INTERNATIONAL DESIGN CONFERENCE - DESIGN 2010
Dubrovnik - Croatia, May 17 - 20, 2010.

COGNITIVE HEURISTICS IN DESIGN IDEATION

S. Yilmaz and C. M. Seifert

Keywords: design heuristics, creativity, design methodology

1. Introduction

Innovative design ideas are the goal of the creative process. One of the most important characteristics of the design process during the conceptual phase is that it is creative, innovative, and unpredictable as an activity. A creative process results in new concepts that were not previously known. The creative process is also opportunistic; that is, design activities vary depending upon the state of the creative process, as observed in empirical studies [Visser 1996]. These particular characteristics of the design process make it a complex subject to study empirically. Yet there are many instances where designers find themselves in need of original designs or elements, and aren't certain about how to proceed to generate novel designs.

It has become widely accepted that business survival and prosperity is strongly attributed to the ability to innovate [Prahalad and Ramaswamy 2003]. Engineering design process models often assume creativity occurs somewhere during the conceptual design phase. For example, the Functional Design perspective links design functions to their structural embodiments within a computer design tool [Tor, Britton, Chandrashekar, and NG 1998]. But this link between the creative process and the design process needs to be better understood.

What are the strategies that lead successful designers to novel products? According to Boden (1990), three approaches have been identified:

- Combinational creativity, in which new ideas arise from the unusual combination or association of familiar ideas.
- Exploratory creativity, which consists of applying search procedures within a defined conceptual space, as with scientific discovery models.
- Transformational creativity, where models are based on evolutionary techniques and include procedures for modifying parts of defined solutions.

The aim of this research is to introduce a new approach to the creation of novel designs. Following Newell and Simon (1972), we can define design as occurring within a "design space" consisting of all possible designs. Some of these potential designs are easy to consider because they involve simple combinations of known features, or involve already-known elements. But a designer may never consider some features within this space, missing the opportunity to consider some types of solutions that don't come to mind during the idea generation process. An alternative process to assist in exploring the design space is the application of strategies that move the designer to new parts of the design space. The key to generating innovative solutions, then, is successively applying different *design heuristics* that assist in novel candidate designs from this potential design space.

Design heuristics differ from other approaches used in idea generation. While most existing approaches are mainly discussion-related, such as brainstorming, "brainwriting," and checklists, heuristics employ idea triggers that assist in creating concepts using simple prompts. Although the importance of design heuristics is well recognized [Finke et al. 1992], little is known about whether designers apply them, what the specific heuristics are, and how they affect the quality and creativity of the resulting design. Previous studies have identified some design strategies used by expert designers; for example, Kruger and Cross (2001) found that designers using a problem-driven (rather than solution-driven) design strategy tended to produce the best results in terms of the balance and creativity of their designs. Several competing heuristic theories, SCAMPER [Eberle 1995], Synectics [Gordon 1961], and TRIZ [Altshuller 1984], have provided suggested heuristics, but without empirical validation. These three approaches appear to drastically differ, but upon closer evaluation, it can be seen that there are similarities among them.

The TRIZ approach provides a heuristic method for finding and using analogies based on past designs found in mechanical engineering patents. Its technical matrix of 39 common engineering problems and 40 possible solution types are combined to apply to the problem at hand. For example, in designing a soda can, a designer employing the TRIZ system may first analyze the technical conflicts caused by engineering parameters; specifically the wall thickness of the can has to be rigid enough for stacking purposes yet cost-effective for manufacturing. Then, using “Increase the degree of an object's segmentation” heuristic, the wall of the can could be redesigned from a flat to corrugated to increase durability. The majority of the TRIZ heuristics do not overlap with Synectics or SCAMPER, as they are focused on specific engineering mechanisms (such as pneumatics), parameters and related conflicts and trade-offs.

The two other approaches provide design heuristics defined at a much more general level. The SCAMPER approach defines seven general heuristics (*substitute, combine, adapt, modify, put to other uses, eliminate,* and *rearrange/reverse*). No specifics are given to guide the designer about how or when to apply them to a problem. For example, given a design problem like redesigning a hand soap dispenser, applying the heuristic, "modify," provides little direction for exploring potential redesigns. The Synectics framework combines more and different heuristics to address needs at different phases of ideation. It focuses on the fusion of opposites through the use of past experiences and analogies. For example, a designer utilizing Synectics may try to “animate” the soap dispenser by applying human qualities, such as adding a "smiley face" to the dispenser. The heuristics proposed in Synectics provide very general theme suggestions, including *parody, prevaricate, metamorphose*, and *mythologize*. These seem to focus on the in-context setting or meaning of the product, comparing it to markets and other similar products it may compete with.

Comparing these three approaches to heuristics, there are some clear differences and similarities. Some of Synectics' "triggers" are very specific and concrete, while others offer broader options in a style more similar to SCAMPER. For example, one Synectics trigger is *contradict*, which is very similar to the *reverse* concept of SCAMPER. Other examples of this overlap include *repeat, combine,* and *add* vs. *combine; superimpose* and *transfer* vs. *put to another use; change scale, distort,* and *add* vs. *modify; subtract* and *disguise* vs. *eliminate;* and *analogize* vs. *adapt.* SCAMPER and Synectics both provide very broad heuristics at an abstract level, without much guidance about their application. The TRIZ heuristics, designed to address specific mechanical trade-offs in design, are at the opposite extreme in that they apply to very specified aspects of designs. But perhaps the most useful heuristics for creating new designs during the ideation stage may be at an intermediate level between these approaches: more general than TRIZ, but more specific than the broad suggestions posed in SCAMPER and Synectics.

These questions are the focus of our present work on the ideation involved in generating innovative products: How do designers "play" within the space of possible designs to come up with novel ideas? Our related approach attempts to describe design heuristics at the level of transformations of form and function in the ideation phase that can introduce systematic variation in the set of candidate concepts. To investigate this hypothesis, we set out to attempt to identify how the designer might transform concepts by using award winning product concepts. We focused on heuristics that offer a means of generating possible designs by guiding specific types of variations within a problem context. But what are the heuristics that lead to creative designs?

2. Design Heuristics

We propose that designers employ cognitive heuristics in order to enhance the variety, quality, and creativity of potential designs they generate during the ideation stage. Specific design heuristics help the designer to explore the problem space of potential designs, leading to the generation of creative solutions. These cognitive strategies are applied to a design problem to take the designer to a different part of this space of potential design solutions. Design heuristics are transformational strategies that take a concept, and introduce intentional, systematic variation to produce a candidate design.

Designers appear to have general heuristics that they can apply to multiple design situations even when they have little prior knowledge within a domain. With the application of a heuristic, one is not merely recollecting previous solutions in order to apply them to similar problems, but instead, actively and dynamically constructing new solutions by applying a heuristic. Each heuristic provides a starting point for transforming an existing concept, altering it to introduce variation. A single heuristic can also produce a variety of designs depending on how it is applied. This view of the ideation stage involves successively applying multiple heuristics successively to identify a large set of candidate designs.

It may be possible to specify the nature of heuristics and the specific transformation they provide within a design process. But to do so, a method is needed that does not rely on the verbal report of the designer. For experts, the use of design heuristics flows quickly, and they may not be consciously aware of their use of strategy in ideation [Yilmaz and Seifert 2009]. Instead, we investigate the heuristics evident in product designs that are judged to be successful by award competitions, and analyze their content to determine how the designers must have transformed initial ideas into their final innovative concepts.

2.1 Method: Extracting Heuristics from Products

We used a combined approach to derive heuristic rules or "principles" from example designs. We found designs through existing, independent award competitions and in published compendiums of well-known, successful products. The information available about each product included the product descriptions, design criteria, constraints, scenarios, and sometimes critiques provided by professional designers. The source of the example designs we analyzed for this study include:

- International Design Excellence Awards, 2009 (www.idsa.org) IDSA has been honoring design excellence via the IDEA Awards since 1980.
- Red-Dot Product Design Awards, 2009 (www.red-dot.de) With more than 12,000 submissions from more than 60 countries, the international "red dot design award" is the largest and most renowned design competition in the world.
- iF Product Design Awards, 2008, (www.ifdesign.de) Since their introduction in the year 1953, the iF design awards, with an international expert jury, have been a reliable indicator of outstanding quality in design.
- Good Design Awards, 2008-2009 (http://www.g-mark.org/english/) Awarded by jury through the Japan Industrial Design Promotion Organization.
- National Design Awards, 2009, (www.nationaldesignawards.org) U.S. national awards initiated by the Smithsonian's Cooper-Hewitt, National Design Museum.
- Deconstructing Product Design: Exploring the Form, Function, Usability, Sustainability, and Commercial Success of 100 Amazing Products, by William Lidwell and Gerry Manacsa, Rockport Publishers (November 1, 2009)
- Design Secrets: Products, by Industrial Designers Society of America, Rockport Publishers (September 1, 2003)
- Design Secrets: Products 2: 50 Real-Life Product Design Projects Uncovered (v. 2), by Lynn Haller and Cheryl Dangel Cullen, Rockport Publishers (October 1, 2006)
- Process: 50 Product Designs from Concept to Manufacture, by Jennifer Hudson, Laurence King Publishers (May 1, 2008)
- 1000 New Eco Designs and Where to Find Them, by Rebecca Proctor, Laurence King Publishers (June 10, 2009)

The illustrations used in this paper can be found in the *http://www.idsa.org/IDEA_Awards/gallery/*

Our initial database of innovative product designs included hundreds of products from these sources. A detailed investigation was performed on approximately 400 products selected to provide a variety of distinct designs. Major elements and key features of the products were identified for functionality, form, user-interaction, and physical state. We then performed a content analysis of the needs, design criteria, and the design solution. After the products were analyzed, the ones with the same design features were grouped and compared in order to explore the commonalities. The descriptions of each heuristic were extracted. This heuristic extraction process is illustrated in Figure 1.

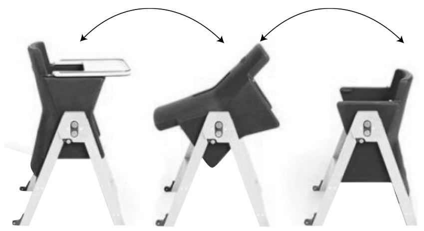
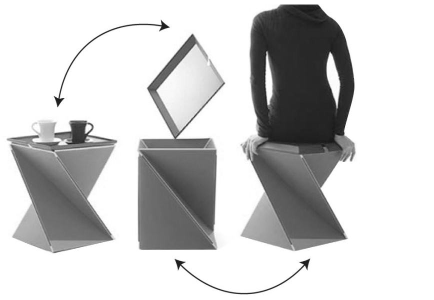
Select an award-winning product from the source list.		
Define its functions and key features of the product.	With a simple swivel, the chair turns from a highchair to an under-table chair. In its high position, it fits under the kitchen counter. In its low position, it lets toddlers sit at any standard-height table without a booster seat. While meeting the needs of secure seating for youngsters aged six months to six years, it also serves as a small desk chair for children aged four to six.	
Hypothesize potential heuristic applications.	The designers possibly recognized consumer needs in flexibility of children's chairs' heights. Instead of adjusting the height in a telescoping fashion, they decided to double the function by using both the top and the bottom of the product for varying needs of different age groups. This double-functionality is accomplished by flipping the product pivot point using the Y axis. Adding the desk on one of the seats also increased the potential flexibility of the overall product.	
Derive primary and secondary context-dependent design heuristic(s) as well as potential context-independent design heuristics.	Primary Design Heuristic: Provide multiple functions by using each side for only one function Secondary Design Heuristic: Adjust the functions according to different demographic needs Context-independent Design Heuristics: Flipping around its pivot Repeating design elements for different functions	
Identify design criteria used in the product.	Secure, comfortable, adjustable, multi-functional, and practical.	
Select another product that shares the same criteria and uses the same heuristic(s)		
Describe how each similar product used the heuristic to identify different ways of implementation.	A secondary design element is chosen for the durability of the form. Two different functions are assigned to this secondary element and the functions differ when the component is reversed and placed again over the main structure.	The form is split into four different functions, which can be accessed easily by reversing the product from one direction to another.

Figure 1. Heuristic Extraction Process

Clearly, subjective interpretation is necessary to derive a potential heuristic from the description of a finished product. The data provided no intermediate steps from the design process, no competing concepts considered, and no process trace of the designer's work. However, the success of this extraction approach is not determined by the correctness of the derived heuristic. It is also possible that the designer may not agree with the characterization of the derived heuristic. However, the standard adopted for this analysis is whether the proposed heuristic is observed in other product designs, and whether it appears to offer a transformation that can be successfully applied to novel designs.

2.2 Defining Design Heuristics

The analysis of the 400 products resulted in 40 heuristic that facilitate the design process. At a general level, they can be organized as content-independent heuristics including *addition, removal, distortion, orientation,* and *substitution*. This list is similar to the proposed heuristics in previous approaches like TRIZ, Synectics, and SCAMPER. However, the generality of heuristics described at this level is problematic because they give little indication of whether they can be applied to a specific design problem, and how to apply the idea to an existing concept.

In the content analysis, we found that a more specific description of heuristics -- context-dependent heuristics -- provides a motivation for applying them, and may consequently make the heuristics more specialized and valuable as aids to design. For example, *twisting forms to create a playful look* refers to *distortion* of the form. However, the reason for applying this heuristic is directly related to the design criteria in hand, which is the audience as children (in the product analyzed, designing a stool for a playground). The design heuristics vary in that some add functionality, suggest use of fewer resources, save space, provide ideas about visual consistency, and form relationships among the design elements. These more specific heuristics go beyond simple transformations to identify why a particular one might be advantageous. Consider these examples of the extraction of heuristics from the set of innovative products in the study:

<u>Heuristic Example 1.</u> Converting two-dimensional materials into three-dimensional products.

Change an object’s dimensions with a change in boundary conditions: Create an object by manipulating two-dimensional geometrical surfaces around an axis or twisting in various directions in order to generate a three-dimensional product; changing or creating a curvature or creating an inner surface by using sheet materials can produce different functional outcomes. For example, Figure 2a shows a trash can concept that is made out of recycled sheet plastic rolled around its center. Since it can be entirely flat, it also enhances the efficiency of transportation and storage. Figure 2b shows a light made out of sheet metal twisted around to give directional options for controlling light intensity.

Figure 2a & 2b. Example designs for Heuristic Example 1
Converting two-dimensional materials into three-dimensional products

<u>Heuristic Example 2.</u> Using packaging as a functional component within the product.

Embed the packaging within the product, where the packaging performs a different function: Create a shell or cover for a component or the entire product using the package, and uncover it when it’s used. In Figure 3a, a set of colored pencils is located inside a package that also serves as a stand during use. In Figure 3b, the lighting unit is packed in a way that it is enclosed inside a wrapped form made out of the same material. When opened, the package supports the structure, and functions as a necessary shade component rather than a separate, unused feature.

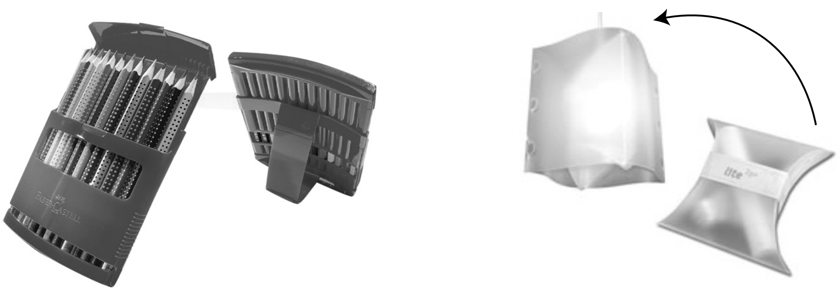


Figure 3a & 3b. Example designs for Heuristic Example 2
Using packaging as a functional component within the product

<u>Heuristic Example 3.</u> Hiding / Collapsing / Flattening design elements when they are not in use using elements nested inside each other.
Place an object inside another object entirely or partially, wherein the internal geometry of the containing object is similar to the external geometry of the contained object: One object is placed inside the other, or one object passes through a cavity or interfaces with a cavity in another object. In Figure 4a, the lighting unit collapses when not in use on the cavity that is defined by the bottom support of the product. In Figure 4b, the container has several layers that are nested inside each other for storage when the product is not in use.

Figure 4a & 4b. Example designs for Heuristic Example 3
Hiding / Collapsing / Flattening design elements when they are not in use
using nested elements inside each other

<u>Heuristic Example 4.</u> Convert the product into modular units by repeating or splitting design elements.
Divide single continuous parts into two or more elements, or repeat the same design element multiple times, in order to generate modular units: The separation of continuous components creates independent parts that can then be reconfigured, and the repetition of a component can also assist in generating reconfigurations. Product modules are distinct building blocks that combine to form machines, assemblies, or components that accomplish an overall function. In Figure 5a, the modules allow several combinations, offering flexibility and rapid adaptation to varying user needs. According to how the modules are set up, the product can be converted to a shelf, a table, or a closet. In Figure 5b, the user configures the gaming tower. Splitting the functions into independent modules also allows for an open structure where they are visible and air flow is improved.

Figure 5a & 5b. Example designs for Heuristic Example 4
Convert the product into modular units by repeating or splitting the design elements

Heuristic Example 5. Visually separate the primary functions from the secondary functions.
Create visual, hierarchical relationships among the functions within the product by changing the individual design elements' dimensions, locations, colors, and materials: Visually emphasize which functions are the most important to facilitate the ease of use by improving the interface. In Figure 6a, even though the two attached forms look alike for visual consistency (similar form and color), the size differs to communicate the two different functions: medicine and drink container. In Figure 6b, the form and color again suggest two similar functions; however, the size difference in the forms emphasizes the different functions used in water flushing.

Figure 6a & 6b. Example designs for Heuristic Example 5
Visually separate the primary functions from the secondary functions

3. Research Results

The results of the product design analysis include the following:

- Demonstration of a proposed methodology for identifying design heuristics
- A set of design heuristics used in innovative products
- Identification of their relationships with the criteria defined in the design problem
- Comparisons of multiple applications of these heuristics
- Demonstration of applying heuristics to new problems

3.1 Design heuristics identified

Each of the forty identified heuristics was identified in at least four different products of the 400 in the database. In some of the products, multiple heuristics were observed (this part of the research is not further reported here). Table 1 presents the forty extracted design heuristics and how many times each was observed in the 400 designs analyzed.

Table 1. Context-Dependent heuristics identified in the content analysis of notable new products

Context-Dependent Heuristics	Products Where Observed
1) Remove the moving parts to minimize potential breakdowns.	24
2) Adjust functions according to different demographic needs.	23
3) Refocus on the core function of the product.	22
4) Apply an existing mechanism in a new way.	21
5) Adjust functions by moving the product's parts.	17
6) Reduce the amount of material needed for the same function.	16
7) Animate product using human features for an approachable look.	16
8) Change the context of where and how the product will be used.	14
9) Convert into modular units by repeating or splitting elements.	14
10) Implement characteristics from nature within the product.	14

11) Replace materials with recycled ones.	14
12) Change physical approaches to the system (from front to side)	13
13) Hide / Collapse / Flatten elements not in use by nesting elements.	13
14) Merge the functions that can use the same energy source.	13
15) Use human-power as the energy source.	13
16) Attach the product to an existing item as an additional component.	12
17) Make the individual parts attachable and detachable.	11
18) Minimize steps in use by creating a hierarchy of the features.	11
19) Convert two-dimensional materials into three-dimensional.	9
20) Visually separate primary functions from secondary functions.	9
21) Provide multiple functions by using different surfaces for each.	8
22) Replace limited-use parts with ones that can be used multiple times.	8
23) Replace solid material with flexible material for compactness.	8
24) Use an extension of the product surface for the handling function.	8
25) Provide sensory feedback to the user (tactile, verbal, visual, etc.).	7
26) Use same design element, color, graphics for visual consistency.	7
27) Use the outer surface space of the product for different functions.	7
28) Convert the packaging into a game after the product is removed.	6
29) Create systems for returning to manufacturer after life cycle ends.	6
30) Make the product expandable in order to fit various sizes.	6
31) Visually separate similar functions using size and color.	6
32) Add a portability feature to existing solutions.	5
33) Use a common base or the same surface for multiple functions.	5
34) Use packaging as a functional component within the product.	5
35) Express cultural values in the product.	5
36) Add motion to the product as a playful attribute (push/pull, etc.).	4
37) Cover the joints for visual consistency.	4
38) Design communal activities for users to unite as a community.	4
39) Include users in customizing or assembling the product.	4
40) Twist forms to create a more playful look.	4

These heuristics differ based on the design problem, the context defined in the problem definition, and designers' preferences. Each heuristic requires specific features within the design problem in order to be applicable, and produces a changed concept altered in a specific fashion. As a result, which heuristic to use highly depends upon the immediate problem context. As implied by the use of "heuristic," there is no determinate heuristic that will lead to a definitive solution.

The presumed goal of ideation is to generate as many varied concepts as possible in order to maximize the variety and novelty of candidates for selection and refinement. The success of this heuristic analysis method in characterizing differences among candidate designs may lead to schemes that assist designers in adding to their concept sets. Further, the identification of heuristics and groups of heuristics may suggest ways for development of computational tools to assist in design. For example, the frequency of the heuristics applied could be analyzed in order to understand which of the heuristics are most commonly used, what kind of design problems they were applied to, what kind of new problem spaces they generated, and which heuristics may be suggested as potentially relevant given the observed patterns. In particular, this approach may hold promise in instruction for novices as they build their experience with heuristic use and design in general.

3.2 A proposed method for using design heuristics

In Figure 7, an example illustrating how a set of three distinctly different heuristics can affect the direction of the concepts can be seen. This illustrated problem is to “design a container that can dispense a specific volume of liquid hand soap."

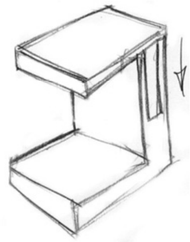
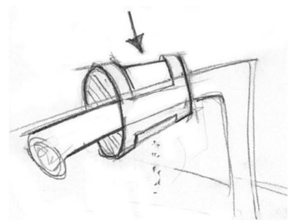
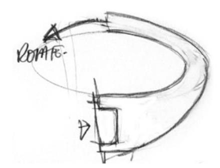
Initial Concept.	Make the individual parts attachable-detachable.	Attach the product to an existing item as an additional component.	Remove the moving parts.
			
Top part is nested inside the main structure which holds the soap. Soap is dispensed by a push-motion from the top. The central open space is used for hand placement.	The two parts are separated easily with a snap-on motion. The location for connecting the parts is also used as the opening to fill it with soap.	The product can be attached to the faucet through a sliding motion. This way the soap dispenser does not occupy additional surface space on the countertop. Soap comes out from the channels on the sides, and the product can be filled with soap from the top part, which also serves as the part users push to receive soap.	Soap is dispensed through the top of the tubing component by rotating the entire product around its center. The cavity on the bottom of the product is used for filling it with soap.

Figure 7. Illustration of Heuristic Use

As the example in Figure 7 demonstrates, each heuristic brings the designer to a new area of the space of possible designs. With each heuristic implementation, additional features are explored beyond the basic criteria defined in the problem. For example, in the above illustration, attaching the product on the faucet let the designer consider alternative ways of using the space around the faucet. The criterion was redefined, as the user interaction with the product was changed. On the other hand, this change brought up new questions to tackle, such as how it will be mounted, how the size will differ according to the varying types and sizes of faucets, how the faucet will be cleaned with the product attached, etc. The application of three different heuristics produced three varied designs for further consideration. In an empirical test of heuristic instruction with novices, training in heuristics resulted in design concepts that were rated as more creative and practical [Yilmaz, Seifert, and Gonzalez 2010].

4. Discussion

Which design heuristics can be shown to enhance innovation most effectively? And how can design strategies be effectively taught in engineering design courses? Pedagogy for enhancing design creativity is essential because most engineering problems demand innovative approaches in the design of products, equipments, and systems. Many engineering undergraduates are provided with general instructions about concept generation, and the importance of creativity in this stage of the design process. However, it is less common for them to be taught specific cognitive strategies that may lead to generating more creative ideas. Rather than getting stuck in one idea, one can choose a heuristic, apply it to the current problem, and see where the resulting transformation leads. Using heuristics in engineering design adds to one’s ability to generate multiple creative ideas to consider.

Exposure to a variety of heuristics and experience in applying them on many different problems may lead to the development of expertise in innovation. For many engineering students, simply having an arsenal of design heuristics to try might lead to improvement in concepts generated. In fact, one factor may be motivational: it is possible that demonstrating the effectiveness of heuristics for creative tasks may, through feelings of efficacy, motivate creative efforts, just as the outcomes of creative efforts lead to an appreciation of creative work [Basadur et al. 1992]. Improvement in the use of heuristics might be indicated by a growing level of complexity in the external representations of the concepts proposed, indicating an understanding of the design heuristics and their application as idea-triggering strategies.

The research study suggests that in design problems, making use of specific design strategies may lead to more varied and creative solutions. Normally, when faced with a design problem, an appropriate heuristic is not obvious; rather, one is applied only if it can be accessed from memory. As an alternative, it is possible to adopt design heuristics through engaging in constructive processes, providing a medium for learning when and how to apply them. Increasing sophistication of integrating and implementing these heuristics in design creation may demonstrate the gradual acquisition of knowledge about design strategies and outcomes. The successful designs analyzed in this study, and further analyses, may reveal the design heuristics developed by innovative designers that may be useful to all practitioners.

Acknowledgement

The authors would like to thank to Richard Gonzalez, Panos Papalambros and Jan-Henrik Andersen for their support in the development of this research program. This research is supported by National Science Foundation, Engineering Design and Innovation (EDI) Grant 0927474.

References

Altshuller, G., "Creativity as an exact science", Gordon and Breach, New York, NY, 1984.

Basadur, M. S., Graen, G. B., Wakabayashi, M., "Identifying differences in creative problem solving style", In S.J. Parnes (ed.), Creative Problem-Solving, Chapter 18. Buffalo, N.Y.: Creative Education Foundation, 1992.

Boden, M., "The creative mind", George Weidenfeld and Nicolson Ltd, Great Britain, 1990.

Eberle, B., "Scamper", Prufrock, Waco, Texas, 1995.

Finke, R. A., Ward, T. B., Smith, S. M., "Creative cognition-theory, research, and application", MIT Press, Cambridge, MA, 1992.

Gordon, W. J. J., "Synectics", Harper & Row, New York, 1961.

Kruger, C., Cross, N., "Modeling cognitive strategies in creative design", in J S Gero and M L Maher (eds), Computational and cognitive models of creative design V, University of Sydney, Australia, 2001.

Newell, A., Simon, H. A., "Human problem solving", Prentice-Hall, Englewood Cliffs NJ, 1972.

Prahalad, C. K., Ramaswamy, V., "The New Frontier of Experience Innovation", Sloan Management Review, Summer, 2003.

Tor, S. B., Britton, G. A., Chandrashekar, M., NG, K. W.,"Functional design", In J. Usher, U. Roy, and H. Parsaei, (eds.), Integrated Product and Process Development: Methods, Tools and Technologies (pp. 29-58), New York: John Wiley & Sons, 1998.

Visser, W., "Use of episodic knowledge and information in design problem solving" in N. Christiaans, H. Christiaans, and K. Dorst (eds), Analysing design activity (pp 271–289), Wiley, Chichester, UK, 1996.

Yilmaz, S., Seifert, C. M., "Cognitive Heuristics Employed by Design Experts", Proceedings of the 3rd International Association of Society of Design Research Conference, Seoul, Korea, 2009.

Yilmaz, S., Seifert, C., M., Gonzalez, R., "Cognitive heuristics in design: Instructional strategies to increase creativity in idea generation," Journal of Artificial Intelligence in Engineering Design and Manufacturing (AI EDAM), Special Issue on Design Pedagogy, 2010 (in press).

Corresponding author full name and title: Seda Yilmaz
Position: PhD Student
Institution/University, Department: University of Michigan, Design Science
Address, City, Country: 2000 Bonisteel Blvd. 48109, Ann Arbor, MI, USA
Telephone: +1.734.3554221
Email: seda@umich.edu
URL: http://designscience.umich.edu/seda.html