The effects of representation on idea generation and design fixation: A study comparing sketches and function trees

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Representations in engineering design can be hand sketches, photographs, CAD, functional models, physical models, or text. Using representations allows engineers to gain a clearer picture of how a design works. We present an experiment that compares the influence of representations on fixation and creativity. This experiment presents designers with an example solution represented as a function tree and a sketch, we compare how these different external representations influence design fixation as they complete a design task. Results show that function trees do not cause fixation to ideas compared to a control group, and that function trees reduce fixation when compared to sketches. Results from this experiment show that function tree representations offer advantages for reducing fixation during idea generation.

Keywords: design fixation, engineering design, conceptual design, design activity, creativity

Engineering design entails and implements a range of design representations to convey and document information; these include text descriptions, sketches, line drawings, photographs, computer–aided designs (CAD), and functional models. Previous research (Adler & Davis, 2007; Goldschmidt, 2007; Larkin & Simon, 1987; Linsey et al., 2010; Linsey et al., 2011; Yang, 2009) has explored the use of representations in problem solving and concludes that effective diagrammatic representations (e.g. CAD, sketches, photographs, line-drawings, etc.) hold many advantages over detailed textual representations. This research has determined that diagrammatic representations explicitly present the relationship between the visual depiction and elements of the problem by co-locating necessary and useful information in the representation (Larkin & Simon, 1987). From processing this grouping of information, the designer avoids two cognitively expensive tasks associated with a purely textual representation: (1) having to match and understand symbolic labels and (2) searching for specific elements within the problem statement that are needed to establish a problem-solving inference. Seemingly, due to these disadvantages of textual

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descriptions, designers frequently prefer diagrammatic representations for engineering ideas and designs.

Despite the long-standing popular use of sketching for early idea conceptualization, CAD renderings and photographs are increasing in use due to advancements in technology. Due to the advent of computer modeling and drafting packages, i.e., CAD, which are readily available, engineering students tend to sketch less (Grenier, 2008; Schmidt, Hernandez, & Ruocco, 2012; Ullman, Wood, & Craig, 1990; Westmoreland, Ruocco, & Schmidt, 2011). Grenier's study (2008) demonstrates that students pursue alternative representations to sketching as a form of design during the early stages of conceptualization. In a similar study, Westmoreland et al. (2011) analyze visual representations (sketches, line drawings, CAD, and photographs) for their use in Capstone Design and obtain comparable results. Westmoreland finds that students rarely use sketches until specifically prompted. Additionally, students are increasingly reluctant to submit rough sketches since they can quickly transform a sketch to a CAD drawing (Westmoreland et al., 2011). Likewise, photographs are growing in popularity due to the availability of digital cameras and due to the ability to copy images from the Internet.

Functional modeling and decomposition is another method used for representing designs. However, functional modeling represents a design very differently than the diagrammatic representations already discussed. As the name implies, functional models and function trees list the functions on a design. These functions are in the form of action verbs necessary to system objectives and are listed in a top-down manner. Conceptualizing, defining, or understanding a product or system in terms of function is a fundamental aspect of engineering design (Otto & Wood, 2001; Pahl & Beitz, 1996; Pahl, Beitz, Feldhusen, & Grote, 2007; Ullman, 1992; Ulrich & Eppinger, 1995). Functional modeling provides an abstract, yet direct, method for understanding and representing a product's overall function (Hirtz, Stone, McAdams, Szykman, & Wood, 2002). Functional models serve as an asset in the idea generation process, as well as for storing and extracting design knowledge from existing products (Altshuller, 1984; Murdock, Szykman, & Sriram, 1997; Stone, Wood, & Crawford, 2000). Viola, Corpino, Stesina, and Fioriti (2012) state that functional models are advantageous when used in engineering idea generation because the abstract view of function trees fosters the search for alternative solutions and as a result, avoids biased ones. The function-means tree method by Dym and Little (Dym, Little, Orwin, & Spjut, 2004) is an example of how function trees or diagrams are used in the idea generation. Functions (what the design will do) and means (how the design will do it) are listed in a

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