An Integrated model of Reflective Practice for Learning and Solving Design Problems

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Abstract

Design tasks are ubiquitous in our everyday life. Previous research shows that reflective thinking is important in solving design problems. Related research has attempted to capture designers' reflective thinking process. Yet the explicit impacts of reflective thinking on design performance have been ignored. To empower the full capacity of reflective practice, we have developed a model of reflective practice which can guide educators in examining and facilitating reflective practices in solving real-world design problems. This model uses three dimensions to guide the understanding of designers' reflective thinking: (1) the points of reflection, indicating the timing that reflective thinking occurs during a design process, (2) the objects of reflection, showing different types of objects that designers may reflect upon during a design process, and (3) the quality of reflection, referring to the depth of each reflection point. This framework provides important aspects of reflective thinking situated in the design process, which can be an important foundation for further research on reflective thinking in design task. Furthermore, this framework can guide educators to derive appropriate strategies for facilitating novice designers' reflective thinking.

Introduction

Design tasks are ubiquitous in our everyday life, such as architectural design, software design, mechanical engineering design, industrial design, and instructional design. Moreover, most of artifacts that we are using for our daily life are the results of professional design activities such as buildings, computers, word processors, instructional materials. "Design is a disciplined inquiry engaged in for the purpose of creating some new things of practical utility" (Rowland, 1993, p. 80). It is the foundation for manufacturing, constructing, or developing objects. Not only that, design also has major impact on primary business outcomes: cost, timeliness, and the quality and capability of the products (Boehm, 1970; Fleischer & Liker, 1992; Goel & Pirolli, 1992). Design is clearly a very important element for the advancement of human life, but it is not a natural talent for everyone. Indeed, the very nature of design problems makes it difficult for many neophytes to produce an effective design.

The Purpose of the Study

In attempting to improve design problem solving ability, there has been extensive literature investigating the process of solving design problems (Cross, 2000; Jonassen, 2008; Lawson, 1997) and how novice and expert designers differ in a process (Atman et al., 2007; Newstetter & McCracken, 2001). It has been suggested that reflective thinking plays a critical role in this process (Adams, Turns, & Atman, 2003; Rowland, 1993; Schön, 1987). However, a paucity of empirical studies in relation to reflective thinking situated within design problem solving context has provided needs for understanding of what in essence designers reflect upon, how they reflect during their design processes, and in what ways their reflective thinking influences their ability in solving design problems. Without investigating these aspects, it might be unconvincing to propose strategies for facilitating designers' reflective thinking ability so as to advance their design skills. Thus, the purpose of this paper is to develop a conceptual framework that attempts to provide a comprehensive understanding of reflective thinking situated within the context of solving design problems. Such understanding will allow us as researchers to see the associations between designers' reflective thinking and their ability in solving design problems. Based on the framework, we are hoping to help educators in the field of design to develop a series of instructional strategies that will facilitate designers' reflective thinking in the process of solving design problems. In this paper, we will discuss the nature of design problem and two different processes of solving design problems. Then we will propose three possible dimensions of reflection related to a design process. Finally, we will conclude our paper with implications of our model and further research directions.

The Nature of Design Problems

Design is a purposeful and goal-oriented activity. According to Gero (1990), "the metagoal of design is to transform requirements, generally termed functions, which embody the expectations of the purposes of the resulting artifact, into design descriptions" (p. 28). Design problems are known for its ill-definedness and complexities. Design problems have been categorized as a type of ill-structured problems (Jonassen, 2000; Reitman, 1965; Simon, 1973) with characteristics that include:

- the lack of information in the goal state, in the start state, and in the transformation processes from the start to the goal state (Goel & Pirolli, 1989; Reitman, 1965; Simon, 1973),
- initially no definite criterion for product evaluation and stopping rules (Simon, 1973),
- no predetermined solutions paths or no right or wrong answers (Goel & Pirolli, 1989; Simon, 1973), and
- the need for integrating multiple knowledge domains (Simon, 1973).

Other features particular for design tasks include the large size and complexity of the problems (Goel & Pirolli, 1989), the limited or delayed feedback (Goel & Pirolli, 1992), the context-dependent characteristics (Rowland, 1993), and the independent function of the final product from designers (Goel & Pirolli, 1989). In addition, contextual factors have contributed to the performance of design tasks, such as the support from clients, the budget, the timeline, the politics within the organizations, and the availability of the tools and resources (Wedman & Tessmer, 1993). Considering these factors, designers without adequate training are likely to be overwhelmed or directionless when solving design problems.

The Process of Solving Design Problems

Divergent Design Processes in Solving Design Problems

Helping novice designers learn to solve design problems is a challenging task for educators. It is difficult to introduce a set of systematic procedures as the best design guidelines for a novice to follow. Each designer and different design tasks are likely lead designers to adopt different approaches when solving design problems. The adoption of divergent approaches can be affected by various factors, such as designers' knowledge, skills, perspectives, previous trainings, and experiences; working environments; available resources; and interactions with stakeholders (Lawson, 1997; Rowland, 1993). Based on the existing literature, the design processes can be classified into two approaches: problem-driven and solution-driven approaches (Cross, 1982; Lawson, 1997). In different design-related disciplines such as instructional design

(Gustafson & Branch, 2002; Visscher-Voerman & Gustafson, 2004), architectural design (Lawson, 1997) , and engineering design (Atman et al., 2007; Eastman, 1970; Heywood, 2005), these two approaches can be consistently found in professionals' design activities.

Problem-Driven Approach

Designers using problem-driven approach are depicted as scientist-like designers (Cross, 1982; Lawson, 1979). The goal of their design is to achieve an optimized solution (Simon, 1981). With this end, they largely engage in defining and analyzing problems based on the collected data at the onset of the design process to achieve a thorough understanding of the problem. Their design process does not proceed to solution generation until they fully complete the analysis of the problems (Cross, 1982). With each of the generated solutions, they will then evaluate its feasibility against to the pre-defined objectives, functions, and criteria so as to arrive the final decision. Designers with problem-driven approach tend to process design tasks in a linear fashion (Heywood, 2005). They see design process as a sequence of discrete steps. Even though existing models with problem-driven approach have been criticized, scholars in this school argue that such models can not only provide learners important design skills (Radcliffe & Lee, 1989), but also enable educators to conduct assessment on students' performance (Heywood, 2005). Several models illustrating the design activities with problem-driven approach have been proposed (See Fig. 1). For example, Krick (1969) studying about engineering design presented a five-step design process, which involves problem formulation, problem analysis, search for alternatives, decision, and specification. Maver (1970), in the field of architectural design, depicted that design process begins with analysis, synthesis, appraisal, and decision. The analysis stage in Maver's model corresponds to the problem formulation and problem analysis stages in Krick's model. Comparing to these models developed in the late 1960s and early 1970s, recent models seem to be more elaborated. For example, the Dick, Carey, and Carey's model published in 2009 is the elaborated version of their first model developed in 1978. The most recent version of the model in instructional design have articulated the design process in a much specific manner, which includes assessing needs to identify goals; analyzing instruction, learners, and contexts; writing performance objectives; developing assessment instruments; developing instructional strategies; developing and selecting instructional materials; designing and conducting formative evaluation; and designing and conducting summative evaluation (Dick, Carey, & Carey, 2009). Similar to the Dick, Carey, and Carey's model, Eide and his colleagues also segmented a design process into smaller pieces, consisting of identifying a need, defining a problem, searching information, establishing constraints, developing criteria, generating alternative solutions, analyzing the solutions, and making decisions (Eide, Jenison, Mashaw, & Northup, 2002). Even though design models developed in the 21st century are more detailed and specific, their design models in principal are not deviated from the ones established in late 1960s and early 1970s. From the problem-driven approach models we have reviewed here, we have identified six essential steps being shared across these models: (1) identifying a goal, (2) gathering information, (3) defining a problem, (4) generating solutions, (5) evaluating solutions, and (6) making a final decision. This six-step model is used to compare with the design process that is based on the solution-driven approach.

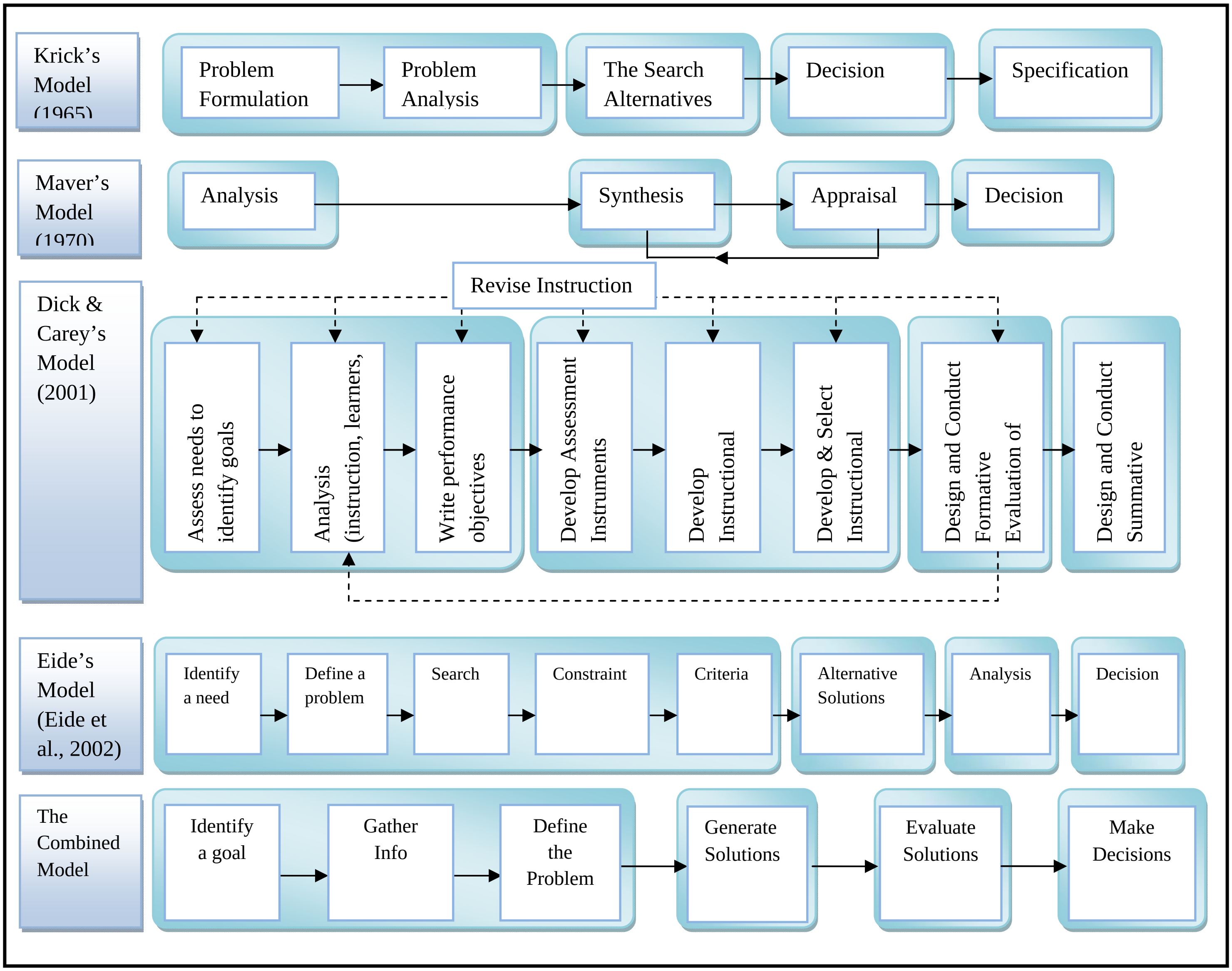

Figure 1. The Prescriptive Design Model with Problem-Driven Approach

Solution-Driven Approach

Dissimilar to the problem-driven approach, the solution-driven approach is not systematic and prescriptive. Additionally, the aim of designers rooted in solution-driven approach is to achieve a satisfactory solution, but not an optimized one (Gregory & Design and Innovation Group at University of Aston in Birmingham, 1966; Jonassen, 2008; Simon, 1981). The designers targeting to generate an optimized solution tend to complete the exhaustive analysis of the problem and finalize the problem definition before proceeding to generate any potential solutions because they believe the importance of analyzing all the essential information regarding how things are before they attempt to generate solutions for the design problem (Cross, 2000; Simon, 1981). Therefore, their design process is fixed and linear. However, many scholars have identified a number of drawbacks by rigorously following the prescriptive problem-driven approach models. First, due to the linearity of the problem-driven approach models, designers have higher possibility to oversimplify the process of solving the complex nature of design problems (Puk, 1995; Robinson, 1986). Second, the definition of the problem established by the problem-driven approach models in the early stage of a design process tends to be fixed and is rarely refined after its formulation (Robinson, 1986). Third, in a realistic design process in practice, most of the problems are not susceptible to exhaustive analysis before any conjecture is developed due to the unavailability of overarching design brief (Cross, 1982; Darke, 1979; Jonassen, 2008; Lawson, 1997). With these criticisms, many scholars believe that solving design problems with solution-driven approach is a more practical way (Cross, 2000; Darke, 1979; Jeffery, 1991). Furthermore, the design process with solution-driven approach is descriptive not prescriptive, which will prevent designers from rigidly following the procedure to conclude the design (Cross, 2000).

Scholars proposing to solve design problems with solution-driven approach conceive design as an iterative cycle of decision making (Accreditation Board for Engineering and Technology, 2007; Cross, 2000; Hybs & Gero, 1992; Jonassen, 2008; Rowe, 1987). During design process, designers need to make several decisions upon the constraints, criteria, functions of design products. As Jonassen argued (2008), design process is a series of constraint explorations and constraint operations. The constraints are unveiled through the analyses of the conjectured solutions. In turn, later identified solutions are generated based on the emergence of the constraints. With the same concept, objectives, criteria and functions of a problem are usually established after the conjectured solutions are evaluated, analyzed, or criticized. All in all, the stage of problem definition can hardly be completely concluded at very beginning of a design process. Rather, both solutions and problem definition are gradually uncovered from the start to the end within the iterative design process. The similar argument are found in Cross's article (2004). Cross summarized that "the [design] problem cannot be fully understood in isolation from consideration of the solution" (2004, p.434). The solution conjectures and definition of the problem co-evolve throughout the entire design process (Kolodner & Wills, 1996; Ullman, 1988). It is believed that design process has no clear separation between the problem analysis and the solution generation activities. In fact, these two main activities are inseparable and interrelated (Darke, 1979; Eastman, 1970; Hybs & Gero, 1992). To illustrate the design process deriving from the solution-driven approach, some descriptive models are identified (Fig 2). Darke (1979), bringing a new insight of design process in the late 1970s, proposed the importance of anchoring on a designer's self-imposed particular objective or small groups of objectives to come up with a conjecture at the early stage of the design process. Then, using that conjectured solution to understand the design problem by analyzing the solution. Thus, the iterations between solution generation and problem definition stages are expected to occur frequently in one's design process. In the 1980s, Robinson (1986) proposed a view on design similar to Darke's conception, delineating design as an exploration. What she meant by exploration is

> that there is more than one way to proceed, that the goal itself is not fully known, that the method of getting there has an impact on where you end up, and that the end point is only a temporary end point or resting spot, and that it is one of many possible such points. (p.68)

More specifically, her heuristic conception of design process starts off with a designer's idea. With that idea, the designer will be able to uncover his or her assumptions and hypotheses on the design problem. After more assumptions and hypothesis have been revealed, the designer then further generate other ideas that fit the designer's continuously changing conceptualization of the

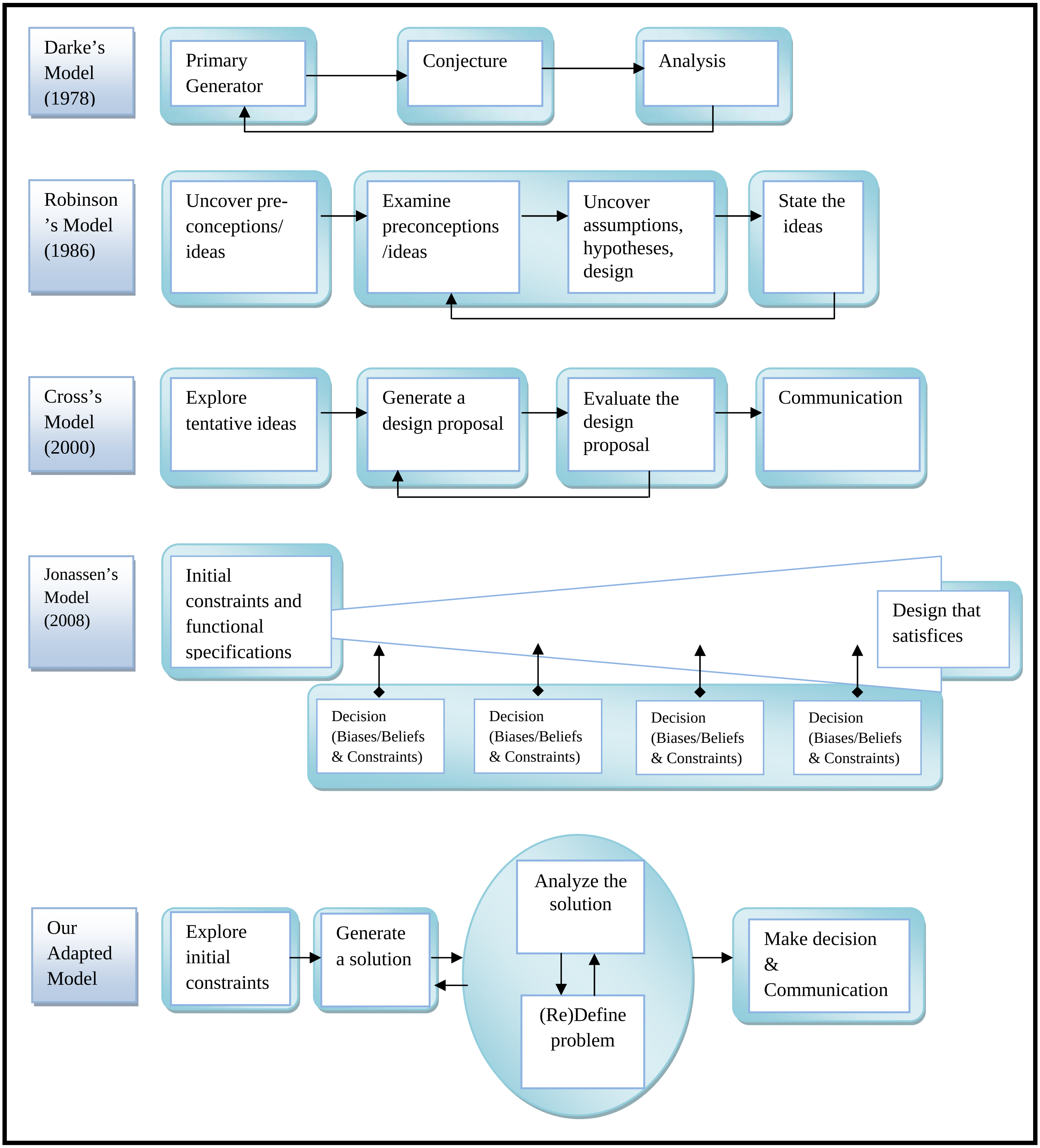

Figure 2. The Descriptive Models with Solution-Driven Approach

design problem. In addition to the scholars in the field of architectural design, Cross (2000) studying engineering design affirmed the significance of beginning a design with a tentative idea. This tentative idea is then used to generate a design proposal so that the proposal can be subjected to the following evaluation. In most cases, the results from evaluation yield several loops of decision-making between generating a design proposal and evaluating the design proposal activities. Another scholar from the field of instructional design, Jonassen (2008) also perceived the iterative nature of design process. He argued "what makes design an iterative process is simultaneous constraint satisfaction and constraint propagation" (¶ 13). Several cycles of decision are made based on the emergence of constraints, personal beliefs, and biases. The design concludes when it satisfies the constraints embedded in the context. A design process is cyclic, iterative, and spiral. No specific stages or phases are provided to illustrate the criticality of decisions points throughout the process.

In an attempt to identify reflective activities during the process of solving design problems with solution-driven approach, we adapt the existing models and describe the design process with four main components, including (1) exploring initial constraints, (2) generating a solution, (3) possible interplay between analyzing the problem and defining the problem, and (4) making decision and communication.

The Importance of Reflective Thinking in Solving Design Problems

Reflective thinking is a critical element to facilitate designers' design problem solving skills. Several researchers have argued the importance of reflective thinking in the process of solving design problems (Adams et al., 2003; Greeno, Korpi, Jackson, & Michalchik, 1990; Rowland, Fixl, & Yung, 1992; Schön, 1983). In the following, three main reasons are identified to illustrate the significant role of reflective thinking for designers.

Allowing Designers to Control Their Design Process

As argued by Rowland (1993, p. 86),

> Design expertise is thought to lie not only in knowledge and skills, but in the designers' ability to reflect on his or her actions… The designers must be a self-organizing system capable of controlling both rational and creative processes, knowing when to apply each and varying strategies and tactics as the situation demands.

During the process of solving design problems, designers are reflecting on the design process itself, their existing knowledge that is related to the task, their skills, their previous relevant experiences, the final strategies and outcomes, the feedback from stakeholders, the policies of their organizations, the social trends, and/or even their personal taken-for-granted beliefs. By reflecting upon these elements, the professionals keep controlling the process and exploring any possibilities in an effort to identify better solutions. Thus, a better outcome can be achieved. Without reflective thinking involved in the process, designers will hardly come up with strategies that are relatively effective.

Enabling Designers to Handle New Design Problems

Another argument made by Schön (1983) that illuminate the essential role of reflective thinking in solving design problem is that by engaging in reflection designers will be able to solve the problems that embed messy and indeterminate zones. As Schön (1983) argued it is difficult for professionals to handle all the situations only by adopting theories, techniques, or systematic procedures because the majority of the problems that they face in real-world practice fall outside the range where they can solely apply professional knowledge learned previously. Instead, the professionals will depend extensively on “a kind of improvisation, inventing and testing in the situation strategies of [their] own devising” (Schön, 1983, p. 5). The driving force to engage professionals in the process of improvising, inventing, and testing the strategies is their reflective thinking. With the reflective process, the designers are more competent in solving design problems that are not well-formed at the outset of a problem solving process.

Increasing the Frequency of Iterations during a Design Process

The last argument demonstrating the importance for designers to reflect is that reflection can increase the frequency of iterations. Based on the expert designers’ behaviors, iterations in the design process are highlighted as an important element. The process of iterations involves professionals being actively engaged in reflection (Adams, 2001). Without constant reflection, designers will not revisit the problem repeatedly to re-frame the appropriate problem space and carefully re-examine their proposed solutions. The designers’ iterative design process and their reflective thinking are interdependent. The frequent transitions between problem framing and solution generating coincide with the idea of situations’ back-talk (Schön, 1987) . Schön proposed situation’s back-talk and used architectural design as an example to illustrate the role of reflection in the design task: “As Quist reflects on the unexpected consequences and implications of his moves, he listens to situation’s back-talk [and] forms new appreciations, which guide his further moves” (p.57). The reflective conversation between a professional and a task is used to continually re-define the problem scoping with the proposed solutions. It is the cycle of appreciations, actions, and re-appreciations that drives the iterative design process. Extending from Schön’s belief in reflection, researchers (Adams et al., 2003; Cross, 2004; Lloyd & Scott, 1994) in engineering design also agree with Schön that reflection is the key element to achieve high-quality design because it helps increase the frequency of iterations. Similarly, scholars in the field of instructional design contend that reflection involves an ongoing cyclic monitoring, evaluating, and revising during instructional design process (Rowland, 1993; Shambaugh & Magliaro, 2001).

Based on the arguments made by Schön (1983, 1987), Rowland (1993) and other scholars in the fields of instructional design and engineering design, it is indisputable to deem that reflection has played a critical role in facilitating one’s design problem solving skills. With continual reflection, designers can function as a self-organizing system to control the design process; they are able to solve the problems when they encounter new problematic situations; and their design process will involve several cycles of iterations so that high-quality design can be attained at the end.

Definition of Reflective Thinking

Reflection has been widely discussed and applied in a number of disciplines. John Dewey (1933) first distinguished reflective thinking from other types of thinking, such as imagination. He defined reflective thinking as “active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds (evidence) that support it and the further conclusions to which it tends” (p.9). He further explained that “reflective thinking involves (1) a state of doubt, hesitation, perplexity, mental difficulty, in which thinking originates, and (2) an act of searching, hunting, inquiring, to find material that will resolve the doubt, settle and dispose of the perplexity” (p.12). To engage individual in reflective thinking, Dewey argued that it is necessary to cultivate one's three attitudes: open-mindedness, whole-heartedness, and responsibility. With both concept knowledge and above-mentioned dispositions at hand, one's reflective thinking can truly enhance his or her problem solving skills.

Following Dewey's path, Donald Schön (1983, 1987) also finds the role of reflective thinking in solving design problems important. By interacting with the problematic situations, a practitioner will research the possible courses of actions and derive a new theory for a particular situation based on his or her previous experiences and already established theories. Reflection is regarded as the interactive conversation between the practitioner and the situation. The practitioner reflects-on-action when he or she thinks back on what has been done and how the similar situations can be better solved in the future. Another types of reflection, reflection-in-action explains that how a practitioner's thought reshapes what he or she is doing while doing it (p.26, 1987). Consistent with Dewey's view, Schön also believed that the origins of one's reflective thinking come from an element of surprise, such as unpleasant or pleasant moments, unexpected result, or unusual actions. This surprise usually conflicts with practitioners' tacit knowledge, which he called knowing-in-action. With this disequilibrium, some practitioners may select to attend to the situations and engage in reflection to solve the new problems, while others may set it aside and stay away from making more effort.

Another view of reflection consonant with Dewey's and Schön's ideas of reflection is Boud and his colleagues' (1985) model. They defined reflection as "an important human activity in which people recapture their experience, think about it, mull it over and evaluate it" (p. 19). Based on their definition, learners' experiences are recognized as one of the key components in arousing reflective thinking. The second component highlighted in the reflective process is helping learners become aware of their emotions and feelings. As the authors argued, both negative emotion and positive emotion can serve as the impetus for individual reflection. With negative emotion, an individual is led to reconsider an issue or a task at hand. By the same token, positive emotion can also stimulate reflection as the learner may have more confidence in reappraising his or her work and making further improvement for subsequent tasks. Another essential component of reflection discussed in Boud and his colleagues' book (1985) is learners' intent. Stated at the beginning of their book,

> Only learners themselves can learn and only they can reflect on their own experiences. Teachers can intervene in various ways to assist, but they only have access to individuals' thoughts and feelings through what individuals choose to reveal about themselves. At this basic level the learner is in total control." (p.11)

With strong intent, learners have greater opportunity to overcome barriers. As the saying goes, "Where there is a will, there is a way." Therefore, to facilitate learners' learning as well as reflection, careful attention must be paid to practitioners' intent. In general, Boud and his colleagues' model of reflection is consistent with that of Dewey (1933) and Schön (1983, 1987). Their discussion on reflection emphasizes its role in improving one's problem solving ability.

A Conceptual Framework for Examining Designers' Reflective Thinking

From the previous section, we have learned how reflective thinking occurs in the process of solving general problems. In the fields of design even though reflective thinking has been deemed as a critical element that facilitates designers' process of solving design problems and that helps improve design ability as well as design performance (Adams & Atman, 1999; Moallem, 1998; Rowland et al., 1992; Schön, 1987; Visscher-Voerman & Henk, 2007). However, due to a scant of empirical studies investigating how designers in practice reflect and in what ways reflection brings positive impact on designers' design ability, there is a need for having more comprehensive model that guide us on what kind of research needs to be done and that inform us how to facilitate reflective thinking during a design task in ways to enhance designers' design performance. With an aim to understand different objects (targets) that designers reflect upon, how deep they reflect upon each time, and how designers' reflective thinking associates with their design performance, a theoretical framework is thus developed.

The framework consists of three dimensions to understand designers' reflective activities situated within the design problem context, including points of reflection, objects of reflection, and the quality of reflection (See Figure 3). The *x* axis of the cube represents the timing of a designer's reflective thinking during the process of solving design problems. The very left end of the axis indicates the beginning of a designer's process of solving design problems whereas the other end of the line shows the conclusion of his or her design process. As for the *y* axis in Figure 3, it demonstrates the objects that designers reflect upon. These objects are categorized into three groups: reflection upon self, reflection upon artifacts, and reflection upon circumstances. For the *z* axis, it provides the different levels of designers' reflection, including single-loop, double-loop, and triple-loop reflective thinking, to demonstrate the depth of a designer's reflective thinking.

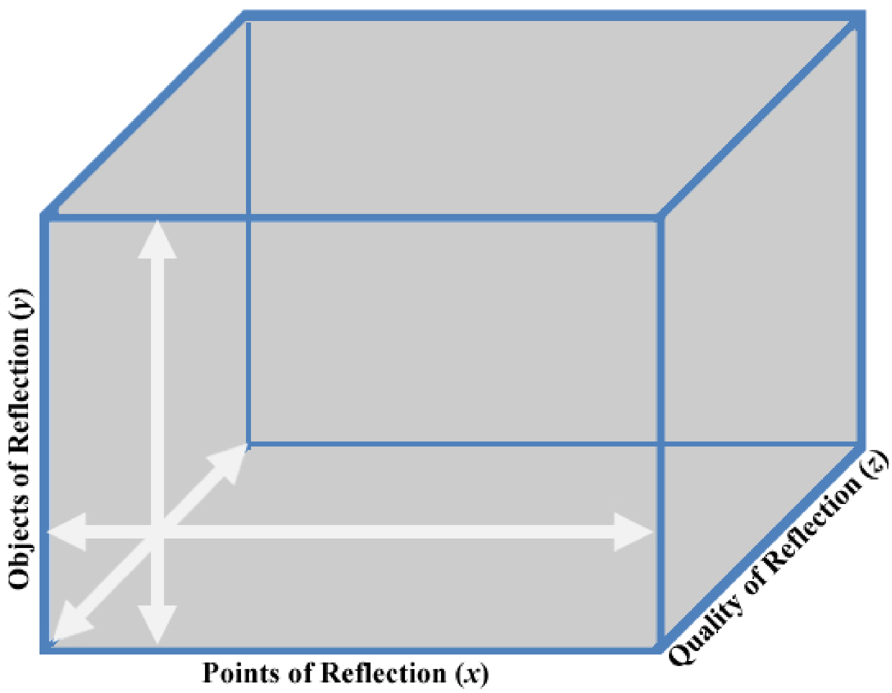

Figure 3. A Framework for Examining Designers' Reflective Thinking during Design Process

Dimension I: Points of Reflective Thinking

This dimension refers to the timings that each of reflective activities occurs during the process of solving design problems. As reflective thinking can happen at any time in any formats, the function of this dimension is mainly used to illustrate the timing that a designer is engaging in reflective thinking and its association with his or her design process.

A good design is a result of several cycles of iterations during a design process (Adams et al., 2003). In a study regarding the comparison of design processes between senior and freshman engineering students conducted by Atman and her colleagues (2005), more iterative behaviors were identified from the design process of senior engineering than freshmen engineering. Underlying these iterative behaviors is the designers' reflective practice. By being engaged in reflective thinking, designers will transition through more design steps, spend more time in iterative design cycles, and increase the possibility to transition back and forth from problem definition and solution generation stages (Adams et al., 2003). Scholars espousing the solution-driven approach argue that problem definition and solution generation co-evolve through the entire design process. The required component for such co-evolution is the designer's reflective thinking in the iterative design processes. By examining the timing of designers' reflective practice, scholars in this field will be in a better position to learn the interplay among designers' reflective thinking, their design process, and design performance. In addition, with the identification of reflective timings along with the designer's approach of solving design problems, we will be able to capture how designers adopting different approaches of design process reflect differently. Therefore, based on these findings in relation to designers' points of reflection, educators in the field of design will come up with the appropriate strategies to facilitate the iterative design behaviors.

Dimension II: Objects of Reflective Thinking

During the process of design, designers have engaged in several cycles of reflective thinking. Since solving design problems is a large, complex, and ill-defined task, designers'

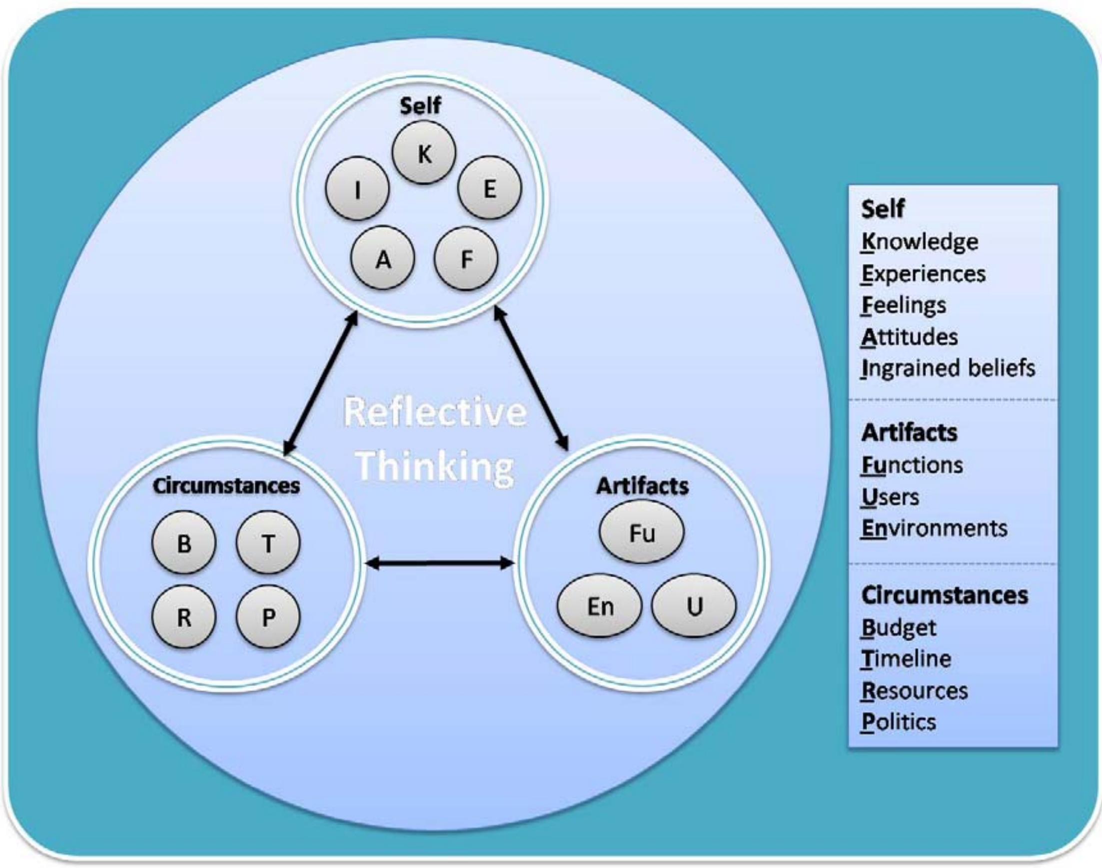

Figure 4. Dimension II: Objects of Reflective Thinking

reflective thinking can be messy and chaotic. Consequently, the objects (targets) that designers have reflected upon each time vary in a variety of aspects. It is further contended by Visscher-Voerman and Procee (2007) that "the concept of reflection is vague, meaning different things for different persons, and that students have difficulty in doing it" (p.344). To investigate how each different aspect affects one's design performance and further consciously plan strategies to facilitate novice designers' reflection in a design process, three different types of objects of reflection are identified in the following framework: reflecting upon self, reflecting upon artifacts, and reflecting upon circumstances.

Reflecting upon Self

One's self is an obvious target that designers usually reflect upon. Santiageo Calatrave, an engineer-architect, describes a design processes as a dialogue between designers' internal mental process and design objects:

> [Design] is very much a dialogue. This dialogue occurs through the designer's perception of the sketched concepts, and reflection on the ideas that they represent and their implications for the resolution of the problem. The design responds to the perceptions, reflections and implications, and so the dialogue between internal mental processes and external representations continues. (Cross, 2000, p. 20)

Reflecting upon self is also captured from the idea of self-reflection, which aims to examine designers' reflection on themselves. With self-reflection, designers will enable themselves to conquer potential conflicts in a design process as well as recognize their weakness in solving design problems (Li, 1996; Lin & Schwartz, 2003). When designers are in the process of design, they reflected upon diversified objects, including their knowledge level on the design task, related previous experiences, feelings, attitudes, and inner self.

Knowledge

To succeed in solving design problems, possessing the knowledge relevant to the design tasks is instrumental to a high-quality design. Design tasks often require designers to integrate multiple knowledge domains (Simon, 1973); however, in practice, designers can hardly equip themselves with all the necessary knowledge. Therefore, it becomes central for designers to recognize their lack of knowledge in a certain domain during a design process. With such recognition, they will begin to expand their knowledge so that they can increase their competency to complete a design task. Additionally, as defined by Dewey, reflective thinking is "active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the further conclusions to which it tends." (1933, p. 9). In the process of solving design problems, designers apply their existing knowledge to solve the problem. It is likely that the application of the knowledge conflicts with the problematic situation. Such instances engage designers in a reflective thinking process, where they will discover other knowledge as well as improve their understanding to settle conflicting situations.

Previous experiences

In design practice, many expert designers reflected back their previous experiences to generate potential solutions. Designers' previous experiences in performing similar task play a critical role in solving design problems (Ahmed, Wallace, & Blessing, 2003; Marsh, 1997). Boud and his colleagues highlight the importance of reflection for professional development. In their discussion, they described reflection as "an important human activity that people recapture their experience, think about it, mull it over, and evaluate it" (Boud et al., 1985, p. 19). Their conception of reflection specifically stresses on the importance of engaging one in reflecting on previous experiences. Visscher-Voerman and Henk, promoting reflection in educating instructional designers, also contends the essentiality to provide opportunities for students reflecting on their previous experiences. Their contention is supported by Kant's (1987/1956) argument on reflection: "concepts without experiences are empty, experiences without concepts are blind. (Visscher-Voerman & Henk, 2007, p. 345). It is through previous experiences that designers can improve their understanding as well as design competency. In addition to reflecting on previous experiences, reflecting on current experiences direct designers' attention to an ongoing design process, during which designers receive messages from the situation so that they will then respond to it. Such process is described as "situation's back-talk" by Schön (1987). Schön finds out that design involves reflective conversations between designers and design situations. A reflective conversation, occurring throughout a design process, enables designers to engage in discoveries of hidden aspects so as to arrive a better design.

Feelings

Reflecting on designers' own feelings is another important factor that can lead to a better design. During the process of solving problems, it is likely that professionals (i.e., designers) experience moments of joyfulness, puzzlement, confusion, doubt, or mental difficulty (Dewey, 1933; Schön, 1983). By attending to their own feelings, designers will continuously reflect on themselves and an ongoing design process. Argued by Schön (1983), "when intuitive, spontaneous performance yields nothing more than the results expected for it, then we tend not to think about it. But when intuitive performance leads to surprises, pleasing and promising or unwanted, we may respond by reflecting-in-action." (p.56). In some cases, when confronting mental discomfort, designers will begin to examine the problematic situation and make effort to sort out this situation in order to eradicate their negative feelings. On the other hand, when they experience pleasing moment during a design process, designer will bathe in their success and are more willingly to critically examine their performances in order to improve themselves for future tasks. With conscious effort on being truthful to their feelings, designers will bring about positive influences not only on their design ability but also on their understanding (Boud et al., 1985; Schön, 1983, 1987) .

Attitudes

To be capable of solving problems, designers should always examine their attitudes. Dewey (1933) asserts that "knowledge of the methods alone will not suffice; there must be the desire, the will to employ them" (p 29). Dewey further urges the importance for professionals to possess the following three attitudes: responsibility, whole-heartedness, and open-mindedness. With their responsibility and whole-heartedness, designers will be more likely to overcome barriers occurred during a design process, be more engrossed in a design task, and take into account the consequences for their actions. Moreover, with open-mindedness, designer will consider multiple perspectives, incorporate new ideas, and adopt alternative possibilities (Dewey, 1933). Possessing these three attitudes will prevent designers' self-conceit and self-sluggishness, which can enable them to stay away from arrogant design, often captured from novice designers' design process (Newstetter & McCracken, 2001). As a whole, examining designers' own attitudes should not be neglected. Otherwise, it can lead to an ineffective design or designers will encounter difficulties in conquering obstacles and exerting persistence to tackle problematic design tasks.

Ingrained beliefs and values

Reflection can enable us not only to correct distortions in our understanding and errors in problem solving, but also criticize our presuppositions on which our beliefs have been built (Mezirow, 1990). This type of reflection is often labeled as critical reflection, which serve as a channel for designers to challenge their beliefs, values, assumptions learned from one's cultural backgrounds, or social structures (Mezirow, 1991). When confronting such challenge, through critical reflection designers will open up opportunities to embrace divergent perspectives, which further bring about insights into new understanding, new alternatives for solving problems at hand, or even new approach to frame design problems. In addition to Mezirow's highlight of reflecting upon one's taken-for-granted beliefs, Confucius (500 BC) also prompt his followers to actively engage in self-reflection, which is described as "deep examination of one's being rather than a thorough investigation of some external objects" (Zhu, 1992, p. 20). One of Confucius' followers, Tzeng Sen, proposed a guideline in his *The Great Learning* (500 BC) for practicing self-reflection: "One should reflect in three ways everyday: in working for others, have I been disloyal? In my interactions with friends, have I been untrustworthy? In my learning, have I not practiced what I have learned yet?" By reflecting on these aspects, designers design performance will certainly be influenced positively. However, this type of reflection is rarely occurred since it requires more time for designers to achieve the transformation within themselves.

Reflecting upon Artifacts

In attempting to solve design problems successfully, it is insufficient for designers to only reflect upon themselves. According to Maier and Fadel (2009), "in design, the entangled relationship between people and artifacts is inescapable, because artifacts are always designed for human use, usually designed by human themselves and situated within a larger context of a complex world economy" (p.18). To tackle complex problems like design problems, Maier and Fadel propose the relational model of design to demonstrate the relationship between designers, users, and artifacts (2009). We find their model has manifested the importance of engaging designers in reflecting upon user as well as artifacts. Furthermore, Schön (1987) demonstrated the interplay between designers and design situations. During a design process, designers "listen" to situations' "back-talk" that results from previous actions. With the need for designers to pay close attention to artifacts, in the following section we discuss designers' reflection on the functions of an artifact, reflection on users' perspectives and perceptions, and reflection on the environment where an artifact is operated.

Functions

In a design process, the major responsibility of a designer is to design an artifact that satisfies the functional requirements (Jonassen, 2008; Mostow, 1985). A series of functions of an artifact is always the first aspect that designers examine: *What functions does this artifact perform?*; *What does it do?* (Norman, 2004). The ultimate goal of a designer is to satisfy the needs of the people, particularly their users. To this end, a design process is a continuous search of these needs. The search can often be identified at the very beginning of one's design process when designers frame the problem. However, it is unlikely that designers can pin down all needed functions at one shot. As Norman argued, "people's needs are not as obvious as might be thought" (2004, p. 70). It is through iterative design process that designers explore the constraints and criteria of an artifact and further identify the desired functions of an artifact (Jonassen, 2008). Such attempts make the role of reflection critical. With designers' conscious effort in evaluating the interplay of human's needs, constraints, and criteria, a set of appropriate and desired functions are more likely to emerge.

Users

A good design can rarely be achieved without thinking of its users. More specifically, the features of a design are remarkably influenced by users' needs, preferences, and the extent of their tolerance (Krick, 1969). As Cross argued, "it is important that the voice of the customer is recognized, and that customer requirements are not subject to reinterpretation by the design team" (2000, p. 113). He refers customers as end users. User experience with artifacts is a key aspect that designers need to ponder over. A good designer should avoid merely designing for themselves (Newstetter & McCracken, 2001). Contrarily, thinking from the users' perspectives can help designers lead to a quality design. Lawson (1997) further suggested that designers also should refrain themselves from only taking the feedback from clients since a lot of design today are commissioned by clients but not end users themselves. To carefully examine user experience, a recommended approach for capturing users' perceptions, perspectives, and operations of an artifact is through observing users' experience with an artifact (Norman, 1996). These efforts have made designers continuously reflect during a design process in terms of users' aspect, which will in turn improve their design performance.\

Environments

Not only do the reflections upon functions as well as users of an artifact can make a positive impact on the final design, but intentional examination on the environment where an artifact is operated also contributes significantly to a good design. During a design process, it is indispensable for designers to appraise the surrounding factors that may interplay with an artifact itself. As Norman argued, "In the actual [design] situation, cultural, social and organizational issues can dominate the user-oriented aspects of design" (1996, p. 234). Moreover, a continuously close inspection on the full economic and political impact of alternative solution is inarguably necessary (Krick, 1969; Norman, 1988). As an agent driving the changes of human society, designers definitely need to reflect upon the impacts of these elements, including direct and indirect effects, adverse as well as beneficial. Without taking into these aspects into consideration, it is likely that the final design will not exert the positive influences as designers plan, and thus a satisfactory artifact will hardly be developed.

Reflecting upon Circumstances

The majority of scholars in the field of design spend their efforts in investigating design methods (e.g., Cross, 2000; Maier & Fadel, 2009), design processes (e.g., Dick et al., 2009; Eastman, 1970; Lawson, 1997), and comparisons between novice and expert designers (e.g., Atman et al., 2007; Lloyd & Scott, 1994; Newstetter & McCracken, 2001) with an aim to improve designers' performance. On the other hand, the studies in reflective thinking mostly focus on how designers reflect upon themselves as well artifacts (e.g., Dewey, 1933; Schön, 1983). Based on the existing literature in the field of design and reflective thinking, few efforts have been paid to discuss the importance of guiding designers' attention to consider circumstances around design tasks, which are mostly considered as constraints for a given design task such as budget, timelines, available resources for a project, as well as politics within an organization. These circumstances are considered as constraints when performing a design and these factors undoubtedly exert their influences on the quality of final result. Jonassen (2008) using instructional design as an example indicates that instructional designers take into account following factors: available technologies, available funds and talents, rules or politics in organizational institutions. Additionally, a designer's performance can be affected by available time as well as budget (Eide et al., 2002). In real situations, design activities always entangle with project management issues. Kenny and his colleagues (2005) concluded in their study that in practice project management (e.g., creating budget and tracking progress) consumes extensive time of instructional designers, which manifests the significance of directing designers' endeavor to reflect upon how these circumstances interplay with their design processes. Moreover, when designers consider these aspects during their design, it is also vital for them to examine how these factors associates with the development or production stage (Fynes & Burca, 2005). A good design can minimize the cost and the needed time during the development stage. All in all, when examining designers' reflection in the process of solving design problems, the inspection on designers' reflection upon circumstances should not be neglected.

To summarize the different types of objects that designers may reflect upon in the process of solving design problems, we have created Table 1 to illustrate the types, the objects in each type, and the related literature.

Types of Objects	Variations of Each Object				
Self	**Knowledge** (Dewey, 1933)	**Experiences** (Boud et al., 1985; Schön, 1983, 1987; Visscher-Voerman & Procee, 2007)	**Feelings** (Boud et al., 1985; Dewey, 1933; Schön, 1983, 1987)	**Attitudes** (Dewey, 1933)	**Ingrained Beliefs and Values** (Confucius, 500 BC; Mezirow, 1990)
Artifacts	**Functions** (Jonassen, 2008; Mostow, 1985; Norman, 2004)	**Users** (Cross, 2000; Krick, 1969; Lawson, 1997; Newstetter & McCracken, 2001; Norman, 1996)	**Environment** (Norman, 1996)		
Circumstances	**Timeline** (Greeno, 1990, Wedman Tessmer, 1993)	**Budget** (Greeno, 1990, Wedman Tessmer, 1993)	**Available resources** (Greeno, 1990, Wedman Tessmer, 1993)	**Politics within organizations** (Greeno, 1990, Wedman Tessmer, 1993)	

Table 1: Objects that Designers Reflect upon During a Design Process

Dimension III: Quality of Reflective Thinking

After we learn the objects that designers reflect upon, another aspect that is indispensable for understanding designers' reflection is to examine the depth of each of their reflection points. This dimension is also interpreted as the quality of designers' reflective thinking. In our interpretation, we see the importance of each different level of reflection as each level serves different functions in the process of solving design problems. For this dimension, Argyris and Schön's idea of single-loop learning and double-loop learning (1978) as well as Flood and his colleague's triple-loop learning are adopted (Flood, Romm, & Flood, 1996) to examine the quality of designers' reflective thinking.

Single-Loop Reflective Thinking

During the process of solving design problems, designers inevitably will encounter unexpected or surprising situations. Such situations may occur when designers detect errors in their knowledge, their understandings of end users' needs, the information about available resources etc. When errors are detected, designers begin to think back what is going wrong. With the single-loop reflective thinking, designers look for strategies or solutions in an effort to achieve already defined goals. As Flood and his colleagues (1996) argue, the single-loop learning adopts means-end thinking. Single-loop reflective thinking enables designers to examine and explore other actions or solutions with the criteria of efficiency and effectiveness to correct the errors and further reach the goal (Argyris & Schön, 1978; Usher & Bryant, 1989). In other words, to deal with the problematic situations they have encountered, designers are asking themselves: *What is right?; What other strategies, knowledge, or information can help me solve this design problem more efficiently and effectively?; What actions should I take to deal with this puzzling situation so that I can achieve the end?.*

Double- Loop Reflective Thinking

Designers' reflection on the single-loop loop is undeniably critical to one's design performance. Nevertheless, to merely reflect in this level may not sufficiently solve all problematic situations. Argyris and Schön (1978) take a further step and bring our attention to also examine the predefined goals, functions to be achieved, criteria, and constraints. This examination lead designers' to question their assumptions (Mason, 2008). With the double-loop reflective thinking, designers may question themselves: *Is it worthwhile to set such goal and embed these criteria for this particular design problem?*; *Is it important to possess such attitude to empower myself in solving this design problem?*; *What is the value of this design product for my end users?.* In a word, designers reflect with the double-loop level place less emphasis on the process or the strategies to achieve the end. Rather, they question the underlying assumptions as well as values (Flood et al., 1996; Van Manen, 1977), which may potentially lead to a major change for a design process.

Triple- Loop Reflective Thinking

Designers' reflective thinking is not confined in the light of the efficiency and effectiveness or examination of their assumptions. Designers' reflection can further expand to take into account broader aspects such as the social, cultural, economical, historical, and political influences to the process of solving design problems. This type of reflection is also labeled as critical reflection (Mezirow, 1990; Moallem, 1998; Van Manen, 1977). This level of reflective thinking leads designers to question the dominant culture and how the power exerted from this dominant culture influences one's design process (Moallem, 1998). When designers engaging in the triple-loop reflective thinking, some examples of questions that they may ask themselves: *When I design, do I only attend to the dominant culture?*; *How some minor groups in our society influence my design?*; *Does my artifact provide the needs for people in any backgrounds?*; *When I reflect on the variety of peripherals, do I attend to the various social backgrounds when I* *interpret the peripherals of a design problem?*. The triple-loop reflective thinking engages designers to reach out from themselves and the culture they are used to. By doing so, their design can possibly attend to a large-scale of transformation of the entire society. Nevertheless, it is worth noting that this level of reflective thinking occurs less frequently then the single-loop and double-loop reflective thinking.

Conclusions

To summarize, most of design problems are ill-structured and complex to solve. Based on the previous research, facilitating designers' reflective thinking is a means to develop expertise in solving design problems. Yet, reflective thinking is hardly observed. Its dynamic nature makes it difficult to capture and interpret, which will easily lead the promotion of reflective thinking to a simply slogan. The proposed framework recognizes the predicament to facilitate novice designers' reflective thinking and hopes to move our conceptualizations of reflective thinking situated in the context of solving design problems forward. With our three-dimension framework, we have attempted to provide important aspects of reflective thinking that is related to a design process. The first dimension is used to identify the timing that reflective thinking occurs in the process of solving design problems. In the second dimension, we summarize possible different objects that designers reflect upon. For the last dimension, the three-level quality of reflection is developed to assess the depth of designers' reflection.

The primary purpose of this framework is to serve as a foundation for researchers in the field of design to examine designers' reflective thinking and further associate that with their design performance. However, this framework is still a work in progress. More experiments, explorations, and dialogues are necessary to validate as well as to continue with the refinement of the framework. Additionally, the development of the framework brings about many unanswered questions for future research. A series of questions are identified as follow: *How does a designer's different reflection timings, reflection on different objects, and different levels of reflection, inform his or her design performance?*; *How do novice and expert designers reflect differently in terms of the points, the objects, and the quality of reflection?*; *How do designers using problem-driven approach and solution-driven approach to process the design reflect differently in terms of the points, the objects, and the quality of reflection?*; *What is the effect of being reflective in a design process?*; *What are the appropriate instructional strategies and learning environments to facilitate designer's reflective thinking for improving their design ability?*. All in all, the development of the framework is hoping to bring up more discussions and investigations on how in effect reflective thinking leads to differences in one's design performance.

As the framework opens up an opportunity to understand the role of reflective thinking in solving design problem, it also provides instructional designer and educators in the field of design a basic guidance on different types of reflection, which as we hope will help them to further come up with appropriate instructional strategies as well as the learning environment that can properly facilitate novice designers' reflective thinking ability so as to improve their design ability.

References

Accreditation Board for Engineering and Technology. (2007). *Engineering Criteria 2000: Criteria for Accrediting Engineering Programs*. Baltimore: Engineering Accreditation Commission, Accreditation Board for Engineering and Technology.

Adams, R. S. (2001). *Cognitive Processes in Iterative Design Behavior.* University of Washington, Seattle.

Adams, R. S., & Atman, C. J. (1999, November 10-13, 1999). *Cognitive processes in iterative design behavior.* Paper presented at the Frontiers in Education Conference, San Juan, Puerto Rico.

Adams, R. S., Turns, J., & Atman, C. J. (2003). Educating effective engineering designers: the role of reflective practice. *Design Studies, 24*(3), 275-294.

Ahmed, S., Wallace, K. M., & Blessing, L. M. (2003). Understanding the differences between how novice and experienced designers approach design tasks. *Research in Engineering Design, 14*(1), 1.

Argyris, C., & Schön, D. A. (1978). *Organizational Learning*. Reading, MA: Addison-Wesley.

Atman, C. J., Adams, R. S., Cardella, M. E., Turns, J., Mosborg, S., & Saleem, J. (2007). Engineering design processes: A comparison of students and expert practitioners. *Journal of Engineering Education, October*.

Atman, C. J., Cardella, M. E., Turns, J., & Adams, R. (2005). Comparing freshman and senior engineering design processes: an in-depth follow-up study. *Design Studies, 26*(4), 325-357.

Boehm, B. (1970). Software and its impact a quantitative assessment. *Datamation*, 1973.

Boud, D., Keogh, R., & Walker, D. (1985). *Reflection, Turning Experience into Learning*. New York: Nichols Pub.

Confucius. (500 BC). The Analects.

Cross, N. (1982). Designerly ways of knowing. *Design Studies, 3*(4), 221-227.

Cross, N. (2000). *Engineering Design Methods: Strategies for Product Design* (3rd ed.). New York: Wiley.

Cross, N. (2004). Expertise in design: an overview. *Design Studies, 25*(5), 427-441.

Darke, J. (1979). The primary generator and the design process. *Design Studies, 1*(1), 36-44.

Dewey, J. (1933). *How We Think: A Restatement of the Relation of Reflective Thinking to the Educative Process*. Boston; New York; D.C.: Heath and Company.

Dick, W., Carey, L., & Carey, J. (2009). *The Systematic Design of Instruction* (7th ed.). New York: Longman.

Eastman, C. M. (1970). *On the analysis of the intuitive design process.* Paper presented at the Design Methods Group, Cambridge, Mass.

Eide, A. R., Jenison, R. D., Mashaw, L. H., & Northup, L. L. (2002). *Introduction to Engineering Design and Problem Solving* (2nd ed.). New York: McGraw-Hill

Fleischer, M., & Liker, J. K. (1992). The hidden professionals: Product designers and their impact on design quality. *IEEE Transactions on Engineering Management, 39*(3), 254-264.

Flood, R. L., Romm, N. R. A., & Flood, B. (1996). *Diversity Management: Triple Loop Learning*. New York: John Wiley & Sons, Ltd.

Fynes, B., & Burca, S. D. (2005). The effects of design quality on quality performance. *International Journal of Production Economics, 96*, 1-14.

Gero, J. S. (1990). Design prototypes: A knowledge representation schema for design. *AI Magazine, 11*(4), 26-36.
Goel, V., & Pirolli, P. (1989). Motivating the notion of generic design within information processing theory: The design problem space. *AI Magazine, 10*(1), 19-36.
Goel, V., & Pirolli, P. (1992). The Structure of Design Problem Spaces. *Cognitive Science, 16*(3), 395-429.
Greeno, J. G., Korpi, M., Jackson, D., & Michalchik, V. (1990). *Ill-structured problem solving in instructional design.* Paper presented at the Annual Conference of the Cognitive Science Society.
Gregory, S. A., & Design and Innovation Group at University of Aston in Birmingham. (1966). *The Design Method*. Longdon: Butterworths.
Gustafson, K. L., & Branch, R. M. (2002). *Survey of Instructional Development Models* (4th ed.). Syracuse, New York: ERIC Clearinghouse on Information Resources.
Heywood, J. (2005). Design. In J. Heywood (Ed.), *Engineering Education: Research and Development in Curriculum and Instruction* (pp. 283-314). Hoboken, New Jersey: John Wiley & Sons, Inc.
Hybs, I., & Gero, J. S. (1992). An evolutionary process model of design. *Design Studies, 13*(3), 273-290.
Jeffery, J. R. (1991). An investigation of systematic design methods in craft, design and technology. *International Journal of Technology and Design Education, 1*(3), 141-151.
Jonassen, D. H. (2000). Toward a design theory of problem solving. *Educational Technology Research and Development, 48*(4), 63-85.
Jonassen, D. H. (2008). *Instructional Design as a design problem solving: An iterative process*. Paper presented at the American Educational Research Association.
Kant, I. (1987/1956). *Kritik Der Reinen Vernunft*. Frnkfurt Am Main, Germany: Suhrkamp Verlag.
Kenny, R. F., Zhang, Z., Schwier, R. A., & Campbell, K. (2005). A review of what instructional designers do: Questions answered and questions not asked. *Canadian Journal of Learning and Technology, 31*(1).
Kolodner, J. L., & Wills, L. M. (1996). Powers of observation in creative design. *Design Studies, 17*(4), 385-416.
Krick, E. V. (1969). *An introduction to engineering and engineering design* (2nd ed.). New York: John Wiley & Sons.
Lawson, B. R. (1979). Cognitive strategies in architectural design. *Ergonomics, 22*(1), 59-68.
Lawson, B. R. (1997). *How Designers Think: The Design Process Demystified* (Completely rev. 3rd ed.). Oxford ; Boston: Architectural Press.
Li, D. Y. (1996). *The Wisdom and Philosophy of Confucius*. SiZuan, China: Educational.
Lin, X. D., & Schwartz, D. L. (2003). Reflection at the crossroads of cultures. *Mind, Culture & Activity, 10*(1), 9-25.
Lloyd, P., & Scott, P. (1994). Discovering the design problem. *Design Studies, 15*(2), 125-140.
Maier, J. R. A., & Fadel, G. M. (2009). Affordance based design: A relational theory for design. *Research in Engineering Design, 20*(1), 13-27.
Marsh, J. R. (1997). *The Capture and Utilization of Experience in Engineering Design.* Cambridge University, UK.
Mason, H. (2008). Levels of Learning. Retrieved March 25, 2009, from http://www.evolutionarynexus.org/category/free_tags/single_loop_learning

Maver, T. W. (1970). Appraisal in the building design process. In G. T. Moore (Ed.), *Engineering Methods in Environmental Design and Planning*. Cambridge, MA.: M.I.T Press.
Mezirow, J. (1990). *Fostering Critical Reflection in Adulthood: A Guide to Transformative and Emancipatory Learning*. San Francisco: Jossey-Bass Publishers.
Mezirow, J. (1991). *Transformative dimensions of adult learning*. San Francisco: Jossey-Bass.
Moallem, M. (1998, 1998-02). *Reflection as a means of developing expertise in problem solving, decision making, and complex thinking of designers.* Paper presented at the Association for Educational Communications and Technology, St. Louis, MO.
Mostow, J. (1985). Toward better models of the design process. *AI Magazine, 6*(1), 44-57.
Newstetter, W. C., & McCracken, W. M. (2001). Novice conceptions of design: implications for the design of learning environments. In C. M. Eastman, W. M. McCracken & W. C. Newstetter (Eds.), *Design Knowing and Learning: Cognition in Design Education* (pp. 63-78). Oxford, UK: Elsevier Science Ltd.
Norman, D. A. (1988). *The Psychology of Everyday Things*. New York: Basic Books.
Norman, D. A. (1996). Design as practiced. In T. Winograd (Ed.), *Brining Design to Software* (pp. 233-247). New York: Addison-Wesley.
Norman, D. A. (2004). *Emotional Design: Why We Love (or Hate) Everyday Things*. New York: Basic Books.
Puk, T. (1995). Creating a quantum design schema: integrating extra-rational and rational learning processes. *International Journal of Technology and Design Education, 5*, 255-266.
Radcliffe, D. F., & Lee, T. Y. (1989). Design methods used by undergraduate engineering students. *Design Studies, 10*(4), 199-207.
Reitman, W. R. (1965). *Cognition and thought; an information-processing approach*. New York,: Wiley.
Robinson, J. W. (1986). Design as exploration. *Design Studies, 7*(2), 67-79.
Rowe, P. G. (1987). *Design Thinking*. Cambridge, Mass.: MIT Press.
Rowland, G. (1993). Designing and Instructional Design. *Educational Technology Research and Development, 41*(1), 79-91.
Rowland, G., Fixl, A., & Yung, J. (1992). Educating the reflective designer. *Educational Technology, 32*(December), 36-44.
Schön, D. A. (1983). *The Reflective Practitioner: How Professionals Think in Action*. New York: Basic Books.
Schön, D. A. (1987). *Educating the Reflective Practitioner: Toward a New Design for Teaching and Learning in the Professions* (1st ed.). San Francisco: Jossey-Bass.
Shambaugh, N., & Magliaro, S. (2001). A reflexive model for teaching instructional design. *Educational Technology Research and Development, 49*(2), 69-92.
Simon, H. A. (1973). The structure of ill-structured problems. *Artificial Intelligence, 4*(3), 181-201.
Simon, H. A. (1981). *The Sciences of the Artificial*. Cambridge, Mass.: The MIT Press.
Ullman, D. G., Dietterich, Thomas G., Stauffer, Larry A. (1988). A model of the mechanical design process: Based on empirical data. *Artificial Intelligence in Engineering Design and Manufacturing, 2*(1), 33-52.
Usher, R., & Bryant, I. (1989). *Adult Education as Theory, Practice and Research*. London: Routledge.

Van Manen, M. (1977). Linking ways of knowing with ways of being practical. *Curriculum Inquiry, 6*(3), 205-228.

Visscher-Voerman, I., & Gustafson, K. L. (2004). Paradigms in the Theory and Practice of Education and Training Design. *Educational Technology Research & Development, 52*(2), 69-89.

Visscher-Voerman, I., & Henk, P. (2007). *Teaching systematic reflection to novice educational designers*. Paper presented at the Association of Educational Communications and Technology.

Visscher-Voerman, I., & Procee, H. (2007). *Teaching systematic reflection to novice educational designers*. Paper presented at the International Convention of Association for Educational Communications and Technology.

Wedman, J. F., & Tessmer, M. (1993). Instructional designers' decisions and priorities: A survey of design practice. . *Performance Improvement Quarterly*, *6*(2), 43-57.

Zhu, W. Z. (1992). Confucius and traditional Chinese education: An assessment. In R. Hayhoe (Ed.), *Education and Modernization: The Chinese Experience* (1st ed., pp. 3-22). Oxford, England ; New York: Pergamon Press.