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Enhancing Design Creativity With Intuitive Thinking

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A traditional engineering education primarily teaches students to use analytical methods when solving problems, which are effective in most real-world scenarios outside of design. However, heavily analytical approaches often hinder creative output and therefore intuitive methods have the potential to increase novelty in design. Using dual-process theory as a starting point, Type 1 processes, which are fast and intuitive, are examined to understand how they can be harnessed in a way that stimulates creative thinking. Existing methodology, particularly axiomatic design, stresses logical Type 2 thinking, which is slow and analytical. Innovative thinking methods that currently take advantage of these intuitive processes are discussed, and it is discussed how these methods may be mapped onto existing design methodologies.

1. Introduction

By its nature, engineering design balances the technical requirements of engineering with the holistic and artistic knowledge required to execute a successful design. However, rarely in engineering education do students get much training on how to harness creative and artistic thinking. There is evidence suggesting that favoring intuitive thinking is correlated with increased creative output and divergent thinking in an individual's brain (Raidl & Lubart, 2001; Simonton, 2003). Many great thinkers in history have a quote to the effect of Albert Einstein's, "To these elementary laws there leads no logical path, but only intuition, supported by being sympathetically in touch with experience" (Policastro, 1995). Supporting his stochastic model, psychologist Keith Simonton remarks, "inductive and deductive reasoning alone do not suffice to reproduce the psychological phenomenon of creative behavior" (Simonton, 2003). Thus, models such as stochastic process theory have been created to explain how intuitive thinking contributes to creative behavior.

For valid reasons, logical individuals are hesitant to make decisions based on instinct, but at the same time engineering design depends too much on analytical thinking, which limits creative potential. A balance can, and should, be struck. It has been shown that creativity can be trained (Ma, 2006). Methods such as Synectics generate creative ideas through simple but intuitive methods that require little training to stimulate abstract thinking that leads to creative idea generation. How can we incorporate more of these intuitive approaches into the formal engineering design process?

To a certain extent, axiomatic design aims to serve as intuition by leading designers down a proven path (Suh, 2005). Axiomatic design analyzes previous successful design processes and guides students to identify customer needs, determine functional requirements of those needs, and create design parameters to meet each functional requirement independently. Indeed, teaching such a design method can be used as a training tool, but its inherent structure does not allow room for deviations from traditional design thinking. The creativity in axiomatic design is emphasized in the problem definition of explaining the customer needs and formulating design parameters for functional requirements, which due to its open-ended nature could greatly benefit from improved creative approaches. In this way, the intuitive thinking methods proposed will be able to aid both discursive and intuitive methods of design.

2. Related Work

There are a number of existing methods outside of engineering that generate very creative, novel, and original ideas by taking advantage of intuitive approaches. These methods use the luxury of an open-ended problem and generate potential solutions that are less bound by details and functional requirements as in engineering design.

2.1 Synectics

The Synectics process emphasizes the need for creative and divergent thinking throughout the process. There is an emphasis on reserving judgment of ideas and letting the mind freely explore associations. In an ideation session, metaphors related to potential solutions are generated by the group, and solutions are effectively built on those metaphors. Uniqueness and novelty are highly valued, though this goes against the norm, as it has been shown that in general, unique ideas are generally less likely to be explored (Efros, 1985). Pahl et al. (1984) categorized Synectics as an intuitive approach to design, developed for nontechnical problems but applicable to creative idea development.

One of the most important aspects of Synectics is setting a positive team dynamic that cultivates a comfortable dynamic between team members and allows for absurd ideas to be offered. For example, "Discount-Revenge cycles" where team members will discount the ideas of others who previously put down their ideas are important to isolate and eliminate. A strong dynamic is important to create an environment that supports innovative thought and is free of premature judgment. Another hallmark of Synectics is the use of “excursions” to mitigate fixation. This involves moving away from the problem at hand and generating a list of unrelated ideas (for example, what are five things you would want at your dream vacation resort). Through analogical thinking, associations are forced between the ideas generated in the excursion and the original problem at hand. This process infuses the group discussion with a new set of ideas and stimuli that effectively drives the innovation process (Gordon, 1961).

2.2 Design Thinking

IDEO's approach to innovative consulting takes the phrase of "design thinking," and Tim Brown supports the idea that "human-centered design" can be applied to all walks of life. They highlight the value of being immersed in creative spaces and creative cultures, so that diverse teams can effectively generate original ideas. Their process highlights the need for empathetic feeling, observing, and experience as much as possible about the problem. Like Synectics, design thinking takes advantage of convergent and divergent thinking. The large number of ideas produced through divergent thinking drives quality in the convergent phase of the process (Runco, 2003). This is not a new idea, however, it is important to reiterate that it is much more difficult to develop an uncreative idea into a creative one – it is much better to start with a large selection of unique ideas and converge on one or a few.

2.3 The Stochastic Model of Creativity and Conscious Impulses

Simonton's model indirectly supports the efficacy of these approaches to creative thinking. Based on Donald Campbell's model of blind variation and selective retention in creative thought, three key conditions to creativity are identified: "a mechanism for introducing variation, a consistent selection process, and a mechanism for preserving and reproducing the selected variations," introducing the concept of evolutionary epistemology (Campbell, 1960). With these three components, as preinventive forms are explored in the subconscious, new associations are made and the most useful associations rise to the conscious surface (Simonton, 1999). True to Campbell's first component of introducing variation, this is optimized with the widest range of external stimuli possible. Simonton notes there is "restricted amount of chance, randomness, or unpredictability" required in the creative process, and so the best one can do is set themselves up to increase the chances of stumbling upon a brilliant idea (Simonton, 2003). This is done through "extraneous influences" such as reading on unrelated fields, which leads to increased instances of unexpected associations and ideas similar to the excursion in the Synectics process.

However, seemingly unexpected associations are not as random as one may think. Benjamin Libet first demonstrated, since extended, that conscious impulses are premeditated by electrical signals in the brain by up to ten seconds (Libet, Gleason, Wright, & Pearl, 1983; Soon, Brass, Heinze, & Haynes, 2008). These findings support the stochastic model, as there is a measureable proxy of unconscious activity in the brain leading to a given conscious impulse. One can imagine that the amount of processing done in those ten seconds is likely much more widely focused than conscious processing, as the brain takes in as much relevant information as possible to produce the optimal result. It seems natural that there should be more effort spent on honing those preconscious processes to produce conscious ideas that are more original, creative, and innovative.

2.4 Unifying Trends

In the preceding three sections, one sees a heavy dependence on remote associations born out of stochastic and divergent thinking that direct individuals in creative and unexpected directions. Contrary to engineering design there is little rational deduction involved, but at the same time there is a high amount of creative value in the Synectics and design thinking methods. Paired with these remote associations is an imperative to avoid premature judgments of ideas, which will be discussed in the following sections. These coincide with the *opportunistic assimilation* hypothesis, where insight in a problem is triggered by external stimuli observed when one temporarily sets a problem aside (Seifert, Meyer, Davidson, Patalano, & Yaniv, 1994).

3. Dual-Process Theory and Creative Thinking

A promising method to understand the effectiveness of intuitive thinking in the design process is by applying dual-process theory, an established model that divides cognitive processes into two camps: Type 1 and Type 2. Type 1 processes are fast, intuitive, heuristics-based, and emotional, and answer simple questions like, "What is 2 x 4?" or when one reads the emotion on a colleague's face. Type 1 processes are only effective when there has been enough experience for implicit learning to take place. Conversely, Type 2 processes are slow and analytical, and answer more difficult questions like “What is 24 x 17?” and also kick in if they detect an error is about to be made (Stanovich, 2011). Engineering education is focused on producing analytical, thoughtful individuals, effectively honing Type 2 processes. However, much of the creative methodology described in Section 2 seem to harness Type 1 processes. It is very likely that Type 1 processes will prove to be stronger contributors to the creative process than Type 2 processes alone. A correlation has been found between dependence on intuitive thinking and creative potential, and we look to formalize and expand on this result (Raidl & Lubart, 2001).

There is plenty of evidence demonstrating both the value and danger of using Type 1 reasoning. Heuristics-based (Type 1) reasoning is most valuable in a benign environment that supports the use of heuristics through experience and implicit learning (Kahneman & Klein, 2009). In certain instances, Type 1 processes can perform better than Type 2 thinking (Hartwig & Bond Jr, 2011). However, much effort has been spent demonstrating how Type 1 reasoning breaks down in more complicated situations (Tversky & Kahneman, 1974).

A first attempt was made to distinguish the roles of Type 1 and Type 2 processes the in the design process of students (Moore, Sauder, & Jin, 2014). In this exploratory pilot study, it was found that Type 1 thinking was more prevalent in the earlier, conceptual stages, and Type 2 processes more prevalent in the later, embodiment stages. This is to be expected, as ideation naturally involves taking advantage of some quick thinking, like unexpected associations, and later stages involve more convergent thinking and solution analysis. In addition, this finding coincides with axiomatic design that employs more creativity in the early stages of the design process, which focuses more on social issues and artistic value. Later on, the process employs the physical and technical details central to engineering design. It should be noted that this finding shows room for potential improvement. If our theories are correct, more creative designs may be achievable if Type 1 thinking is sustained throughout the entire process.

Hogarth (2005) explored the balance of intuitive and analytical thinking in various realms of problem solving, based on the complexity and potential for bias, such as experience and characterization of problem environment. He suggests that for problems with low complexity but high potential for bias, analytical approaches are favored over intuitive approaches. Conversely, for problems with high complexity, but low potential for bias, intuitive approaches are favored over analytical approaches. For problems with high complexity and high potential for misleading bias (such as a first year design student approaching their first design problem), it is unclear whether intuitive or analytical approaches are superior. While the analytical approach seems to naturally be preferred, it is possible that inexperience may keep an individual from isolating the critical information required to solve a problem, and as a result fixate on irrelevant or misleading information. This coincides with Smith and Linsey's (2011) definition of fixation. As such, there may be value in Baylor's (2001) U-shaped model of intuition, where the level of expertise correlates with availability of intuition. Novices, not being able to depend on previous experience, can harness immature intuition (an approach favored by the Synectics process), and experts can harness mature intuition, developed through experience and implicit learning. With a moderate level of expertise, one is too timid to use intuition, but does not know enough to fully analyze and solve a problem, so they are left with limited options and a hesitance to suggest innovative solutions due to the lack of confidence that comes with full expertise in the field. In addition, one does not have the freedom to blame potential failure on inexperience.

4. Towards a Model of Intuitive Thinking

Having established the prevalence and efficacy of intuitive thinking in innovative design processes, it is now necessary to understand the underlying theory behind these methodologies. With this theoretical understanding, it will be possible to map the innovative thinking methods onto engineering design methodology. The following model (Figure 1) is a first attempt at organizing the characteristics of intuitive thinking. At the center is stochastic association, which is influenced by internal and external factors. External factors include the given design problem, environment, and random external stimuli. These elements feed information to the mind's Type 1 associative processes, which will naturally contextualize the problem with prior knowledge. The quality of these associations will also be influenced by the mental openness to associations and prior experience. The result of these associations could either be ideas, which will vary in novelty depending on the stimuli, or fixation, if the individual focuses on incorrect issues of the problem, or the problem becomes overcontextualized.

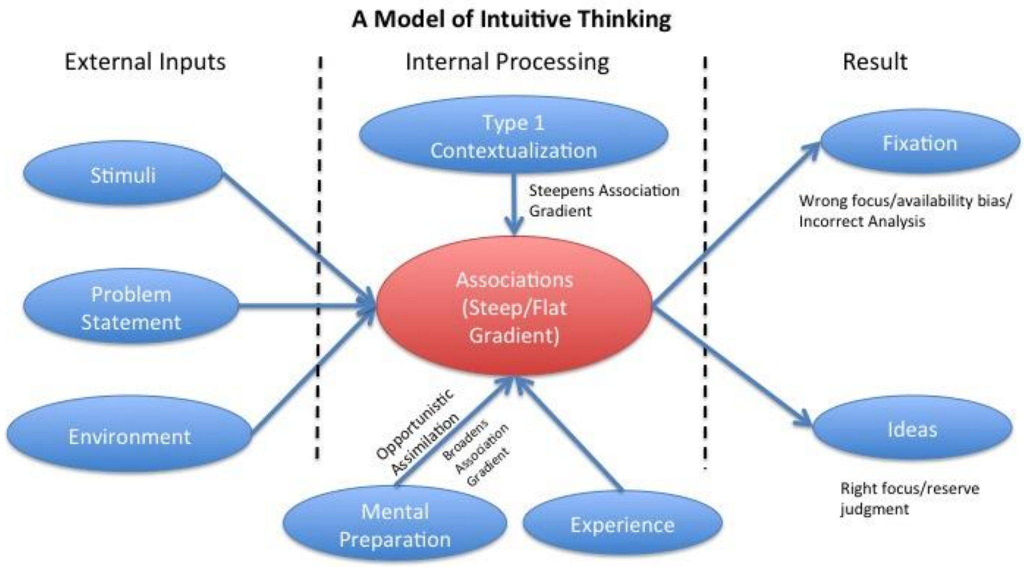

Figure 1: A Proposed Model of Intuitive Idea Generation

4.1 Problem Contextualization

In engineering design, it is a blessing and a curse that we often have ill-defined problems and open-ended solutions. This makes the design process challenging, and simultaneously there is a freedom that allows for a wide range of creative possibilities.

One inherent stumbling block to creative solutions is the automatic contextualization of stimuli by Type 1 processes with prior knowledge, coined the "fundamental computational bias of human cognition" (Stanovich, 2011). While it is true that extraneous influences cause more unexpected associations in our brains, contextualization and idea generation is prone to availability bias, where the set of suggested ideas is limited by recently observed information and stimuli (Smith, Ward, & Schumacher, 1993). When preinventive structures are supplied, an individual's thinking will be more focused, leading to a steeper association gradient with predictable ideas. Ideally, with ill-defined problems, one wants a flat association gradient (see Figure 1), where a wide range of heuristics and remote associations can be applied (Simonton, 2003).

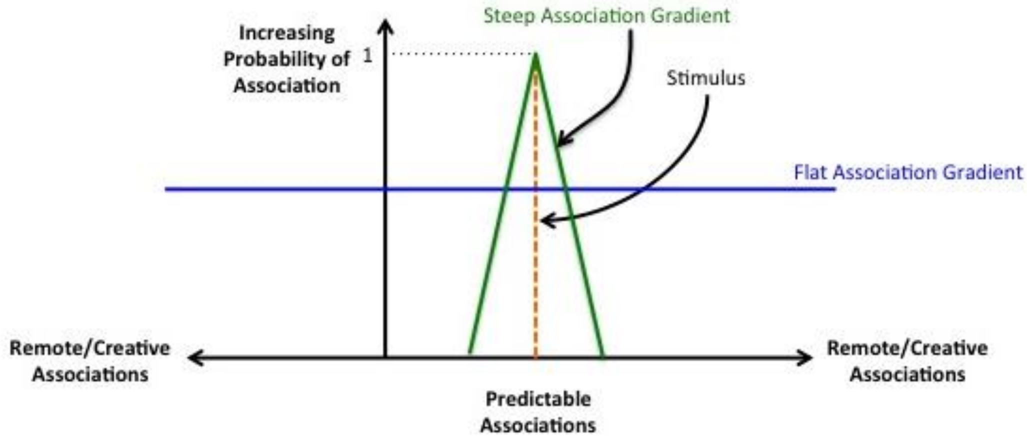

Figure 2: Flat vs. Steep Association Gradients (Adapted from Simonton, 2003)

Synectics avoids this by only giving the resources in the group as little information as possible for them to begin innovating. With too much information, the Type 1 associative machine gets too bogged down in contextualization and details. They suggest freely thinking, keeping an uninformed, child-like curiosity. Once an idea is focused on, similar to observing an electron in quantum mechanics, the associative gradient collapses to a steep function. That is, it is likely to limit the freedom and creativity of the group. Ideas that fall outside of this range of acceptability are quickly discarded and are less likely to be explored (Efros, 1985).

4.2 Personal Disposition

It has been shown that individuals induced into a positive mood performed better on the Remote Association Test (Mednick, 1968; Rowe, Hirsh, & Anderson, 2007). Having this associative ability is key to the Synectics and design thinking processes, and explains why they are so intent on developing a safe, positive environment. In addition, the variety of stimuli and ideas is central to the stochastic model (Simonton, 1999). A positive dynamic increases the likelihood of remote associations, supporting divergent thinking. Avoiding judgment of ideas early on in the design process is that having a low *feeling of rightness* is correlated with more Type 2 processes being used, which we believe hamper the early stages of the design process.

The ability and fluency of individuals to draw remote associations to stimuli and notice otherwise mundane details in observation is correlated with latent inhibition (LI). Individuals with a high IQ and low LI have the potential to be highly creative people (Carson, Peterson, & Higgins, 2003). However, it is important to avoid sensory overload, as individuals with average to low IQ and low LI are prone to psychotic disorders. It seems like LI is something that could be trained, but no literature has yet been found in support of this.

4.3 Metaphor and Analogy

The Synectics model states that with a higher suspension of reality, one moves into the realm of analogy, metaphor, absurdity, and ultimately the realm of novel idea generation

(Gordon, 1961). Lakoff describes the value of "cross-domain mapping" to help to understand problems and ideas (Lakoff, 1993). For example, thought experiments such as Schrödinger's cat are famous in physics and articulate counterintuitive implications of quantum mechanics. Developing metaphors or thought experiments is a logical process, but in the process, it renews one's view of a problem and may help to cause serendipitous associations or novel interpretations of the problem. The extent that metaphorical thinking is intuitive or logical has yet to be identified.

Bringing a metaphor into the design process stimulates creativity as it brings in a whole new set of ideas and associations. Instead of systematically returning to the list of functional requirements, it may be more stimulating to return to global and local creative metaphors related to desired outcomes of the design process. This kind of thinking is costly in time and cognitive energy, and is not necessarily as immediately rewarding as traditional problem solving in which one quickly converges to a solution. Hey et al. (2008) analyzed the use of metaphors and analogies in engineering design by how much teams of students would use metaphors and analogies for communication by words only, sketches only, or a combination, as well as by how team members exchanged ideas. The study is one among many (Linsey, Wood, & Markman, 2008; Linsey, Laux, Clauss, Wood, & Markman, 2007) which indicate that student design teams employ both analogies and metaphors in the design process, primarily to generate solutions to the design problem. A design by analogy method was created by Hey et al. (2008) that encourages the creation of multiple representations of a design problem that would stimulate designers to think of a larger set of analogies that can reframe the problem in other ways to provide different perspectives to generate a more creative solution. However, such creativity is focused on the beginning of the design process in the problem definition, and it it not emphasized to maintain such abstraction throughout the duration of the design.

5. Future Work

5.1 Dual-Process and Creativity

It is essential to confirm link between Type 1 thinking and creativity in design, to characterize the value of intuitive thinking in the design process. Our early results suggest that a balance of Type 1 and Type 2 thinking may be optimal, but these results are not yet statistically significant. Naturally, it is also important to understand when are the optimal times to employ Type 1 and Type 2 thinking throughout the design process. Likely, this will mirror the methods of divergent and convergent thinking. By coordinating engineering design with dual-process theory, there is a large literature that can be harnessed that has analyzed different ways to stimulate Type 1 and Type 2 thinking. For instance, inducing cognitive strain, such as with a difficult to read font, activates Type 2 analytical reasoning (Alter, Oppenheimer, Epley, & Eyre, 2007). Not all methods are as trivial, but an understanding could help to realize when unintentional cues are hampering the design process.

5.2 Mapping Existing Methods onto Engineering Design

Intuitive methods of design creativity are only taught in limited classroom settings, and their efficacy in the engineering design process is unknown. Synectics produces solutions to problems that are creative and unexpected, and perhaps these results are generally too out-of-the-box to be considered useful for engineering design. Similarly, Finke demonstrated that if function followed form in design, then the solutions were generally more creative. However this freedom is not always available in the engineering domain. It is important to understand how these methods work to effectively map them onto engineering design methodologies. In addition, it may be beneficial to examine other fields, such as music, to understand how they educate and take advantage of intuitive thinking.

The role of intuitive thinking may involve carefully increasing the thinking space that allows for a wider range of possible ideas. For engineering design, it seems imperative to broaden the association gradient from where it currently is. However, it may not be effective to use as flat of an association gradient as Synectics employs, as in the end every design must conform to the specific requirements set forth by the customer. In addition, not all stimuli are positive. For example, designers conform to previous examples and ideas, an example of availability bias, which shows that the comfort and inherent limitation of relying on previously used ideas (Smith et al., 1993). It is clear there are additive associations and reductive associations. However, maintaining an element of the child-like curiosity key to Synectics throughout the design process may help to naturally improve creative idea generation and embodiment.

5.3 Understanding and Fixation

One possible implication of these methods is a deeper understanding and mitigation of fixation. Fixation as it is defined (Smith & Linsey, 2011) is inexperience leading to focusing on irrelevant information in a problem. This is still a danger with using immature intuition (Baylor, 2001), but through carefully tempering immature intuition and contextualization with a conscious open mind to stimuli that lead to creative ideas. If the mind is too set in an analysis of existing data, it can be easy to avoid new information and stimuli.

6. Summary

Intuitive thinking is critical to the creative process. While engineering often teaches students to discount intuitive reasoning in lieu of analysis and logic, it is useful to take advantage of the natural stochastic randomness inherent in the creative process. It is important to strike a balance between not enough stimuli and too much that would cause information overload. Type 1 processes naturally contextualize problems and stimuli, so it may be limiting focusing too much on abstracting the root of the problem and determining essential functional requirements. All of this analysis will be tainted by prior knowledge and experience, often leading to a detrimental steep association gradient and reduction in creative potential. We need to let our associative machine be free and avoid judgment of ideas.

Our goal is not to reinvent the design process but rather to enhance it through natural, intuitive thinking. Anything that leads to an increase in thinking space could be a positive input to the creative process. We often use logical reasoning to back up our intuition, as society has an inherent distrust of intuitive reasoning. Our goal should be to maintain high mental entropy in the design process as late as possible. Only when there is a strong foundation of ideas should we converge on a solution or set of solutions to explore. Those solutions can be iterated and reimagined as necessary.

There is much to be gained from harnessing intuitive thinking in the design process, and there is still much to explore. In closing, we recall the words of Sigmund Freud, "When making a decision of minor importance, I have always found it advantageous to consider all the pros and cons. In vital matters, however, such as the choice of a mate or a profession, the decision should come from the unconscious, from somewhere within ourselves."

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