Information Visualization Techniques of Beginning Designers: Patterns and Opportunities

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Abstract

Information throughout the design process is repeatedly interpreted, visualized, and acted upon to evolve design ideas. However, when navigating iteration in the design process, beginning designers have overlooked salient information, for example, making changes without careful consideration of prototype data. This case study provides examples of the visualization techniques used by novice designers in an iterative design challenge, based on observations and design artifacts. Student strategies for visualization focused on sketching and data displays. Opportunities for design education include more robust technical drawings, modeling/simulation, and data visualization. With a clearer understanding of how information is interpreted and visualized during iterative design, educators can be better equipped to support beginning designers.

Introduction

While the design process can be distilled to central elements of analysis, synthesis, and evaluation, cycles of iteration lead to a more intricate pattern of behavior. Numerous design process models show the range of approaches that can be taken while designing (Dubberly, 2004). Expert designers are fluent in their understanding of the design process (Lawson & Dorst, 2009), in contrast to beginning designers. This fluency with design can lead designers to tacitly navigate design, following their own "personalized way of working" (Cross & Clayburn Cross, 1998, p. 147); furthermore, the processes of expert designers are consistent in their flow of information, iteration, and sustained time modeling (Atman et al., 2007). On the other hand, beginning designers have been seen to work in a linear or haphazard way, missing salient information in the design process (Crismond & Adams, 2012; McDonnell, 2015). In this way, the flow of information for beginning designers might be disjointed or nonexistent.

Congruent with an ideal flow of information while designing, the information management and visualization processes have been described as interconnected and cyclical (Fry, 2007). Previous research has examined the nature and effectiveness of information searches by high-school to expert designers, showing better use of search time with experience (Atman et al., 2007; Mentzer, 2011; Pieper & Mentzer, 2013). Dasgupta and Kosara (2012) described how assumptions and user perceptions affect the interpretation and handling of information; new information sources from this feedback loop can then be used to build better solutions. Fosmire (2012) developed a framework to this effect—the framework juxtaposed steps and language of information literacy and engineering design, showing that "information gathering activities do have a place throughout the engineering design process" (p. 51). Indeed, *effective* information management happens throughout a project to ensure that incoming information is accessible and reused (University of Virginia Library Research Data Services + Sciences, 2017).

An aim of design education, then, might be information management competencies with which a designer can capture and utilize information from the environment to improve their solution. While previous research has examined the nature and frequency of information requests, this work examined beginning designers' documentation and subsequent use of information visualization in an iterative design project. In this context I use a broad interpretation of information visualization while designing—for example, sketches and brainstorming represent early visual information, data and decision-making rationales are a synthesis of information by the designer, selected designs might be enhanced through more rigorous technical drawings, and so on.

The following research question guided this study: "What information visualization techniques are seen in the documentation of beginning designers?" My pragmatic reflection on the experience of these designers contributed to the discussion of gaps in information visualization hereafter.

Case Context

The context for this examination of design process information gathering and use was a week-long design lesson based on soft-robotics. Soft robotics is a developing field of engineering that leverages the material properties of compliant components to meet human needs (Trivedi, Rahn, Kier, & Walker, 2008). Students were challenged to design a soft gripper to meet the needs of a small agricultural facility in sorting produce (for example, see Figure 1). Due to the novelty of the subject for students and material fabrication constraints, the soft robotics design experience promotes tinkering and iteration on ideas (Jackson, Mentzer, Godwin, Bartholomew, & Strimel, 2019; Jackson, Mentzer, & Kramer-Bottiglio, 2018).

Figure 1. Students testing an inflatable soft gripper.

I observed the complete design process of 4 pairs of students, in two different classrooms, as they navigated design and fabrication challenges of the soft robotics experience. The patterns offered by these 8 students might speak more broadly to the behavior of beginning designers, framing this work as an instrumental case (Stake, 1995). In the classrooms I collected both “descriptive and reflective notes” (Creswell & Poth, 2017, p. 168). At the end of each day I scanned design journals to record students’ progress and treat the design journal as an evolving information source in the design process. Daily design journal scans were then compiled to annotate the day-to-day work of each student.

Results

Analysis for information visualization techniques was conducted by reviewing the annotated design journals of each student for similarities and relationships among the information displays as documented. The selection of information visualization techniques was focused on 1) sketching brainstormed and selected designs, and 2) data displays (e.g., tables or decision matrices) to present information. Few journals included orthogonal or isometric projections of selected designs. Although I observed each team conducting research, and these steps were documented, only one journal included prior art, or visual inspiration attributed to other sources.

Brainstorming and Idea Evolution. Each journal included visual representations of several ideas in conceptual design phases of the project. These initial visual information sources shaped conversation and in some cases led to the evolution of new ideas. For example, Figure 2 shows three ideas: an design of equal length and joint count, a design of asymmetric length but equal joint count, and an asymmetric design with additional joints. These beginning designers tended to meet the minimum number of design ideas before continuing in the design process.

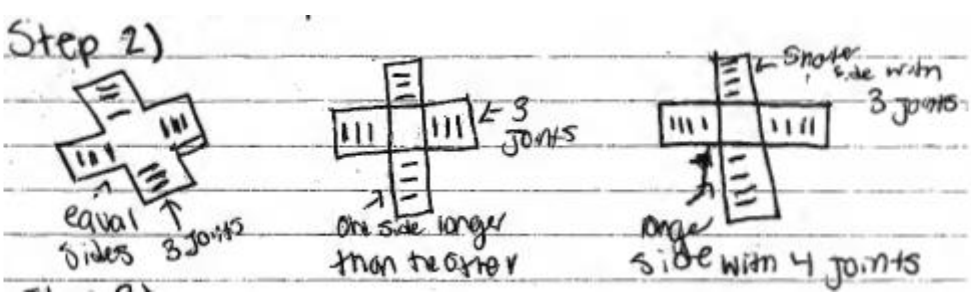
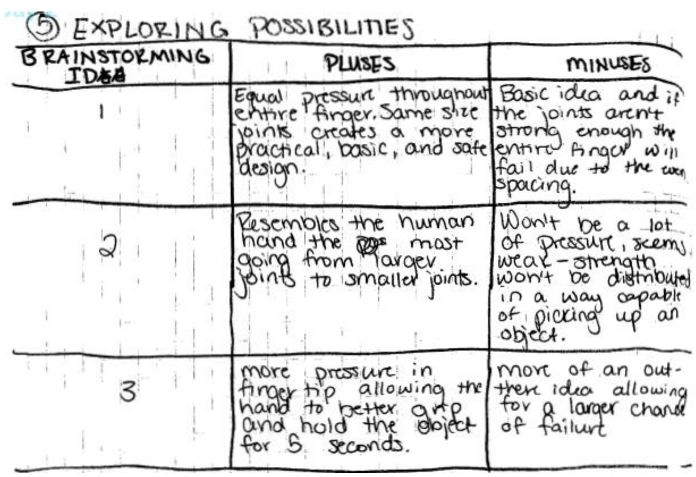


Figure 2. Brainstorming sketches with idea evolution between concepts.

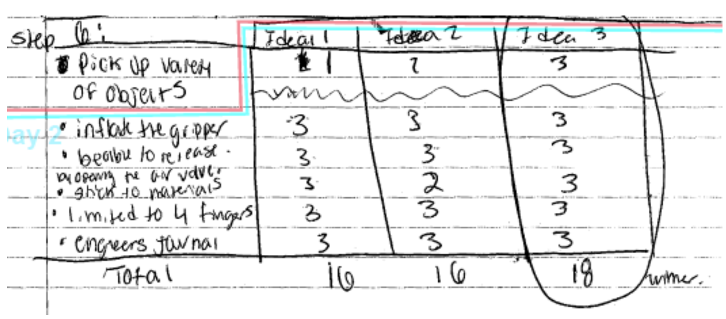
As ideas evolved, the quality of visual representation changed only minimally. Instead of producing a technical drawing with orthographic projection and detailed measurements, most students maintained a sketch approach to communicate their final design. Visual depictions for fabrication were coupled written instructions, arguably providing enough detail to reproduce the idea. However, discourse surrounding these designs made reference to part names and counts, instead of specific measurements; this suggests that contextual factors including artifacts of the design process can obfuscate the information visualization process of beginning designers. Sketching in collaborative design builds a common language among team members (Tversky & Suwa, 2009). In addition, in this design context some of the fabrication materials were provided to students, which may have reinforced a common understanding among the team and reduced the perceived need for detail in the final drawings.

Data Displays. Another typical rendering of information in the design journals was in the form of data tables to organize information. These tables followed brainstormed sketches and were used as decision aids. Two forms of data displays were observed: narrative analysis of brainstormed ideas, and quantitative analysis using a decision matrix (see Figure 3 and Figure 4). Crismond and Adams (2012) noted that the act of creating decision charts or matrices, in and of itself, may be useful to develop ideas.


⑤ EXPLORING POSSIBILITIES

BRAINSTORMING IDEA	PLUSES	MINUSES
1	Equal pressure throughout entire finger. Same size joints creates a more practical, basic, and safe design.	Basic idea and if the joints aren't strong enough the entire finger will fail due to the even spacing.
2	Resembles the human hand the most going from larger joints to smaller joints.	Won't be a lot of pressure, seems weak - strength won't be distributed in a way capable of picking up an object.
3	more pressure in finger tip allowing the hand to better grip and hold the object for 5 seconds.	more of an out-there idea allowing for a larger chance of failure

Figure 3. Data table showing narrative description of "pluses" and "minuses" of each idea.



Step 6:	Idea 1	Idea 2	Idea 3
• Pick up variety of objects	1	2	3
• inflate the gripper	3	3	3
• beable to release - by opening the air valve	3	3	3
• stick to materials	3	2	3
• limited to 4 fingers	3	3	3
• engineers journal	3	3	3
Total	16	16	18 winner.

Figure 4. Decision matrix showing quantitative analysis to support decision making.

Gaps in Visualization. Among the strategies for information visualization used by beginning designs in this context, sketches and information displays tended to be "loose." One opportunity to reinforce information visualization practices would be to emphasize the improvement of representation quality along with the evolution of the idea, generally. In this way, final selection representations would be more thorough and offer complete information about the fabrication of an idea, beyond the common language of the design team. Similarly, no teams transformed or summarized data into charts or graphs. It is possible that for this context the testing criteria were more qualitative; however, the collection, interpretation, and representation of quantitative information is an important skill for data communication. Visual summaries of data can support prediction (e.g., a regression slope might be used to predict future trends) or build rationales for design selections. Indeed, moving beyond surface sketching to conduct "deep drawing and modeling" is a pattern of proficient design (Crismond & Adams, 2012). In practice, modeling can lead to benefits such as 1) making thinking more explicit, 2) extending short-term memory and developing more complex ideas, 3) enhancing problem-solving and collaboration, and 4) supporting "designers' own dialogs with ideas and their evaluations" (Crismond & Adams, 2012, p. 759).

Contextual elements may have had a greater influence on the information visualization practices of these beginning designers than is known. As mentioned, a shared set of materials for construction may have masked the need for communication to the end user. The classroom traditions and prior instruction were beyond the scope of this study and may not have emphasized information visualization to the extent hoped for. On the other hand, the paper and pencil format for this design documentation may have resulted in the basic information visualization techniques; perhaps given digital tools, these students would in fact show aptitude for generating technical drawings, models, or other information graphics.

Conclusions

Better understanding the flow of information in the design process, including how it is interpreted and used by beginning designers, can offer insights for design educators. Seeing the preference of beginning designers for basic sketches, educators might provide instruction on rigorous technical drawing or modeling, along with the development of the design process. The congruent evolution of design ideas and sketch quality may also be a useful heuristic for beginning designers' documentation.

Information tools can be used as a narrative form of the design process, showing the lessons learned and effectively communicating the decisions made. The documentation process is reflective in and of itself, yet students failed to reference their journals or offer deep reflection beyond the expectations of the design process. This hallmarks another opportunity for educators—to leverage information visualization as a reflective activity and reinforce the cyclical nature of design. Identification of the beginning designers' information visualization strategies is an important step toward developing curriculum tools to improve these techniques.

Acknowledgement

This material was supported by the National Science Foundation under Grant DRL-1513175.

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