness of sketching is evident in the large number of form transformations in most cases, presenting it as the more suitable design medium for design development.
Types of Transformation in Physical Modeling

The second stage started after two weeks by employing physical modeling to formulate tentative forms and to explore more sequences of design actions. This stage was set to ten weeks. The explicit representational records with the supplementation of subjects’ textual explanations helped in tracking the two kinds of transformation. Some designs, after sketching phase, started in advanced formal compositions that are considered adequate in details and complexity in response to this design stage. Few designs had a lack of this complexity. This observation resulted from the difference of creativity level between subjects.

Figure 5 shows the relation between the times employed in physical modeling and the transformations occurred in form creation. The time unit of X scale was set to a week; the two week period of sketching was included in the total time. In many design cases, subjects applied more than one transformation per one physical model. The changes in form presented in Y scale was set for each divergent to be ‘-1’, and for each convergent to ‘+1’. The three cases previously presented in Figure 4, are shown in Figure 5 to represent the two stages of sketching and modeling. Presenting the form transformation in the two different design media would help in highlighting the difference of using these two media. In all design cases, the transformations in sketching are larger in number and more dynamic than the transformations in physical modeling. This observation indicates the appropriateness of sketching in conceptual designing more than physical modeling. In another level, the nature of physical modeling helps designers in the processes of imagination and visual design thinking, particularly in perceiving and conceiving the third dimension of forms during designing.

Results and Discussion

The cyclic movement of design thinking described by many researches (Faruque, 1984 and Zeisel, 1981) has a reciprocal relationship to the design medium used. The proposed measure to scale the design medium effectiveness is through identifying the transformation movement and its direction,
convergent and divergent, during form creation. A simple, effective methodology is used which can be described as follows: the more dynamic the movement is between crests and troughs the more effectiveness and flexibility the medium offers to subjects.

During the observation period the number and kind of transformations, convergent and divergent, were identified. In the sketching period, the total number of transformations for each subject was recorded and calculated whereas each transformation kind was separately presented during the physical modeling period. The reason behind this technique is the large number of transformation in the short sketching period comparing to the physical modeling period. Table 1 and Figure 6 show in more details the previous three case studies presented in Figure 4 and 5, with their crests and troughs.

From Table 1 and figure 6, an important observation can be recorded. The representational structures of physical modeling employed in reasoning and visual design thinking is towards convergent transformations, rather than divergent transformations, particularly at the end of observation period. This observation could be related to the fact that the initial arrangement of design problem has long-lasting effect hardly being changed and reformulated (Rowe, 1988).

Physical modeling often helps study component assembly and other aspects of construction rather than surface qualities. The advantages of employing this design medium have been also appeared in subjects' textual explanations. Subjects highlighted few areas in using physical modeling in their discussions and presentations throughout the studio. There were more and high awareness of form and its properties during form creation activities. Their visual design thinking through physical modeling that has been improved is different than the one they used through sketching. Subjects altered their visual design thinking in response to the constraints and opportunities of this design medium. Most subjects retain a main concern with form creation; maintain assumptions about construction; and in the same time relinquish aspects of a formalistic habit.
The foregoing analysis resulted from qualitative observations which did not appear in the quantitative analysis. In the same context, subjects frequently used sketches throughout the period of physical modeling to apply form transformations to the plan and to modify functional relationships.

The group of students contained much variety in levels of media use and visual design thinking; however, the simple methodology applied and the various factors neutralized overcome the impact generated from human variation and creativity. This variety is highly important to understand when sketching, physical modeling or computer (with its various programs) as a design medium is more helpful in a particular situation than the other media.

**Conclusions and Future Work**

This research paper presents the results of an experiment during an architectural design studio in which physical modeling was employed in form creation processes in order to investigate its effectiveness as a design medium.

This study has confirmed that sketching is prevalent in the conceptual phase of design. Sketches also provide insight into the architect’s visual design thinking at any particular point in the processes of form creation. On the other hand, designing by using physical modeling involves the study of components and assembly. When an architect uses a certain material and builds up the physical model, his awareness of the structural properties and component assembly of the form at hand is definitely increased.

The research area is interrelated with individual ways of visual design thinking and design techniques. Indeed, the architect uses his/her visual design thinking in a way fits each design medium and its own idiosyncrasies. It could be stated that each design medium requires a special way of visual design thinking and
perception that varies from one medium to another and in the same time varies from one designer to another.

Media and thoughts, therefore, are inextricably related. Perhaps more than any design medium, physical modeling facilitates selective
reinterpretation. Physical modeling also allows designers to oscillate easily between formal properties, abstract representation, component assembly and material making in a single design activity.

The work reported in this paper is the first stage of a longer project to investigate the creativity of architecture students during employing manual and digital tools in conceptual designing. The next step is to propose a measure for the creativity in order to compare between different uses of media, digital and manual. Another design studio may be conducted to apply the next step.

Physical models have a presence that is very engaging, and they are an excellent way involving form creation issues in a discourse. On the other hand, computers offer additional ways of exploring form creation that ease imagination and form complexity, and should therefore be considered as an option to provide a richer representational environment for conceptual designing.

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**References**


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