

Investigating Ideation Flexibility through Incremental to Radical Heuristics

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Abstract

Ideation flexibility is the ability to shift between a designer's preferred and non-preferred ways of generating solutions as required by the presented task. There are many tools that exist to support ideation; however, there is a lack of research defining how to facilitate ideation flexibility and how to support designers in this process through use of such tools. In this paper, we report on the development of a new tool, the "Incremental to Radical Heuristics" (I2Rh), which may provide inspiring prompts for ideation, ranging from more incremental to more radical examples. We tested the use of this I2Rh with a small set of industrial design and architecture students and aim to report on ways in which designers with varying cognitive styles perceive and apply these heuristics and further the impact of the heuristics on the students' problem solving processes and ideation outcomes. Preliminary results demonstrate that more innovative students found the adaptive applications of the heuristics to trigger more novel solutions, whereas the more adaptive students found that the innovative applications to be more inspiring.

Keywords: ideation tools, design heuristics, adaption-innovation theory

Ideation is critical as it allows designers to form many diverse ideas to choose from and eventually test and validate them (Sheppard, Macatangay et al. 2009). However, in many cases, designers find it difficult to come up with many diverse ideas as a result of fixation they experience on particular ideas (Crilly 2015). Being a flexible designer means being able to move from one solution to another, in order to produce the most promising solutions for the given context. In this movement, idea generation methods play a critical role as facilitators of this movement while pushing designers to think differently (Silk, Daly et al. 2014).

The focus of the proposed work is *ideation flexibility* (Yilmaz, Daly et al. 2014), defined as the ability to ideate in both incremental and radical ways – or, more precisely, to ideate along a continuum of thinking between the two, depending on the needs of the problem. Building on the theoretical foundation of Kirton's adaption-innovation theory (Kirton 1976), we defined the ideation success as a designer's ability to move between his/her preferred and non-preferred ways of generating ideas as required in the design brief. To specifically target ideation flexibility, we took an empirically-driven and validated ideation tool, Design

Heuristics (Yilmaz, Seifert et al. 2016), and modified it based on the Kirton's adaptive-innovative theory. This revised set, called the "*Incremental to Radical Heuristics*" (I2Rh), illustrates heuristics' application both incrementally and radically to the same example design problem. I2Rh is intended to help designers execute an ideation strategy based on prompts, examples, and directions to incorporate more incremental or more radical changes to their naturally preferred ways of generating ideas, through facilitating flexible thinking. Our goal in this paper was to investigate how designers with different cognitive styles perceive and apply these revised heuristics and their impact on the students' ideation outcomes.

Literature Review

Adaption-Innovation Theory

Our work is grounded in Kirton's Adaption-Innovation (A-I) Theory (Kirton 1976), which provides a robust framework for understanding and managing cognitive diversity in problem solving, with a particular emphasis on cognitive style. Cognitive style is an individual's preferred approach for solving problems and can be measured along a continuum from *adaptive* to *innovative*. While adaptors are more prone to improve the current system, innovators are critical of the current system, choosing to create entirely new products, processes, models, and solutions. As designers understand their own cognitive styles and their desired processes for problem solving, one may find the entire design process to progress much smoother and more productively. Further, it is important to note the relationship between one's preferred style and actual applied behavior. Actual behavior, employed towards a design task, is a combination of preferred style and learned coping behavior. If one possesses a more adaptive style, while called upon to perform tasks that have few guidelines or established structures, he or she will tend to resort towards coping behavior, often leading to stress in the long-term. The converse is also true of those of the more innovative style.

Design Heuristics

Design Heuristics is an evidence-based idea generation tool and was developed to help designers think systematically and in a diverse manner throughout their idea generation process (Yilmaz, Seifert et al. 2016). This tool captures cognitive "rules of thumb" used by designers to intentionally vary their series of prospective designs, and was gathered via data collection from protocol studies of designers and engineers talking aloud during ideation, analyses of award winning products, and a case study of a long-term design project. The resulting set of Design Heuristics capture seventy-seven different strategies, each of which can be applied independently or in conjunction to create new designs. Each card displays a different strategy (Figure 1), supported with product examples showing their application.

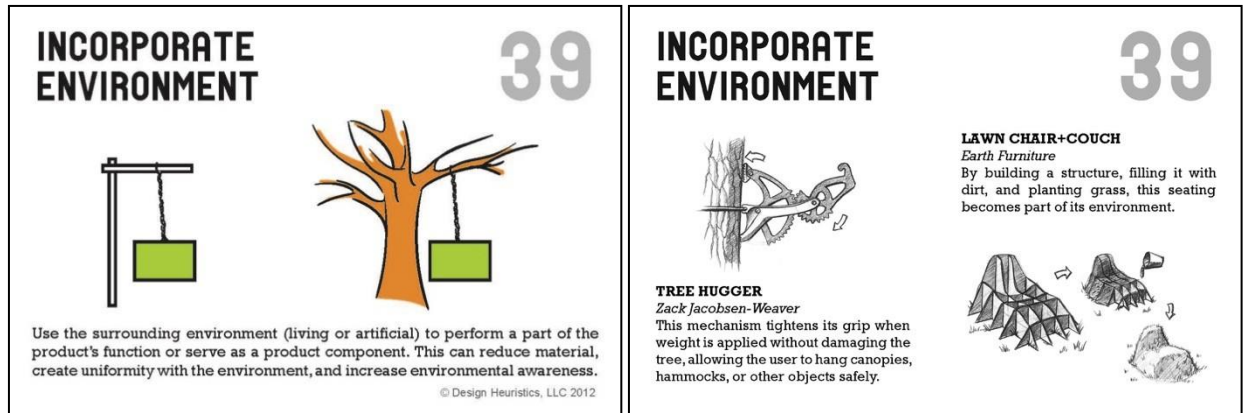


Figure 1. Example of a Design Heuristic card (front and back)

Development of the Incremental to Radical Heuristics (I2Rh)

Using the prior Design Heuristics tool and the A-I Theory, as its foundation we created a modified version of the tool, called the "*Incremental to Radical Heuristic (I2Rh) Cards.*" This revised set illustrates heuristics' application to a design problem from both an incremental and radical, such that both ends of the A-I spectrum are presented, allowing designers link the heuristic with a real-world application.

We started with the original list of heuristics as a basis. We aimed to replace the product examples on the back of the cards with new examples, showing how each heuristic can be used adaptively and innovatively. Award winning products were collected from a variety of sources to create a database to choose the appropriate ones from. Once the product example was determined to fit that heuristic, a problem statement was reverse-engineered for further exploration. Unlike the product examples which align with the heuristics, this problem statement was independent, such that those using the tool may situate the example products in a relatable design problem framework. All problem statements on the cards were phrased, starting with "Design a way to..." and then expressed a constraint from which to design around. Finally, for each card, an additional product example was selected, which fit the heuristic, problem statement, and was either more incremental or radical than its counterpart example.

For example, on Heuristic 39, the front of the card (Figure 2a) presents a synopsis of what it means to incorporate the environment when applied to product design. Using basic geometry and minimal details, the approach is placed the idea into context in an explanatory fashion. On the back of the card (Figure 2b), the orange-framed shape presents the problem statement while the incremental and radical product examples responding to this problem statement are display below, followed by descriptions of the products and why they are either radical or incremental applications of the heuristic. For coding the prototypes, each product example either has a pink (left, incremental) or blue bar (right, radical) to indicate which approach is the incremental or radical example as applied to the problem statement.

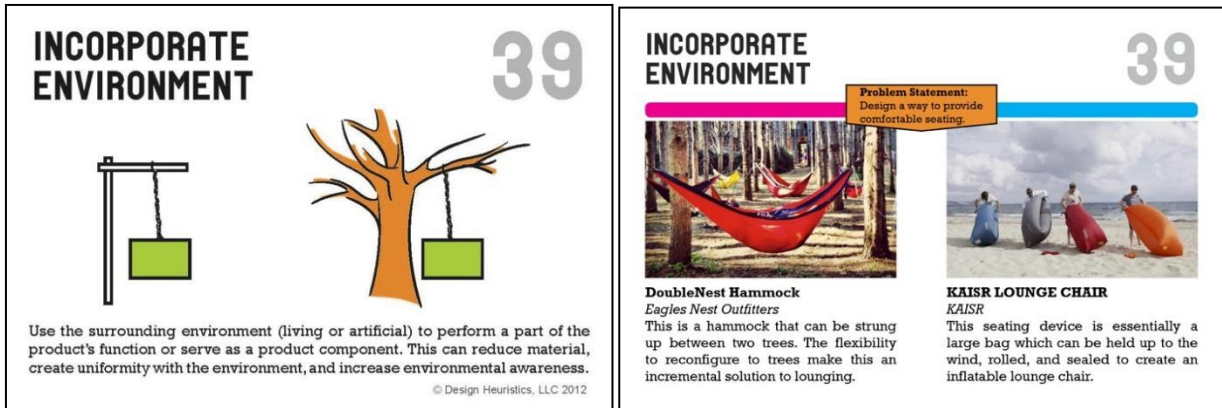


Figure 2a and 2b. Example of a Design Heuristic card (front and back)

Research Methods

Our study was guided by the following research questions:

1. How do design students perceive and use the I2Rh?
2. How do high adaptors versus high innovators use the I2Rh?
3. How do the adaptive versus innovative product examples impact solution outcomes?

To answer these questions, we conducted an exploratory study where participants were introduced to this new tool and asked to generate solutions to one of the two problem contexts provided. Participants were industrial design and architecture students at a large mid-western university. The study was held during a university sketch club event. In total, 26 students participated in the study, 3 freshman, 14 sophomores, 2 juniors and 7 seniors. The group was 17 male (65%), 9 female (35%), ages between 18 and 26.

Each student was provided a study package that had informed consent forms, Kirton Adaption- Innovation Inventory (KAI) to assess cognitive styles, problem statements, two reflection surveys, a post-ideation session survey, a demographic survey, and ten blank ideation sheets (five per ideation session). The design problems have been shown to be accessible by students with diverse cognitive styles and were neutrally-framed (Silk, Daly et al. 2014) to lead participants to generate ideas in their preferred manner. Each student was given only one problem for their session.

Table 1. Problem statements presented in study

Snow Transporter	One-Handed Can Opener
A way for individuals with little skill or experience in skiing or snowboarding to transport themselves on snow	A way for individuals with limited or no use of one upper extremity to open a lidded food container with one hand

Data Collection and Analysis

Figure 3 depicts the steps taken for this experimental study. Students were asked to fill out the KAIs. Next, students were given one of the two problems (Table 1) and asked to generate solutions without the tool, for twenty minutes. This was followed by the reflection survey.

After this initial, neutral ideation session, students were introduced to *I2Rh*, and were provided a small subset of the cards (10). Students, then, once again, were asked to generate solutions for the same problem they used for the first ideation session in twenty minutes; however, this time, with the *I2Rh* tool. Participants were prompted to use the *I2Rh* to either build off their previous concepts or create totally new concepts. They were free to select either the adaptive or the innovative example presented on the back of the cards to inspire their ideas. On the ideation sheets, they were then asked to report on the heuristic and the product example they used to initiate their concepts, using the color coordination. Though, participants were not told which color was associated with incremental or radical to avoid swaying their preference. Following this session, participants completed a second reflection survey. In total, students were given twenty minutes for the two ideation sessions and ten minutes for the reflection surveys. Finally, participants concluded the study by completing a post-ideation session survey, asking questions on the ease of use and the effectiveness of the tool, and their demographics.



Figure 3. Experimental Study Steps

Our preliminary analysis focused on the overall use of *I2Rh*, as well investigating the ‘extreme’ cases (high adaptors versus high innovators), comparatively. We identified high adaptors as participants with KAI scores lower than 78, and high innovators as participants with KAIs higher than 112, based on Kirton's hypothesized mean of $\mu = 95$, plus/minus one standard deviation ($\sigma=17$). We compared the students’ ideation outcomes achieved using the *I2Rh* with the outcomes they generated during the neutral ideation session, all relative to their KAI scores, to determine whether and to what degree the *I2Rh* facilitated a shift in the students’ ideation to be more adaptive or more innovative.

Discussion

In this paper, we report on the results of 25 participants, as one participant was removed from the data due to not completing the second ideation session. A histogram of the KAI cognitive style distribution for the 25 students is provided in Figure 4. It is interesting to note the slightly more innovative mean for our sample (96.64), when compared with the general population (95).

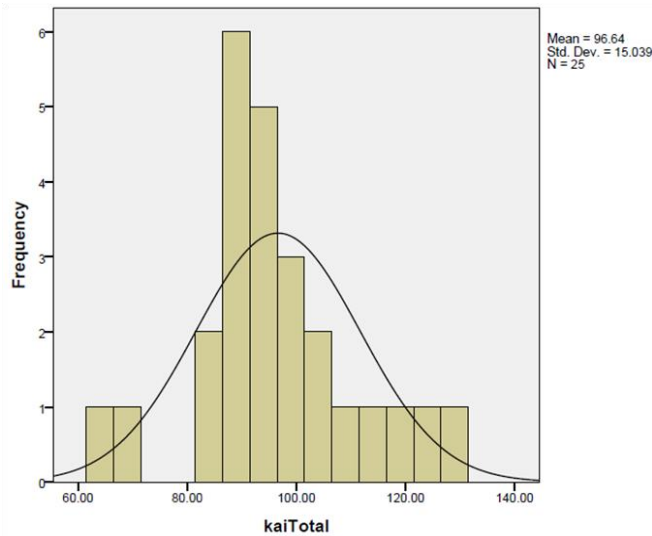


Figure 4. Distribution of reliable KAI total scores [N=25]

25 students generated 109 concepts in the Neutral ideation session ($M=4.16$; $SD=0.89$) and 88 concepts in the I2Rh ideation session ($M=3.52$; $SD=1.12$). A paired-samples t-test showed significant difference in the concepts generated for the Neutral condition ($M=4.16$; $SD=0.89$) and the I2Rh condition ($M=3.52$; $SD=1.12$) conditions; $t(24)=3.720$, $p=0.001$. This drop in the number of concepts generated may suggest that the students needed more time to read, reflect and apply the I2Rh cards, as the time for both sessions were 20 minutes, each. This may also partially be due to fatigue as the Neutral condition was given first to all participants. Although there is a decrease in the number of concepts in the second session, students continued generating concepts for the same design problem. When compared the two problem context, there is no significant difference in the number of solutions generated (both 96).

22 participants out of 25, reported use of the I2Rh, while 3 participants (KAIs: 84, 124 and 130) did not claim the use of either example in generating solutions. Instead, they used the heuristic as a prompt:

P2: “While I didn’t always follow the prompt on the card it gave me a solid jumping off point.”

P4: “Instead of imagining scenarios/problem, I was creating them trying to make the card work instead of looking at the problem already there.”

21 participants (out of the 22 who claimed I2Rh use) used the adaptive example while 17 people used the innovative example, as prompts to diverge from preferred ideation approach. This difference might be due to the fact that the adaptive examples were the first example students saw. This is consistent with the use of the innovative example versus the adaptive example to generate the very first concept. 15 participants used the adaptive example first whereas only 5 participants used the innovative example to assist generating the first concept. 16 participants used both examples, whereas 5 participants used only the adaptive examples (varying KAIs between 88 and 113), and 1 participant used only the innovative example (KAI=64). In this pool, only 2 participants claimed that they used both examples to generate a solution.

TWIST 66

Problem Statement:
Design a way to take music on the go.



AeroTwist
Kateryna Sokolova
This Bluetooth speaker can be opened and thus easily attached to a bag or bicycle. This donut shape allows it to twist and loop onto other products.



MUSIC WRAP
Wistron Corporation
This product has a flexible construction for various usages, such as wrapping around bicycle, docking for smartphone or tablet, or even wearing on neck.

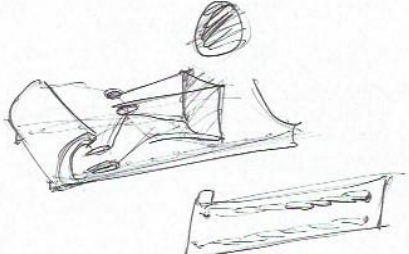
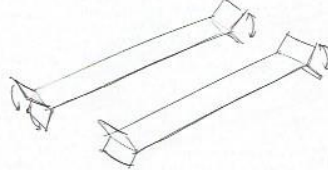
			
P5 (KAI 120)	Used Incremental e.g.	P6 (KAI 69)	Used Radical e.g.
“Sled that moves through snow like an auger.”		“These skis have tips that can bend the opposite direction to turn them into snow shoes.”	

Figure 5. Example card (#66 Twist) and its use in incremental versus radical way.

Figure 5 demonstrates how a high innovator used the incremental product example and how high adaptor used the radical example on the same heuristic card. The incremental example (the left) on the card shows a speaker that gives opportunity to the user to twist it in one way, in order to attach it on a bag or a bike. The radical example (the right) extends the flexibility in unexpected ways through suggesting the speaker be wrapped around anything.

For the snow transporter problem, Participant 5 (KAI= 120), using the incremental example, designed a sled with an auger mechanism on the bottom to propel the user over the snow. They seemed to use the incremental example in a more literal way, similar to a helix, and connected

that to a common form for propulsion, the Archimedean screw turbine. They applied the twist to the mechanics, to describe how the product would function. On the other hand, Participant 6 (KAI= 69) used twist to apply flexibility and dynamic properties to skis so they may transform into snowshoes. This idea exemplifies the prime connection adaptors have with radical examples. They combined two products which already exist, skis and snowshoes, through using the flexibility feature given in the example. Even if this is only one case, we can see how an incremental way of applying the heuristic led the designer to think about elaboration on existing concepts, versus how radical use of the heuristic led the designer to explore new solutions through connections provided by the principle.

The I2Rh cards worked in different ways with adaptors and innovators. Adaptors sometimes had a difficult time connecting the card to their ideas because they would become fixated on the product examples being something they “had already thought of” in the neutral session. Other remarks from adaptors were related to speed. They felt the need to read and understand the entire card which greatly slowed down their ideation process. Innovators said the cards helped them to generate more radical ideas, but felt it took longer to understand the problem. They had a hard time relating I2Rh to their given problem prompt and they took the focus from creating solutions for a problem to feeling they need to make the heuristics fit the problem.

We saw a greater number of participants using the cards as inspiration for their previous ideas as opposed to using the product example in its literal form to be incorporated. Sometimes the cards caused unnecessary confusion in the participant due to the amount of information on each side. CO-P8 claimed the product examples didn’t relate well enough to the I2Rh cards’ title causing creating unwarranted confusion for the participant to apply the card towards their own ideation. Conversely, many people found the cards to act as an aid to their ideation process rather than a hindrance.

Extreme Cases: High Innovators versus High Adaptors

Within this particular sample of 25, there were 6 "extreme" participants (Table 2). High innovators demonstrated KAI scores greater than 112, while high adapters possessed KAI scores less than 78. The four high innovators (KAIs 113-130), used four incremental cards with only one radical card. Conversely, the high adaptors, two incremental cards versus six radical cards were used. This difference, although within a small subset of participants, appears to show that the students on the extreme sides of the cognitive style continuum preferred using examples that were on the opposite side of their preferred ideation approach.

Table 2. Distribution of cognitive styles, number of concepts generated in the two ideation sessions, and the use of incremental versus radical examples, by the 6 ‘extreme’ cases

<i>Participant</i>	<i>KAI</i>	<i># of concept Neutral</i>	<i># of concept I2Rh</i>	<i>Use of Incremental Example</i>	<i>Use of Radical Example</i>
ST-P4	130	5	4	0	0
ST-P8	124	2	2	0	0
ST P5	120	5	4	3	1
CO-P8	113	3	2	1	0
ST-P6	69	4	3	2	1
CO-P3	64	5	3	0	5

Conclusions

Capability to ideate both incrementally and radically, based on the problem context and the requirements, and the awareness to move on this continuum is critical for designers. In order to help designers in navigating the solution space both incrementally and adaptively, we developed a tool, called, I2Rh. We found that high innovators tend to favor the incremental examples and high adaptors favor the radical examples. We also saw evidence of how radical use of the heuristics led to building new connections to create a new concept whereas

incremental use pushed the designer to consider identifying mechanisms and further details. Although this paper's focus was not the investigating the impacts on concept sketches, it is apparent that the examples on the cards often led to very literal and directly inspired ideas. This may speak to a potentially detrimental effect of the tool's use, as often allowing the mind to naturally wander can be incredibly rewarding for designers. Alternatively, the tool may sometimes feel forced, rather than act like an aid for designers. During the neutral session, participants thought their ideas were very creative and they were comfortable with their personal ideation processes. That said, the cards may have demonstrated their value for once a designer has exhausted his or her ideas, is stifled by a creative block, the cards may assist in producing a larger pool of ideas to spark a new direction to pursue or suggest a way to manipulate earlier ideas.

References

- Crilly, N. (2015). Fixation and creativity in concept development: The attitudes and practices of expert designers. *Design Studies*, 38, 54-91.
- Kirton, M. J. (1976). Adaptors and innovators: A description and measure. *Journal of Applied Psychology*, 61(5): 622-629.
- Sheppard, S. D., Macatangay, K., Colby, A., and Sullivan, W. (2009). *Educating engineers: Design for the future of the field*. Jossey-Bass: San Francisco, CA.
- Silk, E., Daly, S. R., Jablokow, K. W., Yilmaz, S., and Rosenberg, M. (2014). Using Adaption- Innovation Theory to build a framework for constructing design problem statements. Annual Conference of American Society of Engineering Education (ASEE) Indianapolis, IN.
- Yilmaz, S., Daly, S. R., Jablokow, K. W., Silk, E. M. and Rosenberg, M. (2014). Investigating impacts on the ideation flexibility of engineers. Annual Conference of American Society of Engineering Education (ASEE), Indianapolis, IN.
- Yilmaz, S., Seifert, C. M., Daly, S. R., and Gonzalez, R. (2016). Evidence-based design heuristics for idea generation. *Design Studies*, 46, 95-124.

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