Cognitive Heuristics Employed by Designers

Seda Yilmaz* Colleen Seifert**

** Design Science, University of Michigan*
Ann Arbor, MI, USA, seda@umich.edu

*** Department of Psychology, University of Michigan*
Ann Arbor, MI, USA, seifert@umich.edu

Abstract: The proposed research investigates how designers use heuristics, or cognitive strategies, to identify specific solutions in a "trial and error" creative process, and how team collaboration may use multiple heuristics across team members as a means to generate robust designs; that is, designs that remain successful despite variability in consumer preferences, both over people and time. The intent of this study is to understand the cognitive heuristics that support creative, innovative, and robust designs. *Heuristics* are reasoning processes that do not guarantee the best solution, but often lead to potential solutions by providing a "short-cut" within cognitive processing [8]. It is proposed that designers utilize specific design heuristics to explore the problem space of potential designs, leading to the generation of creative solutions. Further, these design heuristics can be taught, and their use will facilitate design at multiple levels of instruction.

Key words: Heuristics, Cognitive Processes, Creativity, Idea Generation, Design Expertise.

1. Introduction

The focus of this research is on studying the process of generating novel designs. How can we develop a process to assist designers and design engineers in creating innovative designs? How do successful design teams make use of the varying perspectives of team members to produce better designs? And, how do we design for users whose assessments may vary with the context of use, or who develop new goals or functions after the design is in use? The planned work addresses these questions by bringing models and methods from the fields of cognitive and decision sciences to help in understanding the cognitive and social processes in creating innovative designs.

2. Problem Domain

The paradigm underlying design education is the experiential learning approach [12]. The curriculum of experiential learning activities usually takes the form of complex projects consisting of generally structured, guided experiential activities [12]. While project-based learning has also been adopted as the key teaching-learning strategy in most design schools, questions about the effectiveness of this approach remain unanswered. It assumes that students will have their curiosity aroused with an increased motivation to learn, and that when in a novel design situation; students will transfer the meaningful insights they learned in school into other design tasks [10]. However, in these later activities, students are often faced with unstructured, ambiguous design problems, for which they may not have acquired strategies to assist them in developing new solutions. Indeed, with a critique-based evaluation of student projects, the set of design knowledge and strategies acquired may not be apparent even to the successful student.

More commercial reasons for this research are the increased market demands for new products and the elevated levels of competition; both of these requiring the ideation phase of the design process to be shorter and more effective than ever. It is estimated that 70% of a product's cost is defined during conceptual design [9]. Since it is commonly accepted that this phase is highly iterative, it necessitates that designers employ heuristic processes and strategies. Adams and Atman [1] argue that these processes take place as designers attempt to gather and filter information about a design problem, and result in the revision, improvement, or modification of possible solutions. Even though these processes are believed to lead to better quality solutions at a faster pace, there is little research that identifies the competencies that may contribute to performance and expertise.

3. Literature Review

With the purpose of assisting decisions making in the design process, both design researchers and cognitive scientists have structured a variety of process models to study human creative behavior in design. The models generated are often based on observations of design processes and analysis of design protocols. French [5] developed a model of design processes that includes analysis of the problem, conceptual design, embodiment of schemes, and detailing. Cross [4] described a four-stage model of the design process, which is composed of exploration, generation, evaluation, and communication. Shah et al. [11] proposed a model of Design Thought Process to describe generation and interpretation of ideas. Benami and Jin [3] introduced a cognitive model of creative conceptual design to capture interactions between cognitive processes, design entities, and design operations. In these models, the focus is on clarifying the thinking steps involved in design rather than the information generated by these steps and strategies processed in various iterations. Finally, Jin and Chusilp [7] claimed that concepts are created and elaborated after repeated mental iterations of idea generation followed by evaluation. When engaged in the design process, designers appear to generate questions and choose directions from within an internal dialogue where strategies may flow without reflection.

Heuristics are not guaranteed to produce a high quality or innovative design, nor do they systematically take the designer through all possible designs. Instead, heuristics serve as a way to “jump in” to a new subspace of possible solutions. Design heuristics move the designer into other ways of looking at the same elements, and provide the opportunity for a novel design to occur.

The use of heuristics in design has been previously explored in TRIZ [2], which provides a systematic method for finding and using analogies based on past designs (stored in a relatively abstract form). For example, in designing a soda can, a designer employing the TRIZ theory may first analyze the technical conflicts caused by engineering parameters: i.e., the wall thickness of the can that has to be rigid enough for stacking purposes yet cost-effective for manufacturing. Then, using “Increase the degree of an object's segmentation” principle, the wall of the can could be changed from a continuous wall to a corrugated one to increase the durability. The Synectics [6] framework, on the other hand, combines different techniques to address needs at different phases of ideation. A designer utilizing Synectics may try to “animate” the can by applying human qualities, such as adding a smiley face to the same can. While TRIZ focuses on engineering parameters, and related conflicts and trade-offs, Synectics highly relies on the fusion of opposites, both focusing on the use of past experiences and analogies. As a result, the heuristics proposed tend to centralize on known, specific engineering mechanisms, or very general theme suggestions such as the one presented in the “animation” example.

The approach defined in this research attempts to describe design heuristics at the level of transformations of form and function that can lead a designer to introduce systematic variation to their current concepts, producing a more varied set of candidate designs. Rather than generalized principles and triggering questions typical in brainstorming sessions, focusing on those cognitive heuristics that offer a means of generating possible designs by guiding specific types of variations within a problem context is proposed.

4. Methodological Approach

This research proposal addresses these topics through a series of empirical studies of expert, student, and novice designers, along with consumers. Multiple methods to collect a body of design heuristics, drawing from engineering design literature as well as the decision making and problem solving literatures will be used where the heuristics and their resulting output will be evaluated using multiple measures, including quality, originality, utility, aesthetics, and value. Building on new research in cognitive and decision sciences, along with studies of engineering design, I will

1. Study design heuristics used by expert designers in generating innovative designs
2. Evaluate these heuristics through empirical tests with novices and students,
3. Study design teams to identify whether and how heuristics play a role, and specifically, whether multiple heuristics are employed within the group,
4. Develop a framework that demonstrates how to leverage design heuristics and team processes to produce designs that are robust to the heterogeneity of consumer-constructed preferences, and
5. Create design pedagogy, including a computer tool that makes design heuristics accessible and useful to engineering designers.

I will analyze how individuals and groups use design heuristics to arrive at candidate solutions, and how this relates to robustness; that is, what features of good design help to produce a product that consumers will prefer at the time of purchase and when used over its lifetime? Decision research shows that consumers construct their preferences at the time of decision; as a result, consumers pose a moving target when used as design evaluation criteria. Contrasting perspectives may lead to more robust designs that are less sensitive to this moving target.

5. Preliminary Research Outcomes

The two studies recently completed have validated the hypothesis: (1) designers utilize specific design heuristics to explore the problem space of potential designs, leading to the generation of novel and creative solutions, and (2) these design heuristics can be taught to novices, and their use facilitates more diverse and unusual form. In the first study, through comprehensive analysis of an expert designer's initial ideation process (first fifty sketches) over several months as case study, over twenty heuristics were identified. Two blind coders confirmed these heuristics with a high interrater reliability, and agreed on the heuristics promoting variation in concepts and altering existing solutions, which supports the claim that expertise incorporates the use of heuristics to explore potential designs.

The second study was done with 120 freshmen psychology students under four instructional conditions, where they were asked to generate multiple concepts for the same design task, in a sequence using the instructed heuristics. Drawings were coded according to their content, use of heuristics, creativity and practicality by two blind coders. The most creative concepts emerged from the instructional conditions where the heuristics were introduced. They appeared to help the participants to "jump in" to a new problem space, resulting in more varied designs, and more designs judged as the most creative. Even for non-designers, a few minutes of text and illustration on six specific heuristics led to diverse designs, judged as more creative. Through the use of heuristics, the designs created were more engaged with visual form, more varied, and more successful than those in the control condition which suggests that the ideation phase of design can be assisted by explicit instruction on design heuristics.

6. Future Direction

The purpose of the larger study is to empirically explore and identify heuristics use in design, and to develop a model for representing these activities in terms of (1) how these behaviors contribute to analysis, synthesis and evaluation skills, (2) how differences in these behaviors are related to expertise, and (3) how these behaviors may influence performance as a function of process efficiency and the overall quality of the final solution. There are three research themes: 1) identify design heuristics and develop instructional and computational tools that support their use; 2) observe design teams to identify the role of heuristics in collaborative processes, and create interventions that facilitate their use; 3) examine the robustness of designs by comparing the use of heuristics, and the resulting output, in individuals and teams. A combination of laboratory experiments and field studies will be used to maximize control and improve generalization to real world settings. The proposed project will also produce a formal model using agent-based computer modeling and a discrete choice model of constructed preferences as well as computer tools that can be used both in research and in pedagogy. Together, these studies, models, tools and instructional techniques evaluate how design heuristics influence the perceived quality of engineering designs.

The intellectual merit of this research is deeper understanding of how expert designers use heuristics to create designs. Previous research has shown that creative problems are rarely solved with systematic, linear solutions; instead, people often use heuristics to “guess” at a possible solution. Studies suggest that use of heuristics (in domains like “chess”) emerges with increased frequency as expertise develops. However, existing studies have not cataloged the variety of heuristics experts employ within a domain, nor provided a theory that accounts for the use of cognitive strategies during creative design. The proposed studies will provide further evidence of heuristic use, determine the nature of the strategies and when they are employed, and extend the results to design problems. The results will also inform the creation of an instructional framework that promotes innovation in design.

7. References

[1] Adams, R.S. and Atman, C.J. (1999) Cognitive processes in iterative design behavior, In *Frontiers in Education Conference Proceedings*.

[2] Altshuller, G. (1984) *Creativity as an Exact Science*, Gordon and Breach, New York, NY.

[3] Benami, O. and Jin, Y. (2002) Cognitive stimulation in conceptual design. In *Proceedings of ASME 2002 Design Engineering Technical Conferences and Computer and Information in Engineering Conference, DETC2002/DTM-34023*, Montreal, Canada.

[4] Cross, N. (2000) *Engineering Design Methods: Strategies for Product Design*, 3rd Ed., John Wiley & Sons Ltd, Chichester, UK.

[5] French, M.J. (1985) *Conceptual Design for Engineers*, The Design Council/Springer, London, UK.

[6] Gordon, W.J.J. (1961) *Synectics*, Harper & Row, New York.

[7] Jin, Y. and Chusilp, P. (2005) Study of mental iteration in different design situations, *Design Studies*, vol. 27, no. 1, pp 25-55.

[8] Nisbett, R.E. and Ross, L. (1980) *Human Inference: Strategies, and Shortcomings of Social Judgment*, Englewood Cliffs, Prentice-Hall, Inc, New Jersey.

[9] Pahl, G. and Beitz, W. (1996) *Engineering Design-A Systematic Approach*, 2nd Ed., Springer, London, UK.

[10] Pietersen, C. (2002) Research as a learning experience: A phenomenological explication. The Qualitative Report 7(2). Available at http://www.nova.edu/ssss/QR/QR7-2/pietersen.html.

[11] Shah, J.J., Vargas-Hernandez, N., Summers, J.D. and Kulkarni, S. (2001) Collaborative sketching (c-sketch): An idea generation technique for engineering design, *Journal of Creative Behavior*, vol. 35, no. 3, pp 168-198.

[12] Tynjala, P. (1998) Traditional studying for examination versus constructivist learning tasks: Do learning outcome differ? *Studies in Higher Education*, vol. 23, no. 2, pp 173–189.