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Mechanical Engineering Students' Self-limiting Behaviors in Concept Generation

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Mechanical Engineering Students' Self-Limiting Behaviors in Concept Generation

Engineering design requires addressing open-ended design problems. Concept generation occurs during the early phases of a design process where engineers consider potential concepts to address the design problem and these concepts are further iterated and combined to create final designs. During concept generation, the goal is to generate a large number of diverse concepts and consider many possible solutions without evaluating feasibility. However, engineering students face challenges in concept generation as they often consider a limited number of concepts that are similar to existing products with minor modifications. Minimizing the diversity of concepts can limit the possibility of generating novel, innovative solutions. While studies have investigated concept generation practices, questions remain on why engineering students limit divergence and become fixated. We conducted think-aloud studies to analyze mechanical engineering students' concept generation behaviors. The think-aloud method asks research participants to verbalize their thought processes during a task, allowing researchers to capture the details of their behaviors. Ten mechanical engineering students were recruited and asked to generate potential solutions for a design problem. We analyzed patterns in students' concept generation practices to uncover why they limited divergent thinking. Participants narrowed the problem that restricted potential solutions, eliminated potential ideas due to financial costs, directed themselves away from potential solutions outside of their knowledge, and focused on criticizing existing solutions that led them to suggest concepts that were minor improvements on those existing solutions. By understanding specific behaviors that lead to reducing the quantity and diversity of possible solutions, the results of the study can support engineering instructors to provide scaffolding as they provide lessons on concept generation for their students.

Introduction

With the increasing complexity of problems in the world, engineers must develop innovative solutions to pressing problems, as described by the National Academy of Engineering [1]. To equip students with important design skills, design education has adopted project-based courses that require students to tackle open-ended problems [2]. However, despite the changes in the curriculum, studies have indicated the challenges of teaching students how to innovate [3], [4].

Engineers engage in concept generation in design, which serves as an important step that contributes to innovative design outcomes [5], [6]. Understanding the process of concept generation is important to improving design processes and, ultimately, outcomes. During concept generation, engineers are encouraged to explore a large number of creative concepts that serve as the foundation for creating their final solutions [7]. However, research has shown that engineers often do not consider multiple, varying concepts and instead consider variations of existing ideas, called fixation [8], [9]. While studies have investigated concept generation approaches and outcomes, there are remaining questions about why students face challenges in generating a large number of diverse concepts [10]–[12]. Limited studies have investigated and captured engineers' behaviors during concept generation to uncover why engineers face challenges in divergent thinking.

This study examined mechanical engineering students' self-limiting behaviors that lead to minimizing a large quantity of diverse concepts during concept generating using think-aloud studies and semi-structured interviews. Think-aloud studies capture thought processes in people's working memory to provide an accurate picture of their approaches, allowing us to identify specific behaviors and thought patterns [13]. We aimed to study students' behaviors that led to minimizing the quantity and diversity of concepts considered during concept generation tasks.

Background

Design involves a process of understanding a problem from multiple angles, considering potential concepts to address the problem, and testing to ensure that the selected concept meets the needs [5]. The early stages of design, including concept generation, have a significant impact on the success of the design project [14] as these initial concepts can often set the trajectory for the rest of a design process. Best practices in concept generation emphasize the importance of generating a large quantity of diverse, novel concepts [7]. The chance of generating novel ideas increases as designers consider a large quantity of ideas [15]. As engineers explore the design space and consider potential solutions, initial ideas are often the most obvious and conventional solutions. The best practice would be to persist after exhausting initial ideas to consider more novel ideas [15].

To support concept generation, several tools have been proposed and tested to guide concept generation for both novice and experienced designers. There are tools for concept generation across contexts such as brainstorming [16], TRIZ [17], Synetics [18], and SCAMPER [19]. Other tools that align with the domain in which the design work is being conducted such as Design Heuristics [10], [11] that were developed from studying award-winning products and designers' practices in developing consumer products, and microfluidic design strategies [20], which were developed from studying microfluidic device patents. Each of these strategies provides a unique direction in concept generation. Many of these tools have been shown to guide designers to consider more novel ideas [12], [20], [21].

Research has shown that designers struggle to engage in divergent thinking to consider multiple potential solutions during concept generation [4], [22], [23]. Designers often focus on a single idea or variations of similar ideas instead of exploring other alternatives, defined as fixation [8], [24]. In some cases, novice designers have shown to become attached to early solution concepts even after realizing major flaws and challenges associated with pursuing those concepts [25], [26]. Despite available resources and tools, concept generation can be challenging for students and they may limit divergent thinking as they engage in it, sometimes consciously, but also unconsciously. Research has demonstrated that students who have been given design instructions in the classroom can struggle with concept generation as they face challenges generating a large number of diverse concepts [23], [27]. A gap exists in providing a better understanding of why engineering students limit their divergent thinking during concept generation.

Methods

The project was motivated by the following research question:

- How do mechanical engineering students limit themselves from generating a large quantity of diverse concepts?

Participants

Partcipants included 10 undergraduate mechanical engineering students. Participants were recruited on a rolling basis through targeted emails to undergraduate mechanical engineering students at a large Midwestern university. All participants had taken at least one design-related college course and many students had engaged in design activities through extra-curricular activities or internships. With these experiences, students had opportunities to develop their design skills and strategies, including concept generation. Participant demographics are shown in Table 1.

Table 1. Participant information.

Pseudonym	Gender	Level of education
Abraham	Male	Junior
Brie	Female	Sophomore
Chris	Male	Junior
Danielle	Female	Senior
Ethan	Male	Junior
Faith	Female	Senior
George	Male	Senior
Hunter	Male	Junior
Ian	Male	Junior
Julie	Female	Junior

Data Collection

Data were collected in three steps as summarized in Figure 1 and described in the following paragraphs.

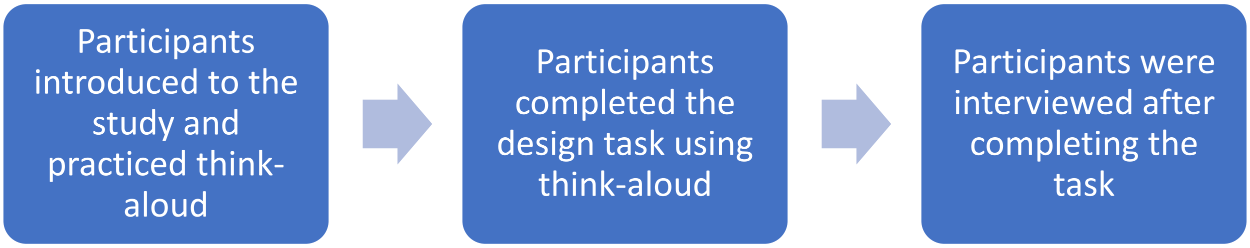

Figure 1. Procedure for collecting data.

Participants who agreed to be part of the research study were introduced to the design task and led in a practice of thinking aloud to verbalize their thought processes prior to beginning the study. Then, participants were given one of two concept generation tasks to complete independently and think-aloud as they did it. These data were collected using a Livescribe Echo pen, which recorded participants' handwritten notes and sketches as well as their verbalizations.

Using two concept generation tasks allowed us to examine behaviors across design contexts. To develop the tasks, we examined previous tasks used in the literature and considered qualities of the task that would make them appropriate for our experiment. The tasks we developed did not require any prior knowledge or expertise to solve, and solutions were product-oriented, aligning with a design area in which mechanical engineering students would be familiar. Of the tasks, multiple were initially developed and piloted, and we chose two that did not require further explanation during pilot tests. The final tasks were: 1) a low-skill snow transporter problem that required participants to design a personal transportation tool or (2) a one-handed opener for food containers problem that asked participants to develop ways for people with limited ability to use their upper extremity to open a food container. The full descriptions of these problem statements are included in the Appendix.

Participants were allowed to use any resources they needed to complete the design task. Many participants requested to use a laptop or smartphone with internet access. Participants spent between one hour and an hour and 45 minutes working on the concept generation task; participants were instructed to spend as long as they needed to complete the task.

After completing the task, participants were interviewed using a semi-structured interview protocol. The interviews served as an opportunity to further explore participants' concept generation approaches and enabled probing for more information to ensure the clarity of data. The interview questions were developed through multiple iterations and two pilot tests. The interview involved open-ended questions that asked participants to describe their process and steps. Open-ended questions minimize the possibility of leading the interviewee to respond in a narrow or biased way. Example questions for the interview are shown in Table 2. One researcher conducted all of the think-aloud and semi-structured interviews for consistency. Approximately 12 hours of think-aloud data and 6 hours of interview recordings were collected among 10 participants.

Table 2. Example open-ended interview questions.

Interview Section	**Interview Question**
Overview	Can you walk me through how you developed solutions and selected a final one at the end?
Idea Generation	How did you generate ideas to address the problem?
Idea Development	How, if at all, did you iterate on any of your ideas?

Data Analysis

The interview and think-aloud data were transcribed and checked for accuracy. The data were analyzed inductively to identify concept generation behaviors and themes that emerged after multiple, detailed readings of raw data. Then, the second round of analysis was completed inductively to identify self-limiting behaviors that led to minimizing divergent thinking during concept generation.

Findings

Four distinct self-limiting behaviors were found in participants' approaches to concept generation. We summarize these behaviors that limited students' divergent thinking in Table 3 and elaborate on each behavior in this section.

Table 3. List of self-limiting behaviors

Behavior	**Number Observed (n = 10)**	**Definition**
Narrowing the problem statement	7	Participants constrained and narrowed the problem statement to limit what solutions could be viable.
Focusing on minimizing the financial cost	4	Participants aimed to reduce the financial cost of the design and eliminated potential concepts that they thought would be expensive.
Eliminating concepts due to lack of knowledge	4	Participants did not consider concepts outside of their knowledge and understanding.
Criticizing and improving an existing solution	6	Participants focused on the limitations of existing solutions and aimed to make improvements to the existing solutions instead of considering other potential solutions.

Narrowing the problem statement

Participants limited their divergent thinking and constrained their potential solutions in the early stage by narrowing the problem. Faith was working on the problem to design a snow transportation device. After reading the problem statement, she narrowed the problem and stated her goal of the design task as “simplify skiing/snowboarding to allow for more people to do it.” Faith focused on variations of skis and snowboards as potential solutions throughout her concept generation as shown in Figure 2 as a result of reframing the problem. She considered solutions that involved a board with motorized wheels on the front and rear to allow the user to go uphill (Figure 3. a), a board with wheels only on the rear (Figure 3.b), a board with skis attached to both sides (Figure 3.c).

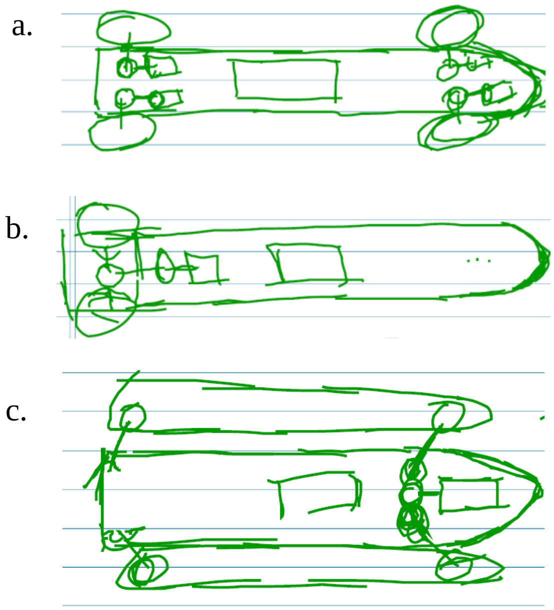

Figure 2. Potential concepts considered by a participant: (a) a board with electric motors and wheels on the front and rear, (b) a board with wheels only on the rear, (b) a board with skis on both sides.

As a second example, Julie was working on the one-handed opener problem and narrowed the problem that limited potential solutions she considered. She focused on a device that could grip the jar or lid as the main goal of the design task and considered variations of mechanisms to provide a grip:

> “I guess came up with the two problems that you'd face when you're using one of your arms. The constraint was just using your one arm to support and you have another arm that you could use. **I wanted something that could grip on the jar and grip on the lid**.”

As a result of this reframing, Julie generated two concepts that emphasized gripping the jar using a squeezing mechanism (Figure 3.a) or stabilizing the lid using a wedge (Figure 3.b).

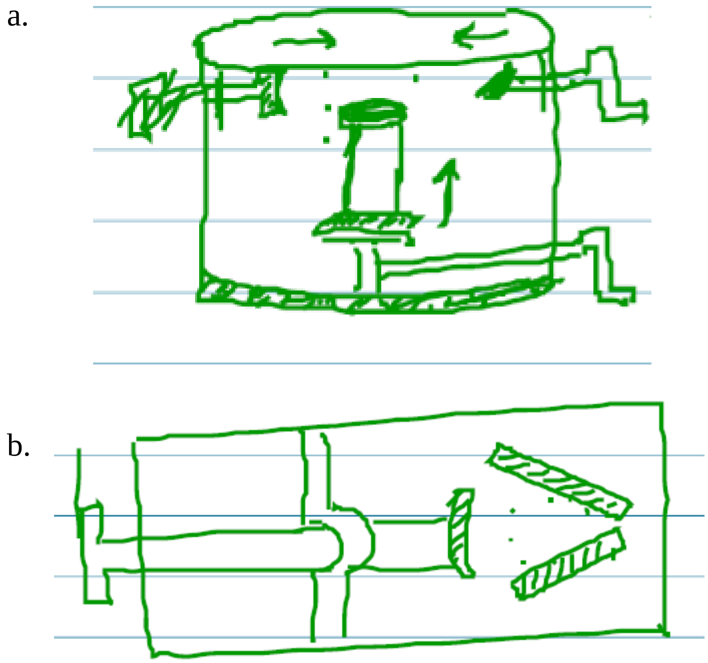

Figure 3. A participant’s concepts emphasized (a) gripping the jar and lid using a squeezing mechanism, and (b) holding on to the jar using a wedge.

Focusing on minimizing the financial cost

Some participants focused on minimizing the financial cost of the device, which constrained their options and limited their divergent thinking. The overall cost of the device was not explicitly stated as a requirement but students were conscious of the potential costs associated with ideas. Hunter was working on a snow transporter problem and indicated that he wanted to consider solutions that did not involve motors, which can be costly:

> *“Something that's probably a lot cheaper, it would be maybe like something similar to a bike… I'm going to make the assumption that this person does not have enough money for a snowmobile because if they wanted to transport themselves on the snow with low skill, I mean they can just buy that.”*

By filtering out potential solutions that would require added financial costs, such as motors, Hunter gravitated toward creating human-powered devices similar to a bike with snowmobile tracks as shown in Figure 4. He focused on considering variations of human-powered bikes throughout the concept generation task.

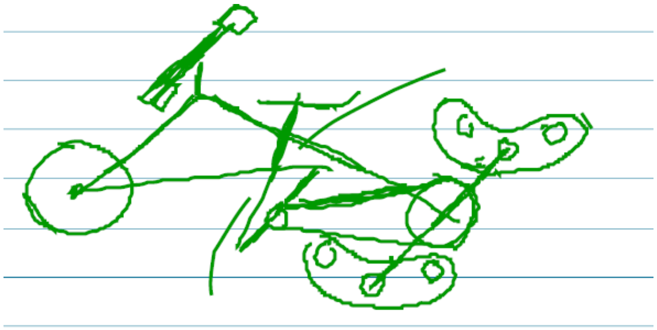

Figure 4. An example of a human-powered device generated by a participant.

<u>Eliminating a possible direction due to lack of knowledge</u>

Some participants filtered potential solutions outside of their knowledge. Hunter worked on the snow transporter problem and considered specific features of a solution. He focused on creating a braking system for the snow transporter and indicated that he did not know how to create a braking system that would involve braking two wheels at the same time. Thus, he quickly eliminated a potential feature and decided to focus on creating an idea similar to a tricycle that only has a braking system for one front wheel:

> *"You squeeze down on the brakes, and the brake pads squeeze on the wheel, the single wheel. I couldn't think of a way that would be able to happen with two wheels, so I changed the design to just have one wheel in front rather than two. Then it became a tricycle, if that makes sense."*

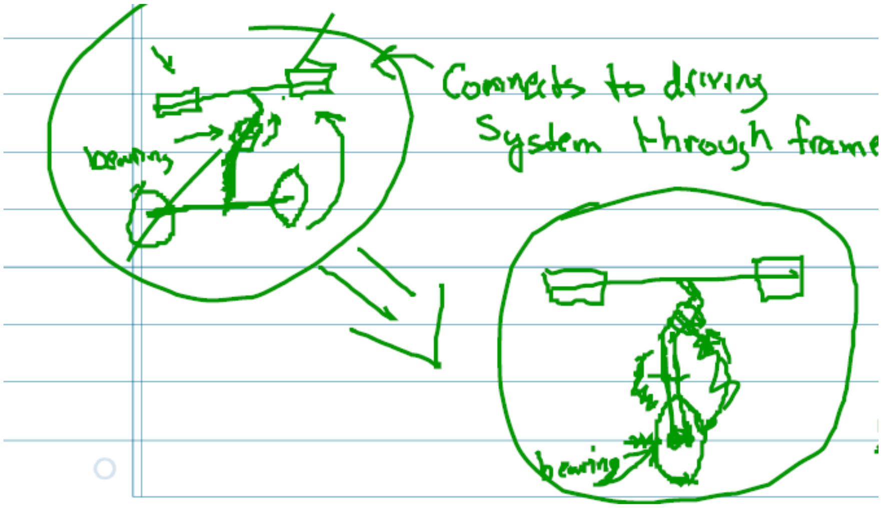

Figure 5. A figure of a participant eliminating a concept based on lack of knowledge.

As a second example, Abraham worked on the one-handed container opener problem and pursued concepts that use mechanical jaws to hold down a container, as shown in Figure 6. He generated two ideas and both of them focused on mechanical features to stabilize a container. During the interview, Abraham described that he did not pursue any complicated mechanisms that may require robotics or electronics outside of his understanding:

> "*That seemed like a good mechanism. The stabilizing seemed like a good mechanism to pursue rather than any sort of complicated robotic thing when trying to actually open it*"

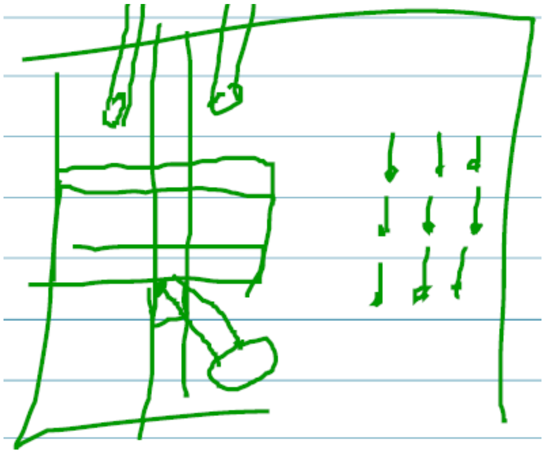

Figure 6. A participant's concept that utilized mechanical jaws to hold onto a container.

Criticizing existing solutions and their features

Several participants often focused on criticizing existing solutions and their features, which led students to consider improving specific features of existing solutions rather than diverging to consider other non-existing solutions to address the concept generation task. For example, Ian, when working on the snow transporter problem, focused on criticizing existing snowboards and considered concepts that improved these negative qualities:

> *"Existing problem with those snowboards ... is* ***that they're really, really bulky and heavy. I would use something lighter****... I think it would have an electric motor ... I think if it's electric, it's definitely going to be smaller because you're removing the fuel tank and all the mechanical parts... I would make the skiing and snowboarding much stronger and much lighter. Much lighter. Reduce the weight.*"

By focusing on the negative qualities of snowboards, Ian considered variations of snowboards with improved features instead of considering different types of solutions to address the concept generation task.

Discussion

This study identified specific behaviors that led to limited divergent thinking during concept generation for mechanical engineering students. Previous studies have shown that designers struggle to innovate during concept generation as they often consider obvious, existing solutions [3], [4]. Utilizing think-aloud protocols, this study captured engineering students' thought processes that can lead them to focus on those obvious, existing solutions.

In this study, participants have demonstrated to narrow the problem by reframing the task. Previous literature has documented that exploring and framing the problem are critical components of design [28]–[30]. Designers can take alternative perspectives of a problem, which can shift the focus of the potential solutions. Designers who reframe problems to consider multiple, varied perspectives can expand the solution space [31]. However, in the case of novice engineers who may not have strategies on problem framing, they can narrow the problem that may lead to conventional, obvious solutions.

An implication of this behavior is that instructors could describe the benefits of reframing the problem from multiple perspectives to support concept generation as well as the challenges of potentially restricting potential solutions if the problem is improperly reframed. Furthermore, instructors can equip students with strategies and tools to properly engage in problem framing before concept generation (e.g. [32]).

We also found in this study that participants limited their divergent thinking during concept generation as their existing knowledge and potential financial cost of the concepts became evaluation criteria. Participants often considered concepts close to what topics they felt aligned with their knowledge and did not consider new ideas or eliminated concepts immediately after generation if they felt they lacked the knowledge to further develop those solutions. Additionally, participants considered the potential cost of potential concepts as an important criterion and focused on reducing the number of components involved. These behaviors conflict with concept generation best practices, which encourage designers to minimize evaluation during concept generation [7], as designers can focus on the feasibility of the concepts as an early filter and limit divergent thinking.

Based on these findings, an implication is that instructors teaching concept generation can emphasize different ways that students may evaluate and filter early concepts. By providing explicit examples of common evaluation criteria that may hinder concept generation, including the feasibility of concepts, lack of knowledge, complexity of features, engineering students can have a better understanding of common pitfalls of evaluating concepts early during ideation.

Participants also limited divergent thinking during concept generation when they focused on negative qualities or features of existing solutions. By emphasizing specific features that can be improved on existing designs, participants considered variations of the existing solutions instead of diverging to consider a large quantity of varying concepts. When engineering students focus on the existing solutions, they may become fixated on particular solutions or small variations of them [8].

An implication for engineering education of this finding is that instructors can emphasize the importance of focusing on solving the problem instead of addressing the limitations of current solutions to ensure that students are not limiting themselves to making improvements to existing features. Additionally, leveraging different concept generation strategies has been shown to reduce fixating on existing solutions [33].

Limitations

One limitation is that participants worked individually in only one session and a maximum of a couple of hours to engage in concept generation, an experience that has differences from how concept generation may occur in their courses and engineering practice. Another limitation is the self-limiting behaviors identified were based on behaviors of 10 students, which did not represent the diverse demographics in engineering. We do not claim our list of self-limiting behaviors is comprehensive, but rather add to what we know about impediments to engaging in concept generation in recommended ways. Relatedly, the goal of our study was not to generalization, but rather to reveal behaviors that may occur as other engineering students engage in concept generation that may limit their divergence.

Conclusions

This paper describes a study of mechanical engineering students' self-limiting behaviors in concept generation by capturing the details of students' thought processes during a concept generation task. The mechanical engineering student participants demonstrated several behaviors that limiting their divergent thinking during concept generation, including narrowing the problem to reduce the potential solutions, eliminating concepts outside of their expertise, focusing on minimizing the financial cost, and criticizing existing solutions. By understanding specific behaviors that lead to reducing the quantity and diversity of potential solutions, the results of this study can support engineering instructors as they discuss, advise, and structure concept generation for their students.

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References

[1] National Academy of Engineering, *The Engineer of 2020: Visions of Engineering in the New Century*. Washington, DC: National Academy of Engineering, 2004. Accessed: Apr. 30, 2014. [Online]. Available: http://www.nap.edu/catalog.php?record_id=10999

[2] C. L. Dym, A. M. Agogino, O. Eris, D. D. Frey, and L. J. Leifer, "Engineering design thinking, teaching, and learning," *Journal of Engineering Education*, vol. 94, no. 1, pp. 103–120, Jan. 2005.

[3] S. Ahmed, K. M. Wallace, and L. T. Blessing, "Understanding the differences between how novice and experienced designers approach design tasks," *Research in Engineering Design*, vol. 14, no. 1, pp. 1–11, 2003.

[4] N. Cross, "Design cognition: Results from protocol and other empirical studies of design activity," in *Design Knowing and Learning: Cognition in Design Education*, C. Eastman, W. Newstatter, and M. McCracken, Eds. Oxford, UK: Elsevier, 2001, pp. 79–103.

[5] N. Cross, *Engineering Design Methods: Strategies for Product Design*, 4th ed. West Sussex, England: Wiley, 2008.

[6] C. Dym and P. Little, *Engineering design*. Hoboken, NJ: John Wiley & Sons, 2009.

[7] P. Yock *et al.*, *Biodesign: the process of innovating medical technologies*, 2nd ed. Cambridge University Press, 2015.

[8] D. G. Jansson and S. M. Smith, "Design fixation," *Design Studies*, vol. 12, no. 1, pp. 3–11, 1991.

[9] A. T. Purcell and J. S. Gero, "Design and other types of fixation," *Design Studies*, vol. 17, no. 4, pp. 363–383, Oct. 1996, doi: 10.1016/S0142-694X(96)00023-3.

[10] S. Daly, S. Yilmaz, J. Christian, C. Seifert, and R. Gonzalez, "Design heuristics in engineering concept generation," *Journal of Engineering Education*, vol. 101, no. 4, pp. 601–629, 2012.

[11] J. W. Lee, A. Ostrowski, S. R. Daly, A. Huang-Saad, and C. M. Seifert, "Idea generation in biomedical engineering courses using Design Heuristics," *European Journal of Engineering Education*, vol. 0, no. 0, pp. 1–19, Sep. 2018, doi: 10.1080/03043797.2018.1514368.

[12] N. V. Hernandez, L. C. Schmidt, and G. E. Okudan, "Systematic Ideation Effectiveness Study of TRIZ," *J. Mech. Des*, vol. 135, no. 10, pp. 101009-101009–10, Sep. 2013, doi: 10.1115/1.4024976.

[13] M. W. van Someren, Y. F. Barnard, and J. a. C. Sandberg, *The think aloud method: a practical approach to modelling cognitive processes*. LondenAcademic Press0127142703978012714270 8, 1994. Accessed: Jan. 15, 2018. [Online]. Available: https://dare.uva.nl/search?identifier=7fef37d5-8ead-44c6-af62-0feeea18d445

[14] S. Pugh, *Creating innovative products using total design: the living legacy of Stuart Pugh*. Reading, Mass: Addison-Wesley Pub. Co, 1996.

[15] B. Kudrowitz and C. Dippo, “When Does a Paper Clip Become a Sundial? Exploring the Progression of Originality in the Alternative Uses Test,” *Journal of Integrated Design and Process Science*, vol. 17, no. 4, pp. 3–18, Jan. 2013, doi: 10.3233/jid-2013-0018.

[16] A. F. Osborn, *Applied imagination: principles and procedures of creative thinking*, 3rd, revised ed. Charles Scribner’s Sons, 1957.

[17] G. Altshuller, *40 principles: TRIZ keys to technical innovation*. Worcester, Mass.: Technical Innovation Center, Inc., 1997.

[18] W. J. J. Gordon, *Synectics*. New York: Harper & Row, 1961.

[19] R. Eberle, *SCAMPER*. Waco, TX: Prufrock, 1995.

[20] J. W. Lee, S. R. Daly, A. Y. Huang-Saad, C. M. Seifert, and J. Lutz, “Using design strategies from microfluidic device patents to support idea generation,” *Microfluid Nanofluid*, vol. 22, no. 7, p. 70, Jul. 2018, doi: 10.1007/s10404-018-2089-6.

[21] S. Yilmaz, S. R. Daly, C. M. Seifert, and R. Gonzalez, “Evidence-based design heuristics for idea generation,” *Design Studies*, vol. 46, pp. 95–124, 2016.

[22] D. P. Crismond and R. S. Adams, “The informed design teaching and learning matrix,” *Journal of Engineering Education*, vol. 101, no. 4, pp. 738–797, Oct. 2012, doi: 10.1002/j.2168-9830.2012.tb01127.x.

[23] J. W. Lee, S. R. Daly, and V. Vadakumcherry, “Exploring Students’ Product Design Concept Generation and Development Practices,” Salt Lake City, UT, 2018.

[24] N. Crilly, “Fixation and creativity in concept development: The attitudes and practices of expert designers,” *Design Studies*, vol. 38, pp. 54–91, May 2015, doi: 10.1016/j.destud.2015.01.002.

[25] L. J. Ball, J. Evans, and I. Dennis, “Cognitive processes in engineering design: A longitudinal study.,” *Ergonomics*, vol. 37, no. 11, pp. 1753–1786, 1994, doi: https://doi.org/10.1080/00140139408964950.

[26] D. G. Ullman, T. G. Dietterich, and L. A. Stauffer, “A model of the mechanical design process based on empirical data,” *Artificial Intelligence for Engineering, Design, Analysis and Manufacturing*, vol. 2, no. 01, pp. 33–52, 1988.

[27] J. W. Lee, *Divergent Thinking in Front-End Design*. Ann Arbor, MI: University of Michigan, 2019. Accessed: Jul. 01, 2020. [Online]. Available: https://deepblue.lib.umich.edu/handle/2027.42/149892

[28] V. Goel and P. Pirolli, “The structure of design problem spaces,” *Cognitive Science*, vol. 16, no. 3, pp. 395–429, 1992.

[29] B. Paton and K. Dorst, “Briefing and reframing: A situated practice,” *Design Studies*, vol. 32, no. 6, pp. 573–587, Nov. 2011, doi: 10.1016/j.destud.2011.07.002.

[30] J. W. Lee, S. R. Daly, A. Huang-Saad, G. Rodriguez, and C. M. Seifert, “Cognitive strategies in solution mapping: How engineering designers identify problems for technological solutions,” *Design Studies*, vol. 71, p. 100967, Nov. 2020, doi: 10.1016/j.destud.2020.100967.

[31] R. J. Volkema, “Problem formulation in planning and design,” *Management Science*, vol. 29, no. 6, pp. 639–652, 1983.

[32] J. K. Murray, J. A. Studer, S. R. Daly, S. McKilligan, and C. M. Seifert, “Design by taking perspectives: How engineers explore problems,” *Journal of Engineering Education*, vol. 108, no. 2, pp. 248–275, Apr. 2019, doi: 10.1002/jee.20263.

[33] D. P. Moreno, M. C. Yang, A. A. Hernández, J. S. Linsey, and K. L. Wood, “A Step Beyond to Overcome Design Fixation: A Design-by-Analogy Approach,” in *Design Computing and Cognition ’14*, Cham, 2015, pp. 607–624. doi: 10.1007/978-3-319-14956-1_34.

Appendix A1 Two problem statements used in this study.

Low-Skill Snow Transporter Problem

Today skis and snowboards are widely used as personal transportation tools on snow. But to be able to use them, a lot of skill and experience are required that a user cannot normally learn within one day. Moreover, skis and snowboards cannot run uphill easily. It would be better if there were other options of personal tools for transportation on snow, which still allowed the user to control direction and braking, but did not require much time to learn how to use.

Design a way for individuals without lots of skill and experience skiing or snowboarding to transport themselves on snow.

Develop solutions for this problem and select a final solution at the end. **You can take as long as you need but spend a minimum of 1 hour to complete this task**. If you need any resources, please let me know.

One-Hand Opener for Lidded Food Containers Problem

The local rehabilitation center helps to treat thousands of stroke patients each year. Many individuals who have had a stroke are unable to perform bilateral tasks, meaning they have limited or no use of one upper extremity (arm/shoulder). A common issue the hospital has observed with their stroke patients is in their ability to open jars and other lidded food containers. The ability to open lidded food containers is particularly important for patients who are living on their own, in which case they often don’t have help around for even basic tasks. A solution to helping them open lidded food containers with one hand would go a long way in helping the patients to maintain their independence.

Design a way for individuals who have limited or no use of one upper extremity to open a lidded food container with one hand.

Develop solutions for this problem and select a final solution at the end. **You can take as long as you need but spend a minimum of 1 hour to complete this task.** If you need any resources, please let me know.