METU JFA 2015/2
(32:2) *151-169*

DOI: 10.4305/METU.JFA.2015.2.5

DESIGN THINKING: A MODEL DEVELOPMENT BASED ON ARCHIVED DOCUMENTS

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Received: 20.09.2014; **Final Text:** 01.10.2015

Keywords: Design thinking, design process, wicked problems, empirical study, studio

INTRODUCTION

To be successful in today's highly technological and globally competitive world obliges a person to have different skills than were formerly required (Pink, 2006). One of these skills is "design thinking," an analytic and creative process and inquiry that provides opportunities to create and prototype models, gather feedback, design and redesign for solving "wicked" problems as well as human-centered open problems (Cross, 2006; Melles et al., 2012; Razzouk & Shute, 2012). Design thinking can also be defined as how a designer sees and how s/he consequently thinks (Liu, 1996). Design thinking is a cooperative process. Designers first seek signs of problem solving concepts and/or ideas, then draw associations among ideas, and view what has been done to proceed further design efforts (Do and Gross, 2001).

Study of design thinking has been enjoying increasing interest in design pedagogy. Blanco's work (1985) made the effort to address fundamental characteristics of design thinking. Rowe (1994) emphasized the significance of design thinking in design education and explored the cognitive process of design. It is widely agreed that previous studies of the design thinking are important since it helps to develop more sophisticated approaches of design pedagogy (Schön, 1985; Eastman, 1999). Previous studies employed empirical methods. Often they obtained design processes of designers and evaluated them on overall quality including a variety of aspects such as creativity. Studies have included observation, interpretation, and analysis of individuals' design process (Cross, 2001a; Oxman, 2004). In this study designs of senior interior design students are obtained to evaluate students' design thinking process and overall quality of their works on a variety of aspects. The purpose of this study was to focus on the nature of design thinking using archived documents from students of a design studio under the theoretical foundation of previous studies. The goal was to create a model that describes the process of design thinking, aiming to

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improve teaching approaches in design disciplines education by examining students' design thinking processes and the relationships between quality of the students' design products and quality of their process.

Literature Review

"Ill-defined" or "wicked" planning design problems violate the assumptions of the rational problem-solving methodology (Blanco, 1985). According to Rittel, most design problems are wicked problems due to their fundamental indeterminacy (Rittel, 1972; Rittel and Webber, 1973). That is because design is considered as "wicked problem settings" (Martin, 2009; Tonkinwise, 2011). There are no definitive conditions or limits to design problems (Churchman, 1967). In other words, the problems designers usually deal with make it difficult to decide on an approach to a solution or even to clearly define goals. That is why Buchanan (1992, 16) defined "design problems" as "indeterminate and wicked because design has no special subject matter of its own apart from what a designer conceives it to be". Since design problems are wicked and indeterminate, the first step of design is usually clarification of what the client really requires (needs) and formulation of the design goals (Rowe, 1994; Rosenman and Gero, 1998; Lu and Liu, 2012). Therefore, design proceeds from a conceptual description of a need to a concrete design solutions for problems created by the needs (Rosenman and Gero, 1998). Today, it is widely accepted that engineering design activities are also determined by needs (Chen, et al., 2015). However, Cross (1982, 224) mentions that "design problems are not the same as the 'puzzles' that scientists, mathematicians and other scholars set themselves. They are not problems for which all the necessary information is, or ever can be, available to the problem-solver." He notes a critical distinction between science and design. The scientific method may not be appropriate for design where results do not need to be repeatable and generally should not be repeated or copied (Cross, 2001a; 2007; 2011). Therefore, design is a third mode of knowing, which differs from science and humanities.

Some of the researchers, on the other hand, suggest that whatever constitutes designerly inquiry is needed to be formulated (Ludvigsen, 2006; Buxton, 2007; Stolterman, 2008). For example, Stolterman (2008, 63) states that "design disciplines such as interaction design have to develop and foster their own designerly approach for education and practice". Cross (2011, 27) explains this approach that due to the criticism of Peter Rowe made that designers tend to fit tightly for too long to solution conjectures that provide inadequate led attempts to provide design methods or guidelines that could encourage designers to work more "rationally". Such guidelines are basically a process of "analysis-synthesis-evaluation" (Cross, 2011) or "formulation-synthesis-analysis-evaluation" (Vermaas and Dorst, 2007). However, this kind of approach has been criticized in design world because this process looks like an inappropriate model adopted from "rational behavior", whereas design is more "intuitive" ways of thinking and reasoning (Cross, 2011). Therefore, in *Designerly Ways of Knowing*, Cross (2007, 55) points out that "design practice does indeed have its own strong and appropriate intellectual culture… we must avoid swamping our design research with different cultures imported either from the sciences or the arts".

In design practice, abductive logic is considered a problem-solving strategy that considers of a set of desired conditions and develops possible ways to realize them by means of seeking an explanation for the phenomenon from current knowledge. This strategy often leads to fruitful hypotheses and plausible solutions, thus enlightening approaches for designers (Blanco, 1985; Lu and Liu, 2012). Hence, abductive logic is considered critical to design process (Yoshikawa, 1989; Lu and Liu, 2012). Abductive differs from other two kinds of well-recognized inference processes (deduction and induction). Abduction is the process of interpretation to best, or most likely, explanations from accepted facts, whereas deduction refers determining the conclusion while induction means determining the rule (Serrat, 2010). Abduction refers to the process of hypothesis formation based on an observed phenomenon: If an observed circumstance *a* can be explicable as a matter of course if hypothetical explanation *b* is true, then it is reasonable to surmise that *b* is true. In another word, *b* is sufficient but not necessary for *a* (Blanco, 1985). In addition, *b* is the most compelling one among all conceivable explanations. For example, it is observed that the lamp cannot be turned on, and if its bulb burned out, then the lamp would not be able to be turned on. Therefore, according to abductive logic, the bulb burned out. Abductive logic is low in the degree of surety since there may be an infinite number of possible explanations for the observed circumstance (Peirce, 1958; Blanco, 1985; Lu and Liu, 2012) nonetheless it is highly problem-solving oriented, leads designers to better understanding by providing some possibilities for further directions, and can be used to support design sub-solutions formulation. Abductive logic also helps designers diagnose the ''bad'' design concepts and recommend corresponding improvement strategy (Lu and Liu, 2012). As a result, abductive reasoning is a type of ''intelligent guessing'' that has significant effects on design process (Lu and Liu, 2012).

Furthermore, pragmatic maxim also takes place in the step of design of alternative strategies. It is accepted that pragmatic maxim helps "how designers approach and explore design challenges, and how users make sense of and employ the products of design" (Dalsgaard, 2014, 149). The pragmatic approach suggests a systemic understanding of situations, it relates the alternative strategies, which are sets of actions based on different interpretations of the goals, to the consequences, which are conceivable effects for each alternative. Combining the two, it makes the choice of certain design alternative reasonable. Additionally, according to Peirce's (1958) original argument "the sum of these consequences will constitute the entire meaning of the conception" (Blanco, 1985, 95), the process of clarification of a design strategy can in turn benefit and further develop the problem formulation.

Starting from this fundamental characteristic, what designers do can be better comprehended as two levels: 1) on a general level: to form an idea or a working hypothesis about the nature of product; and 2) on a particular level: to conceive a design that will lead to a particular choice. Such an understanding helps explain how the process of design thinking is established: "The problem for designers is to conceive and plan what does not yet exist, and this occurs in the context of the indeterminacy of wicked problems, before the final result is known" (Buchanan, 1992, 18). Cross (2001b; 2011) also defines design activity in two levels as 1) problem formulation, and 2) solution generation. In addition, he adds a third level as process strategy since design strategy may change from field to field. Alternatively, Schön (1983; 1987), one of the most influential designers, developed a model called "reflection-in-action" to address wicked problems. According to Schön, problems a designer/practitioner faces are unique and s/he cannot deal with the problem by applying standard

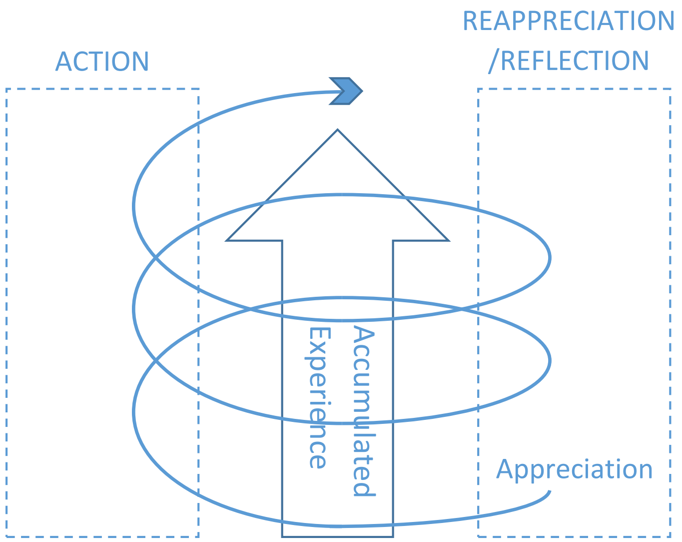

Figure 1. Reflection-in-action model developed from Schön's model

theories or techniques. Hence, a designer/practitioner should treat each case differently. Schön argues that a designer/practitioner appreciates what s/he sees and hears, then s/he reframes the situation once again. When a designer/practitioner realizes something is missing or new, which sets new criteria for further designing, the designer/practitioner's actions produce effort for ongoing reflection and his/her reflections form ongoing actions to resolve design problems or yield new design opportunities (**Figure 1**). The process spirals from appreciation to action and reappreciation/reflection stages (Schön, 1983; 1987). In this process, accumulated experience helps designers deal with wicked problems better.

According to Cross (2001b) four important steps exist in problem formulation level: a) goal analysis, b) solution focusing, c) problem/solution co-evolution, and d) problem framing. Cross explains that designers do not focus on defining problems since they are "wicked problem solvers." Hence, rather than being problem-focused, designers are solution-focused (Cross, 2011, 198). To Cross, designers' attention fluctuates between problem and solution to form partial structuring of the two spaces of them. Cross (2001b; 2011) points out that "problem framing" (i.e. structuring and formulating the problem) is the key feature of a design activity. Cross identifies five important steps at the solution generation level: a) fixation, b) attachments to concepts, c) generation of alternatives, d) creativity, and e) sketching. At this level, designers move back and forth to reach innovative (creative) design. Cross defines this design effort as a double-edged feature of design activity. In this step, designers either choose one of the early solutions or generate a wide range of alternatives. At this level, most creative thinking emerges and sketching serves as an important tool for designers. Creative leap is recognized as a creative bridge, or bridging concept, between the problem space and the solution space to overcome design problems and constrains during sub-problem and sub-solutions process (Cross, 2011; Hasirci and Demirkan, 2007; Alhusban, 2012). Creative leap is considered important because, design problems can be narrowed, design complexity can be reduced, and design constraints can be resolved with creative leap in design process (Stempfle and Badke-Schaub, 2002; Al-Sayed, Dalton, and Holscher, 2010; Hsiao and Chou, 2004). Like Cross, Stolterman (2008, 61) also portrays designerly inquiry as an intentionally repeating process of moving between the whole and the parts: "... a rational designer works on many alternative designs in parallel in an iterative way, while going back and forth between the whole and the details. This way of doing design is not a choice. It is at the core of what it means to act in a rational, disciplined, designerly way".

Present Study

The aims of this study was to further explore the nature and critical steps of design thinking under the theoretical foundation of previous studies by analyzing documents from students of a design studio. The goal in this study was to create a model which describes the process of design thinking and that could improve teaching in design disciplines. The following research questions were investigated: 1) What are students' design thinking processes? 2) What are the relationships between qualities of the students' design products and qualities of their process? The hypotheses in this study were: 1) Students follow the basic steps of design thinking while they design their projects; 2) There is a positive relationship between quality of students' design products and quality of their processes (following a better design process produces a better quality product).

METHOD

In this study, the methodology was based upon three steps. The first step was to combine knowledge from existing literature and our experience then create our design thinking model. Because design model in this text addresses beginners, not experts, the second step was observation and examination of students' design processes. The final step was to compare our design thinking model and students' design process to see how the works of the studio members fit the model we proposed. At first, we began examining the existing literature to create our design thinking model. In this step, the important steps of the design thinking process from the literature were highlighted. After determination of the important steps of design thinking process, we combined the knowledge gained from literature with our experience and a model was created.

Second, we began to observe students' design process in the Vision/Goals Formulation Stage through the end of students' design. The instructor informed us that students had already finished the previous part and focused on later processes. During this examination, we attended student presentations and asked them questions about their project and design process. During the examination of the students' design process, we studied students' archives and documents and analyzed students' works. The following criteria for students' work assessments were used: a) Design process: Did the student's work demonstrate a clear process? Did the design process proceed in the continued improvement of the design? b) Hard skills (analytical, critical, and technical thinking): Did the student's design respond to pragmatic and abstract constraints? Did the student's design respond critically and analytically to the program? c) Soft skills (communication): Did the design representations clearly communicate the scope and depth of the student's design work? Did the representations clearly communicate the student's design intentions? And d) product: What is the design innovation and quality (i.e. average, strong, excellent design) of the student final design? As a final step, our design thinking model with students' work was compared. In this step, we looked how similar to or different from our model is the students' process, whether students followed a recognizable process but one different than our model. If they followed a different process, the differences were analyzed.

Model Building

Because the vast majority of the problems addressed by designers are "wicked problems" (Buchanan, 1992; Martin, 2009; Tonkinwise, 2011), the design thinking begins with the analysis of the context of the design problem, which we call the problem formulation stage. The first step in problem formulation is to determine what the clients (or users) require (need) (Rowe, 1994; Rosenman and Gero, 1998; Lu and Liu, 2012). The second step is data collection. It is followed by a data synthesis, which means allocating data into well-developed categories (not overlapping) and establishing relations among these data in various categories based on our previous experience. Abductive logic occurs here to help find potential relations among the data in different categories (Blanco, 1985; Lu and Liu, 2012). The fourth step is data analysis, including the identification of strengths, weaknesses, opportunities, and threats (SWOT). The data analysis can provide design constraints as well as potential directions designers need to look into (Archer, 1984). In addition, the knowledge gained from the process of data synthesis and analysis can help designers better define the realm of the design. These four steps comprise the problem formulation stage. The second stage is visions/goals formulation. The visions and goals are a set of desirable conditions designers aim to achieve (Blanco, 1985, Cross, 2011). Visions are the overall sense of qualities while the goals address more specific and practical issues.

The next stage, design alternative development, is the core of design. In practice, designers cannot deal with the overall design problem directly. The first step is to decompose the overall problem into sub-problems. The next step is to find sub-solutions (Cross, 1990; 2011). Here is where the creative bridge and abductive logic occur. Creative leap is considered a central component of the conceptual design phase (Pedersen and Burton, 2009). The creative bridge represents designers' act of "throwing a bridge across the chasm between problem and solution" (Blanco, 1985, 112) and this bridge thinking takes advantage of abductive logic (Cross, 2011). Creative bridge, or creative leap, is considered important since it helps designers narrow design problems, reduce design complexity, and resolve design constraints (Stempfle and Badke-Schaub, 2002; Al-Sayed et al., 2010; Hsiao and Chou, 2004). In this stage, designers become more specific for each design alternatives to reach the best design solutions. Hence, sketches play important role by helping designers to reach the best design solutions (Cross, 1997; 2001b; 2011). Usually, after proposing a solution, designers assess it with the respect to the goals they had set. Therefore, this is one step where we believe pragmatic maxim comes into play. Each sub-solution (called an alternative strategy by Blanco) is evaluated by the sets of conceivable effects it brings (Blanco, 1985). Consider the decision for sub-solutions as a "tree" with nodes and links (Rowe, 1994). A designer can improve the quality of a solution by process examining each result. If the result turns out to be positive, this certain direction may be worth further exploration. Otherwise, it may be dropped from further consideration. Zeisel (2006) highlights that testing the design is one of the most important processes of design development and implementation. By looking "backwards and forwards simultaneously" help designers determine the design for its success promising aspects as well as it is refined for further progression (Zeisel, 2006). The next step is to assign priority and weight to each sub-solution based on the ranking of the significance of the sub-problem to which it responds (Oxman 1997). Pragmatic maxim happens here as well. Then the last step in design alternative formulation is to combine the sub-solutions found into an overall solution (Cross,1990).

Once the overall design solution is proposed, the design process continues to the design execution stage (Archer, 1965; 1984), which includes two steps: implementation and evaluation. The former one involves description and translation of the design proposal and the later one is to evaluate the overall quality and level of satisfaction. The evaluation step includes induction and explanatory science (Blanco, 1987). During the steps of data synthesis, data analysis and design alternatives development, the designer's previous experience/case studies also play a significant role. Considering these steps, we created the design thinking model shown in **Figure 2**.

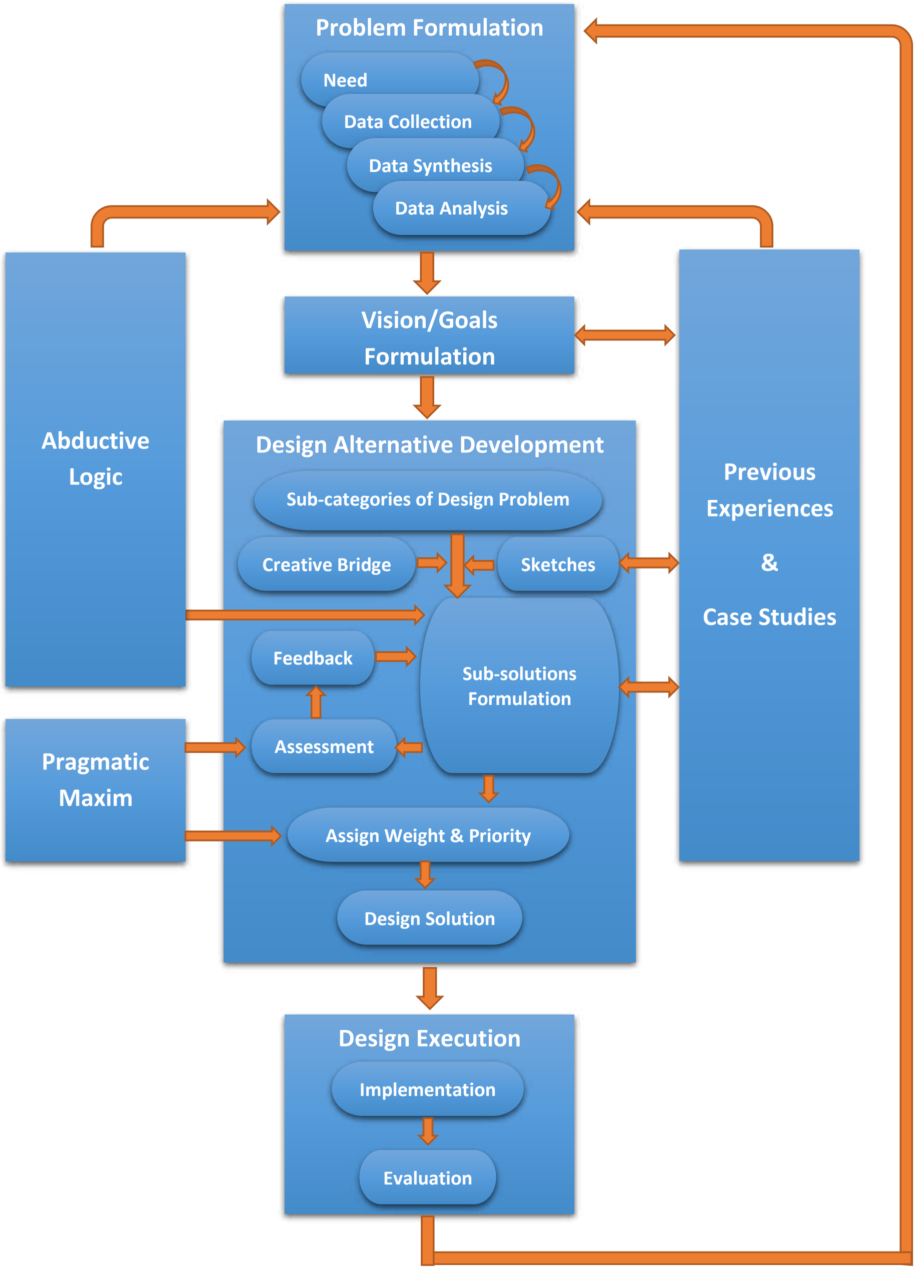

Figure 2. Design thinking model

Studio Set Up

The aims of this studio were to teach students to think as designers and help them to prepare to deal with difficult situations and to solve complex problems in school, in their careers, and in life in general. Having good design thinking skills can help students solve complex real world problems and adjust to unexpected changes. Hence, the studio aimed to teach them how to define and analyze design problems, design goals, and design solutions, through an understanding of critical design thinking steps.

In this design studio, students were supposed to keep an archive of their project work throughout the term. Each student was supposed to submit a set of five design process slides on eight specified days during the process. The teacher expected that the design process slides would consist of four snapshots of the developing design plus a final slide representing the current state of the student's design. The teacher recommended that students rename their digital files at the beginning of each work session and date all hand-drawn images to maintain a chronological record of work. During the process interviews week, the studio instructor met each student to review the complete set of process slides and discuss the student's cumulative design process.

Introduction of the Studio

The project was an interior design of an existing building located in Spokane, WA. The aim of the project was to redevelop this building and convert it to a special hotel. The hotel acts as a healthcare facility for patients' temporary dwelling. Each student was expected to: 1) integrate egress, plumbing, HVAC, fire-sprinkler, communication, and electrical systems, 2) engage the interior and exterior of the existing building, and 3) respond to relevant building codes and other regulations.

Each student was expected to maintain an archive of project work from the beginning of the design to end of the term, including design process slides on eight dates through the whole process. This documentation and personal interviews would later help researchers understand the student's design thinking process. Before this project, students were required to research the current situation of temporary dwellings and healthcare facilities in Spokane. This effort occurred at the problem formulation stage in our model. Therefore, our study of their archival materials started from the vision/goals formulation Stage. We did not consider their work at earlier stages because it had already been completed.

Documentation Analysis

Analysis of Selected Students' Design Processes

In this study, design archival materials of four students whose design thinking process were considered to be clearly illustrated in the archives and representative of the work of among 16 students by the instructor were chosen. We coded students as Student 05, Student 12, Student 25, and Student 40.

Analysis for Student 05's design process

Based on Student 05's literature review, Student 05 formulated the following vision: providing residents with opportunities to interact with others during their healing process and (because most clients would be utilizing the facility during medical procedures) providing a way for them to be involved in the social atmosphere of the hotel without feeling exposed or uncomfortable. The aforementioned vision was reasonably good, but Student 05 added concepts to the vision that showed lack of a clear separation between design goal and solution. The concepts of "providing public areas with several levels of privacy" and "different experience within the building" indicate a creative leap. Then, student 05 tried to develop initial thoughts of healing and recovery and came up with the concept of "bridge", which helped ease residents' transition into daily life by "providing passage over the obstacle" and enhancing social interactivity. In his/her vision formulation stage, it seemed this student employed abductive logic to push the abstract vision forward and explore more specific kinds of desirable conditions s/he aimed to achieve.

At the next stage, design alternative development, Student 05 did some brainstorming (abductive logic) to explore potential design concepts responding to previously proposed design problems and goals. Student 05 mentioned several solution concepts including: 1) splitting the restaurant area to provide variance in food options and views (gained from the goal of several levels of privacy); 2) employing spatial forms, such as bridge, atrium, veranda, piazza, arcade, and balcony that enhanced public connections. Clearly Student 05 took "assessment and feedback" steps here. S/he identified the initial layout of columns and space as potential constraints for "connections" and decided to "break up the existing column grid" and "angle rooms to have a better outside view." In addition, Student 05 realized that the split restaurant area might cause food transportation problems and that codes must be considered. After considering these constraints and rethinking the design approach of the restaurant, Student 05 refined the design and proposed a ramp as the main entry connecting the ground floor and basement in order to accommodate the code. Student 05 also proposed an atrium to expand "vertical" connection between floors and to open the basement to cooperate with upper floors. Apparently the atrium concept suggested to Student 05 the idea of "pulling light into the building", which led to the solution of "opening up the second floor facade". Finally, Student 05 developed an overall design solution by integrating all the partial solutions.

Analysis for Student 12's design process

Based on Student 12's previous research, Student 12 defined his/her core vision as "biophilia," which s/he believed to be beneficial to the self-healing process. As Student 05 did, Student 12 tried to elaborate this abstract vision by identifying categories of related goals. Using abductive logic during the process, Student 12 formulated the following five goals:1- Introducing daylight into the building, which was considered as a key factor to health; 2- Making residents feel like being outdoors within the building; 3- reducing noise; 4- connecting occupants to nature; and 5- adopting asymmetric form as nature in design. What drew our attention was that Student 12 quickly provided detailed design solutions for 2, 3, and 4. S/he proposed use of natural materials to provide an outdoor feeling, a vegetation screen to mitigate noise from street, and an individual platform area for occupants to enjoy and plant in order to achieve connection to nature. We concluded that Student 12 went back and forth in the steps of goal formulation, design problem identification, and design sub-solution. We could not identify separation of three steps in his/her thinking process. It seemed that this student used abductive logic and pragmatic maxim (maybe unconsciously) in the process of searching for potential goals and solutions related to the core vision of biophilia.

Student 12 stopped the design concepts/solutions development for a while and turned to the functional configuration of the floor plan. Without mentioning social interactivity as a significant issue for health, s/he claimed that the "flow of people" was the core concept in the design. Actually if Student 12 had explored a stronger connection in this design thinking process, s/he might have been able to propose a stronger justification and improve the overall quality of the design. Revelation of insights such as this is one of the potential values of the study of design thinking model. Student 12 organized the 1st floor plan in order to enhance the "physical and visual connections" and created visual connection between services and the public. S/he further developed this concept by specifying that the loading dock, retail, services, and elevator should be located on the south side of the building and that retail facilities should be on the corner for visual access to Division St. Both of these two processes clearly facilitate abductive logic.

Then Student 12 reviewed his/her earlier concepts to make necessary changes. S/he "enhanced the asymmetry concept on each level" and introduced green space. This student also evaluated previous sketches and recognized some contradictions among concepts. For example, Student 12 changed the original shape of the platforms to a rectangle to enable them to work better with the overall scale. After combing these different design solutions, the student proposed a final design.

Analysis for Student 25's design process

Student 25 described the origin of his/her inspiration as the historic context of the building, which was first built in 1920s: "I want to be inspired with something from the time period…I thought about music from the 20's, when jazz was most popular". After further developing the inspiration of jazz, s/he decided to adapt the image/shape of a record player to the floor plan. Later this student decided a pattern of overlapped circles could express this idea. Then Student 25 stopped the design concept stage and moved to floor plan configuration. First, s/he "worked out a list of rooms and spaces" and "categorized them by floor." After that, Student 25 started to "draw bubble diagrams based on adjacency requirements"

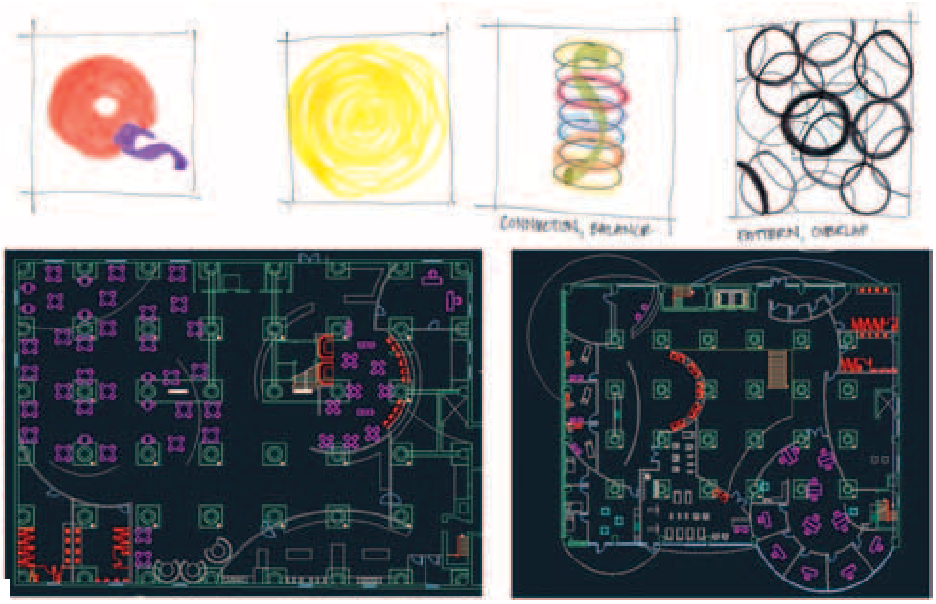

Figure 3. Design process of Student 25

and developed block diagrams of the spaces needed on each floor. Block diagrams and the overlapped circle-shape concept helped Student 25 finish the floor plan (**Figure 3**).

It seemed the student's vision/design solution did not come from users' needs or the student's research, but rather from his/her personal preference of a certain spatial pattern. Student 25 did not identify any design problem and his/her proposed design did not respond to any potential design problems so it cannot even be considered a design solution. In addition, evidence of assessment and feedback was absent in his/her process. We could not identify significant adjustments of the initial adjacency arrangement. His/her final product was also arguably unsuccessful. A model of design thinking process that has been introduced and taught in the beginning stage of the studio might be beneficial for this situation.

Analysis for Student 40's design process

Based on Student 40's research, Student 40 described his/her vision as achieving an idealistic condition that "human bodies work efficiently and naturally." Student 40 admitted that at this point, s/he did not know how to achieve this condition in the building. As a result, student 40 turned to case studies for help: S/he reviewed McDonough's research and works, and then made a list of four basic elements s/he could further work with: 1- natural ventilation; 2- daylight; 3- recycling water; and 4- passive solar design. Student 40 examined a large range of potential design concepts under pragmatic maxim, including the following categories: 1- project site; 2- water management; 3- materials and resources; 4- air quality; and 5- energy. Each of the categories contained several concepts/goals s/he would like to address in this design project.

Then this student conducted a quick evaluation of these concepts to see whether they were practical for this building. Student 40 emphasized passive solar design because the southern side of the building was shadowed by an existing building. This evaluation clearly benefited the proposed design solution, specifically resulting in proposals for "solar panels" and a "light collection well" in the middle of the building. Researchers could easily identify abductive logic and creative bridge in the process. Without clearly realizing it, student 40 successfully went through the design alternative development process in the model to explore and choose optimal design solutions. After refining the design solution in each category, Student 40 moved to draw a floor plan by fitting these concepts into it. Student 40 struggled with the constraint of limited space for residential function and then solved it by employing an angled pattern to allow larger rooms (**Figure 4**).

RESULTS

From the analysis of the design thinking process of each student under the framework of previous literature, some similarities during their design thinking process can be identified. In the vision formulation stage, almost every student (except Student 25) developed his/her vision by understanding the clients' needs for healthcare. Firstly, throughout their research, they looked for what was important for healthcare and how to achieve it theoretically. During this research, each student developed an initial idea (a big vision such as social interact, biophilia, etc.) to reach the favorite idea and continued working with this idea during the whole process. Then they tried to elaborate this big vision and propose more specific concepts/goals from literature review. In this elaboration, students

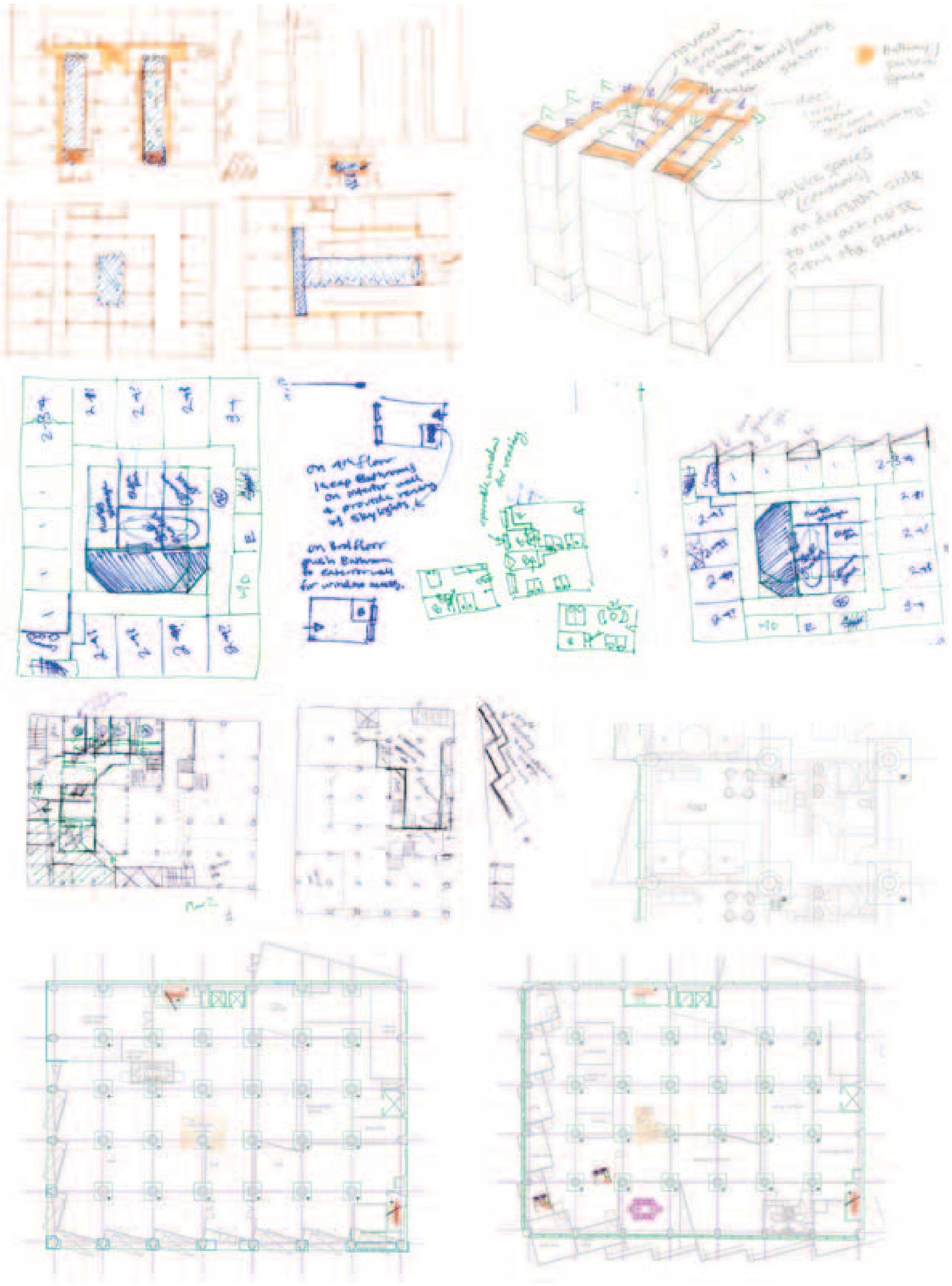

Figure 4. Design process of Student 40

generally adopted blinkered approach and focused on the favorite idea. They usually generated design solutions together with these concepts/goals. When applying these design solutions/concepts to this project, students usually met conflicts between their concepts and practical conditions of the building, or between the concepts themselves.

While students struggled with constraints, creative bridge occurred to solve the constraints of students design concepts and/or solutions. Therefore, students' struggles and efforts to overcome the restraints led to refined design solutions. One good example of creativity is Student 40's design solution of "light well." S/he identified introduction of passive solar design as a design concept but soon realized that the southern side of the building was blocked. Then creative bridge happened and led the student to the design solution of solar panels and a light collection well instead.

After solving the constraints of their design solutions, each student moved forward to integrate the design solutions with a floor plan. Students generally followed the basic steps of design process either intentionally or unintentionally.

We looked into the relationship between quality of the students' design products and quality of their processes, in order to determine whether following a good design process helps a student achieve a better quality of design products. In order to assess the quality of design process and quality of students' design products the criteria were used as follows: students' design processes, hard skills (analytical, critical, and technical thinking), soft skills (communication) and product. We concluded that most of the students followed the basic steps of design process. Among four students, two of them emerged as significant in positive and negative ways: Student 40 and Student 25. During the examination of the Student 40's design process (**Figure 5**), we saw that his/her work demonstrated a clear process and Student 40's design process proceeded in the continued improvement of the design while students 25 failed to demonstrate a clear process and improvement of the design (**Figure 6**).

Student 40's hard skills (i.e. analytical, critical, and technical thinking) were assessed as much better than student 25's. Student 40's design responded to pragmatic and abstract constraints and his/her critical and

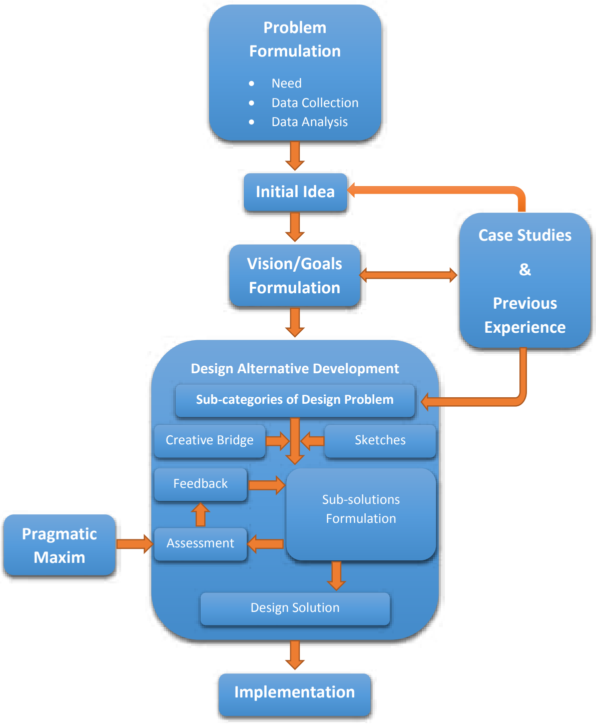

Figure 5. Student 40`s design process diagram

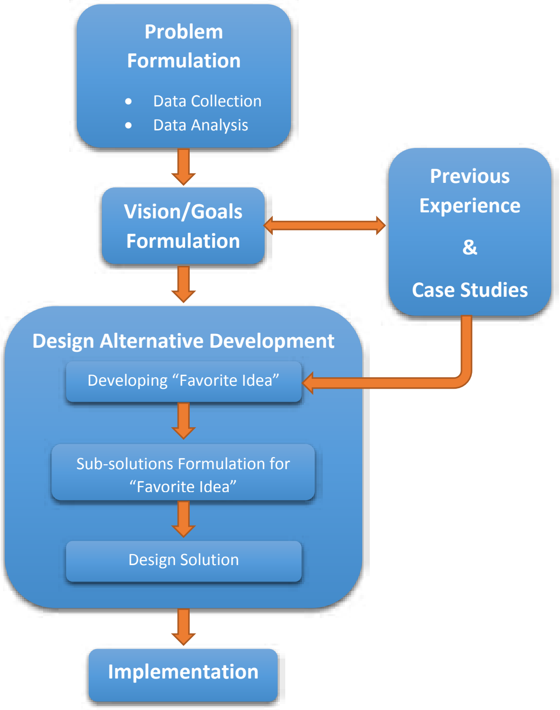

Figure 6. Student 25`s design process diagram

analytical thinking were successful. Student 40 integrated pragmatic constraints into the design well. In addition, Student 40's design exhibited a cohesive integration of ideas. On the other hand, Student 25 did not respond to pragmatic and abstract constraints by integrating them logically into the design. Student 40's soft skills also seemed better. The design representations clearly communicated the scope and depth of Student 40's design work. Furthermore, Student 40's design intentions were clearly represented. In contrast, Student 25's design representations were weak and did not represent the student's intention well. Overall, Student 40's design innovation as well as the cumulative quality of the end-of-studio design were considered stronger than Student 25's final product. We concluded that if a student follows a better design process, chances are greater s/he will end up with a better product.

DISCUSSION AND CONCLUSION

The aim of this paper was to explore the nature of design thinking. Our goal was to create a model that describes the process of design thinking, aiming to produce improvements in teaching approaches. Considering the theoretical foundations of previous studies, we observed student designers as they worked in a design studio and examined the documents they produced. Students' design thinking processes, the relationships between quality of their process, and quality of the students' design products were examined. Our study revealed that students generally follow the basic steps of design process. Examination of the students' quality of the processes and design products showed that a student who follows a better design process may have a better design product.

We wanted to know whether students followed a recognizable process. If they did, similarities and differences when compared with our process model were investigated. We found that the vision/goals formulation stage and design alternative development stage were more tightly related than what we expected. The students did not clearly separate design concept/goals from solutions. Instead, after identifying their initial visions, they proposed a concept together with its relevant design solution. Contrary to most popular design processes in literature, creative bridge was not limited to design solution formulation. It also happened in the goal formulation process. One of the renowned designers, Phillippe Starck, designed a famous lemon squeezer, "Juicy Salif". Phillippe Starck`s creative leap also happened during the goal formulation process (Lloyd and Snelders, 2003). Phillippe Starck was invited by Alessi to design a new product of lemon squeezer. Starck went Italy to visit Alessi and discuss the project. When arrived, he went a restaurant and waited for his food. While waited, he was thinking about the lemon squeezer project to come up with a nice lemon squeezer. He began drawing the sketches and he come up with "squid-like" lemon squeezer. His "squid-like" concept was arose prosaically by applying an analogy, the form of squid, to the problem that was in Starck`s mind (Lloyd and Snelders, 2003; Cross, 2011). Likewise, students employed creative bridge in developing relative concepts/solutions after defining core visions. They also applied pragmatic maxim in this step. Lastly, we noticed that none of the students mentioned the assign weight and priority process. Possibly students did assign weight and priority without explicitly indicating it in their archival materials.

One of the common approaches was observed among students is that students in general kept asking questions and looking at different concepts. However, when students got a good idea for the design solution they in general stuck with that idea instead of coming up with different alternatives for design solutions. After that students adopted a blinkered approach to focus on that particular solution and broke it down with supporting materials. This design approach is consistent with Rowe's (1994) and Cross's (2011) argument for design thinking process. According to Rowe and Cross, a designer can adopt blinkered approach and doggedly "pressing on" a particular solution concept. Cross (2011, 21) argues that this issue "seems to be to do with the predominance of the primary generator in restricting the designer's thought patterns". Rowe (1994, 36) explains this with "dominant influence that is exerted by initial design ideas on subsequent problem-solving directions". Both Rowe and Cross, however, points out a danger. A danger that designers fail to see their inadequacies. Rowe points out that even when serious problems are encountered, a significant effort is devoted to make the initial idea work, instead of backtracking and adopting a fresh point of departure. Cross (2011, 22) explains this with "weaknesses in designer's attitude and approach". Why should designers (even experienced designers) behave in this way? Cross expounds this behavior that designers have to devote some substantial cognitive effort in generating "ordering principle" for a solution concept to be structured and they are reluctant to do so (Cross, 2011). We suggest that in design studies, instructors should make sure that students do not invest too much effort into early ideas of solution concept or do not let them attach too much to favorite idea. Instead, students should be encouraged to be more objective, more concerned to generate and evaluate a range of options (Cross, 2011).

Based on the results above, three critical stages that affect the final quality of a design product were identified. Firstly, the quantity and quality of work during the design concepts/goals formulation stage significantly affected the quality of design products. The more effort devoted to this stage to come up with different alternatives for design solutions, the better were the design solutions and final design plan. Rushing to the floor plan stage did not lead to good results. Secondly, dealing with initial ideas versus constraints proved to be one of the most valuable ways to develop a good design. Cross (2011, 105) states that "…perhaps innovative design arises especially when there is a conflict to be resolved between the (designer's) high-level problem goals and the (client's) criteria for an acceptable solution. Creativity is often stimulated when there is a conflict to resolve…". The conflict may lead to the utility of abductive logic and creative bridge to improve the quality of final design solution. On the contrary, ignoring conflicts result in loss of a good design opportunity. Thirdly, assessment/feedback process also played an important role affecting the final quality of design product. Students who paid significant attention to feedback on their concepts usually succeeded in utilizing abductive logic/pragmatic maxim to improve their initial ideas.

This research provides a fresh perspective on cognitive design approaches. The model (**Figure 2**) we developed contributes to design pedagogy by providing a patterned cognitive-based design analysis approach that can be beneficial for both instructors and learners in design disciplines. Having an explicit structure, this model can help instructors emphasize critical concepts and help learners establish their design concepts and solutions in a more eloquent manner targeting a specific context. The model's pioneering approach also overcomes some deficiencies of traditional teaching methods and supports visions for an improved framework of design pedagogy.

This research had some limitations. Students in this studio had limited time in keeping the records of the design thinking process, which may have affected the quality of their archive files. Most of the students were fourth-year undergraduate students who may have had little experience in developing a thorough and complete archive file. The final conceptual model was based on an interior design problem in a student studio, which is relatively simple and straightforward compared with larger projects that are more common. As a result, future studies are needed in order to test and improve the model based on the context of broader issues. This model helps evaluate the design thinking process and proposes sophisticated measures for the assessment on quality of design thinking. The lack of valid measures may hamper the application of the model.

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Alındı: 20.09.2014; **Son Metin:** 01.10.2015

Anahtar Sözcükler: Tasarım düşüncesi, tasarım süreci, kötü problemler, gözlemsel çalışma, stüdyo

TASARIM DÜŞÜNCESİ: ARŞİV BELGELERİNE DAYALI BİR MODEL GELİŞİMİ

Tasarım düşüncesi tasarımcılara 'kötü' ve 'kötü tanımlanmış' gerçek dünya sorunlarını çözmeye yardımcı olan yaratıcı ve çözümleyici bir süreç olarak tanımlanır. Tasarım düşüncesi ile ilgili çalışmalar tasarım pedagojisinde önemlidir, çünkü bu çalışmalar eğitimcilere daha incelikli ve arıtılmış tasarım pedagojisi yaklaşımları geliştirmelerine yardımcı olur. Bu çalışma yazına dayalı tasarım düşüncesi modeli oluşturup, öğrencilerin tasarım düşüncesi sürecini ve eserlerinin genel niteliğini değerlendirmek için son sınıf iç mimarlık öğrencilerinin tasarımları üzerinde durmaktadır. Bu çalışmanın amacı, daha önceki çalışmaların kuramsal bilgileri temeli ışığında tasarım stüdyosu öğrencilerinin çalışmalarını kullanarak tasarım düşünesinin doğasını keşfetmektir. Bu çalışma üç aşamadan oluşmaktadır: 1) model oluşturma, 2) öğrencilerin tasarım süreçlerinin incelenmesi ve değerlendirilmesi ve 3) oluşturduğumuz model ile öğrencilerin tasarım düşüncesi süreçlerinin karşılaştırması. Öğrencilerin tasarımlarının incelenmesi sonucunda öğrencilerin genellikle tasarım sürecinin temel adımlarını takip ettikleri ortaya çıkmıştır. Ayrıca daha iyi bir tasarım süreci izleyen öğrenciler daha nitelikli ürünler ortaya koymuşlardır. Buna ek olarak, tasarım ürünün nihai niteliğini etkileyen üç önemli aşama da tespit edilmiştir.

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