FORMAL ALGORITHMS IN A RULE-BASED BASIC DESIGN STUDIO

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Abstract

Basic Design in Schools of Architecture is mostly argued to rely on conventions, experience and intuition [1]. Yet it is also a rational process which is not explicitly revealed. This study is inspired from the presence of both intuition and reason within the design environment characterized by the ill-defined nature of a design problem [2]. It seeks to find formalisms of reason within this ill-defined setting from which intuition cannot be held separately. The study adopts a rule based design approach in an ill-defined setting; first to introduce novice designers with computational thinking in the absence of computers [3] and second, to identify the oscillation between reason and intuition as part of a greater conversation between the designer and the materials of the design situation [2].

In the pursuit of rule based design, in this study a scholar attempt is made to understand the rationalistic aspects of Basic Design Studio. The paper presents the methodology followed in the Department of Architecture at Doğuş University, where students were asked to develop formal algorithms for each and every one of the exercises given throughout the semester. Formal algorithms were required to have both verbal and visual instructions, in such a way that a third person can draw (2D) or build (3D) designs without the help of the designer. As such, all the moves of the design process must be included in the formal algorithm since skipping even the small steps of the design process would prevent proper drawing/building of the design by the third person.

At the end of the semester, an online questionnaire was distributed to all of the students. This questionnaire aimed to comprehend (a) how individual design experiences differed, (b) how ‘see-move-see’ [4] process worked in the design process, and (c) which architectural terms were mostly used in algorithms. The results were reviewed in an open coding process and sub-categories were identified.

Initial assumption was that designs of the exercises as well as the accompanying formal algorithms would not be successive events; rather the process would require a ‘see-move-see’ approach. The results supported the assumption. Most of the students developed algorithms in coordination with their see-move-see design processes. Another significant result of the study was that, architectural terms used in the Design Studio were frequently included in the algorithms where thereby a bridge between the abstract (like concepts) and the actual (like dimensions) properties of the designs could be linked. Final conclusion relates to one of the inherent characteristics of the Basic Design Studio: difficulties of ill-defined problem definitions in Basic Design Studios can be overcome by use of algorithms as students become able to de-compose and re-compose the design process into successive steps and instructions.

Key Words: basic design; formal algorithm; intuition; rationalism
1. Introduction

Ill-defined nature of the design problem allows for a multiplicity of approaches in design teaching as well. Two ends of design teaching method in studio are intuitive and rule-based studios. Although each one puts weight on a distinct property of the design process, they cannot be separated completely. It is to say that each intuitive act is regulated by a rule (or limit) and each rule is evaluated with intuition. The study aims to fill the gap between these seemingly far apart approaches. In order to understand the character of a rule-based design studio, retrospective descriptions of the design process reported by the students enrolled in first year design studio are analyzed in terms of Schön’s see-move-see cycle. The results are expected to provide clues regarding the similarities between the design processes in either approach.

2. Theoretical Background

2.1 Seeing in design

Many researchers define architectural design problem as an ill-defined problem [5]. In an ill-defined situation, the designer does not search for the single one correct solution; but an optimal one. Neither the problem nor the end is not definite. Therefore, every architect follows a unique design path with certain similarities [6]. Ambiguities involved in the design problem yield a conversation [4] between the designer and the object during the design process. The conversation evolves as the designer reflects on the design object, re-interpreting forms, shapes and relations. According to Goldschmidt [7] “the dialectic between arguments of „seeing as“ and „seeing that“ during the process of sketching allows the translation of the particulars of form into generic qualities and generic rules into specific appearances.” Similarly, Schön and Wiggins suggest that a design process evolves through a see-move-see cycle [2] in which the designer makes a new design move as a result of visual feedback.

2.2 Intuitive design studio

Architecture (and design) is an intellectually rich field that requires experimenting and it is driven by curiosity [8]. In addition to this, qualities of design problem and setting mentioned in the section above, make design activity an intuitive process. In the seventies, design process had been defined as a “black box” where more recently, Yürekli [9] has defined it as a “black hole” where each and every piece of information and experimenting are melted in to end up with an unpredictable solution. Yürekli [10] suggests, in more detail, that design studio is a „space for change, invention, spontaneous shifts, that can serve as a catalyst drawing out the unique elements“.

All this raise the question whether design can be taught? Architectural education takes architectural design to its center as it needs all the experimenting possible because it cannot be taught [11] [12] [8]. Learning by experience lets students not only deal with “subjective meanings / intuitive descriptions” but also “objective aspects” of design simultaneously [13]. This is the reason why a designer oscillates between dialectic relations of objectivity and subjectivity. This kind of co-existence between subjective and objective aspects of design contribute to new ways of thinking about design teaching [13].

2.3 Rule-based design studio

Rule-based design studios are one of such new ways of thinking about design teaching. Although computers and computational processes were introduced into the field of architecture in 1960’s, they still remain to be a part of later phases of design. Designers benefit the speed and effectiveness of a computer when producing construction documents or graphic representations. However, computational approach is seldom considered when dealing with creativity during the early phases. Pantazi [14] addresses the gap with the contrast between well-defined nature of the algorithms the computer uses and the ambiguous character of design, caused by ill-defined nature of the process. This signifies a distinction between explicit and implicit ways of defining a solution by rules in the field of computation, and intuition in the field of design. Similarly, conventional design tools utilized during the early phase of design, are related to designer’s intuition and allow for the use of implicit actions; and the new computational tools use explicit steps, rules, to systematize the ambiguity [14]. According to Cross [15], what makes design problems hard to address with systematic methods are designers’ tendency to proceed with „ad-hoc“ ways. Therefore, there have been attempts to re-define the design process with more explicit steps in pursuit of systematizing the ambiguity.
Various design methods were developed to deal with the ambiguity of design process and rule-based design is one of these methods. Rule-based design method provides an algorithm, a recipe that makes the design process explicit [14]. The two components of this approach are vocabulary and rules. Vocabulary refers to parts that the designer will work with. And the rules are the limits set by the designer to define the relationships between the parts.

Rule-based design approach does not necessarily require use of computers, rather, a computational thinking. Computational thinking consists of moving according to certain rules that can also be implemented by hand [14]. Similarly, Stiny [16] describes computing as “a way of thought reasoning”; and Özkar [3] realizes the benefit of, “conveying the understanding of design as computation and computation as reasoning precedes the use of computer tools as a strategy to integrate computation to studio”. Along the same lines with Stiny, Özkar and Pantazi, in this studio, the instructors have requested the students to work with rules by building physical models and sketches, and not the computer, in order to make sure the students take their time to compute (or to reason) while acting.

The underlying intention here is to travel the distance between intuitive and rule based design. It is achieved by steering the students to think with design rules which are inherently set with intuition; let them make formal explorations with the rules; see and reflect on the rules, based on the visual feedback from a two dimensional graphic or a three dimensional physical model. Although a definition of vocabulary and a set of tight rules could easily turn design into a mechanical process by completely excluding ambiguity, it is actually expected to trigger a reflective process followed by re-definition of vocabulary or manipulation of rules. In order to track the design process of students, Schön’s see-move-see approach is adopted as an indicator of a designerly way of experimenting with the basic design studio.

a. ARCH 101 at Doğuş University (DOU)

A total of 84 freshman Architecture majors were enrolled in ARCH 101 Architectural Design Studio in four sections where same curriculum was followed. Student projects were assessed within common jury presentations. In the pursuit of rule based design, in ARCH 101 Studio at Doğuş University an attempt is made to understand the rationalistic aspects of Basic Design Studio. This methodology primarily rested on developing “formal algorithms” for each and every one of the exercises given throughout the semester. Algorithm is defined at Merriem-Webster Online Dictionary as “a step-by-step procedure for solving a problem or accomplishing some end especially by a computer”. Formal algorithms, however, required to have both verbal and visual instructions, in such a way that a third person can draw (2D) or build (3D) the associated designs without the help of the designer. No computer tool could be used. As such, all the moves of the design process must be included in the formal algorithm since skipping even the small steps of the design process would prevent proper drawing/building of the design by the third person. An example student project from 2D composition to relief design and associated algorithms are given in Photo 1.

Photo 1: 2D composition, relief design and associated algorithms
Final assignment in ARCH 101 Studio was to design a maximum of 30 m$^3$ living unit, which was supposed to be built on Mars, in such a way that a person could have private, semi-private and common areas. Models were developed without using glue; only way to build up was plugging 2D basic geometric forms into each other. Exceptions were made for students using curvilinear forms where plugging may not a proper way to make the models.

After individual submissions, selected eight projects were built in ½ scale (Photo 2). Groups for the assembly process were formed randomly in order to avoid any bias. Not only the design but also the assembly processes were described in formal algorithms.

**Photo 2: Selected works in ½ scale: plug-in and out using orthogonal units and using curvilinear units**

### 3. Methodology and data

#### 3.1 Data and the method
In this study, a descriptive study is carried out depending on a qualitative survey which was distributed at the end of the semester. The questionnaire included nine open questions all descriptive in nature. In order to ensure adequate time for answers, students filled in the questionnaires online. As all the students were included the survey study, the representativeness of the data is argued to be sufficient.

As independent judges, two of the instructors skimmed and scanned the answers in order to increase the trustworthiness of the study. This process enabled making categorizations out of the raw data. No computer tools were used in this process. Questions were evaluated separately and therefore missing cases, if any, are dropped from that particular answer column rather than permanently deleting from the data set.

Depending on the Rule Based Basic Design Studio at DOU, three research questions were central to the analysis: (a) how individual design experiences differed, (b) how algorithms and ‘see-move-see’ processes worked in the design process, and (c) which architectural terms were mostly used in algorithms.

3.2 Assumptions

Regarding the research questions, the following a-priori assumptions were made. Students may experience completely different processes depending on many parameters, yet it is possible to construct categories out of these unique paths. The answers of students were analyzed in depth hence, a number of design paths in the form of decision trees were obtained (Table 2). Second assumption is that algorithms help to guide students so that they develop design skills to control the design process in a better way. Algorithms therefore serve as a formal medium revealing all the back-and-forth steps of students and accompany the see-move-see process. Algorithms are beneficial in a rule based design studio not only for the students to manage their design processes but also for the instructors to evaluate student performances. Final assumption is that terms used in problem definitions and jury evaluations determine implicitly the vocabulary used in the problem definitions. This may orient students to give priorities to some particular aspects while it may also prevent them to explore other design perspectives.

4. Results and Discussion

4.1 Research Question 1: How did individual design experiences differ?

Students emphasized by far the learning by doing process of the design studio in their answers. Each student has his/her own learning. Therefore, each design process is unique and there are as many design paths as the number of students. Three random students described their design paths as follows:

**Design path 1 (Student 1):**
Thinking and understanding the problem  
Sketches  
Trial and error  
Final product

**Design path 2 (Student 2):**
Research  
Drawings  
Developing initial designs  
Changing the unit and developing again  
Prepare the algorithm  
Develop the design again  
Determine the dimensions  
Drawing sections  
End Product

**Design path 3 (Student 3):**
Develop 3 modules  
Producing many units for developing 3D models by hand  
Concentration on developing spatial hierarchy  
Developing models again and again with small additions and corrections  
End Product

Student 2 never mentions about the ideation whereas Student 1 does not tell much about steps of the trial-and-error part. Likewise, Student 3 describes his/her design process by providing details. Table 1 tells us that it is
difficult to form categories from such answers. One difficulty of this analysis was that every student focused on
different aspects of the problem definition and described their design process accordingly. Additionally, students
use different means to represent their ideas. Therefore, answers reflected different concepts, priorities and
methods implicitly. Another difficulty is that not every answer has same level of information: some provided
more detailed information while some did not.

Depending on the answers, however, these individual paths could be grouped into broader and comprehensive
categorizations. Primary individual design path categories found out of the data are given in Table 1.

Table 1: Design paths

Table 1 branches to its right from larger square units to smaller individual squares each containing a phase
of design activity. Sketching, Rule and Model Making are taken as indicatives of design decisions that Schön
refers to as “moves” and evaluation indicates “seeing”.

Evaluation of decisions have yielded new moves as 85% of the design paths followed consists of at least
one instance of evaluation and other moves afterwards. In 37% of the design paths, evaluation appears at least
twice, further emphasizing the cyclic manner in which rules are applied, evaluated and re-interpreted.

Here, the rules are associated with objective approach that the rule-based design offers, On the other hand,
evaluation cannot be regulated with rules thus; they are associated with intuition. The table not only helps us to
visualize the multiplicity of design paths but it also helps us to visualize the cyclic relation constructed by see-
move-see steps or, objective and intuitive parts of design.

4.2 Research Question 2: how algorithms and ‘see-move-see’ processes worked in the design process

Students described the relation between algorithms and their designs in one particular question of the
survey. Three primary categories were observed. Accordingly, 65% of the students formulated their algorithms again and again in the design process. While on the other hand, 15 % of the students stated that they developed algorithms after the design was completed. The rest, almost 20 % of the students developed algorithms prior to the design and strictly obeyed the initial rules.

Answers of the majority (see-move-see) worth mentioning:

Student 4: As the design changes and improves, algorithm changes accordingly.

Student 5: You cannot start designing without an algorithm but this algorithm changes continuously in
the process. You develop numerous rules and then forget them totally and re-write new rules again. ...
It is like the map of the design process.
As algorithms were compulsory in the submission list, in some instances developing an algorithm was viewed as an end rather than the means. Some students told they changed their designs in such a way that an associated algorithm can be developed easily.

Student 6: While designing, I attempted to make such a design that its algorithm will be easily developed.

Student 7: I avoided doing ... otherwise developing the algorithm would be difficult.

Student 8: When I could not go further in the design process, I put the units together in such a way that its algorithm could be developed.

In some instances, students may have given up their ideas for the fear of failure. As the Student 8 states:

Although beautiful to me, I did not choose some of my ideas as it did not comply with my algorithm. I thought I could fail to develop both the design and the algorithm simultaneously, so I made sacrifices in terms of my design for the sake of obeying the rules of algorithm.

4.3 Research Question 3: which architectural terms were mostly used in algorithms?

Hierarchy, fractal, rhythm and algorithm were the mostly used terms when students were asked to describe their final projects. Following those terms, several design principles like symmetry, balance and order were mostly referred (Table 2).

<table>
<thead>
<tr>
<th>Term</th>
<th>Number of Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hierarchy</td>
<td>52</td>
</tr>
<tr>
<td>Fractal</td>
<td>50</td>
</tr>
<tr>
<td>Rhythm</td>
<td>45</td>
</tr>
<tr>
<td>Algorithm</td>
<td>43</td>
</tr>
<tr>
<td>Relief</td>
<td>39</td>
</tr>
<tr>
<td>Symmetry</td>
<td>32</td>
</tr>
<tr>
<td>Balance</td>
<td>31</td>
</tr>
<tr>
<td>Pattern</td>
<td>20</td>
</tr>
<tr>
<td>Order</td>
<td>19</td>
</tr>
<tr>
<td>Module</td>
<td>18</td>
</tr>
<tr>
<td>Iteration</td>
<td>14</td>
</tr>
<tr>
<td>Unit</td>
<td>12</td>
</tr>
<tr>
<td>Monotony</td>
<td>12</td>
</tr>
<tr>
<td>Exercise</td>
<td>10</td>
</tr>
<tr>
<td>Repetition</td>
<td>10</td>
</tr>
<tr>
<td>Critics-evaluation</td>
<td>9</td>
</tr>
<tr>
<td>Sketch</td>
<td>9</td>
</tr>
<tr>
<td>Structure</td>
<td>9</td>
</tr>
<tr>
<td>Frame of reference</td>
<td>6</td>
</tr>
<tr>
<td>Section</td>
<td>6</td>
</tr>
<tr>
<td>Plan</td>
<td>6</td>
</tr>
<tr>
<td>Jury</td>
<td>4</td>
</tr>
<tr>
<td>Variety</td>
<td>3</td>
</tr>
<tr>
<td>Diagram</td>
<td>3</td>
</tr>
<tr>
<td>Mutation</td>
<td>1</td>
</tr>
</tbody>
</table>

These terms are parallel to the aims of the design studio and they are mostly derived from problem definition of projects. Most of them are conceptual terms, while some are related with assembly and presentation methods and materials.

The results of the study point out relevant information regarding rule based design studio which can be summarized as follows:

- Formal algorithms enforce students to put rules and obey them.
- Algorithms do not necessarily involve a see-move-see process.
- Developing and representing algorithms are themselves design problems which enhance the students’ design skills.
- Creativity is not limited in a rule based design studio. Creativity is limited when the reflective nature of design (see-move-see) is not successfully managed by the designer.
5. Conclusion and future research

This study is a preliminary step towards a better understanding of the rule based design studio. Results reveal the positive effect of use of algorithms. Algorithms support see-move-see process and enables students manage their design paths, benefiting both the intuitive and the objective aspects of design. Use of algorithms also pays a tribute to the mathematical-rationalistic grounds of Architecture discipline. Students remember their analytical capacities and build step by step instructions with ideas, concepts, dimensions, positions and relations included. This can be viewed as a bridge between the abstract (concepts like spatial hierarchy) and the actual (concrete like dimensions and positions).

The survey study definitely opened up new perspectives for this purpose and yet, in-depth interviews are needed for a more comprehensive analysis. A full content analysis can then be carried out. The continuity of the design studio from ARCH 101 to ARCH 102 by the same instructors offers a possibility to develop the analysis with reference to ARCH 102 Introduction to Architectural Design Studio course.

Final conclusion relates to one of the inherent characteristics of the Basic Design Studio: difficulties of ill-defined problem definitions in Basic Design Studios can be overcome by use of algorithms as students become able to de-compose and re-compose the design process into successive steps and instructions.

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