Rolling with the punches: An examination of team performance in a design task subject to drastic changes

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Designers must often create solutions to problems that exhibit dynamic characteristics. For instance, a client might modify specifications after design has commenced, or a competitor may introduce a new technology or feature. This paper presents a cognitive study that was conducted to explore the manner in which design teams respond to such situations. In the study, teams of undergraduate engineering students sought to solve a design task that was subject to two large, unexpected changes in problem formulation that were introduced during solving. High- and low-performing teams demonstrated very different approaches to solving the problem and overcoming the changes. The results indicate that there may exist a relationship between problem characteristics and fruitful solution strategies.

Keywords: design methodology, design cognition, collaborative design, problem solving

Developing a greater understanding of the underlying cognitive processes involved in engineering design could lead to improved design methodologies, design tools, and engineering education. Although much cognitive research in engineering design has focused on individuals, it is well known that the majority of engineering design work is the product of teams (Paulus, Dzindolet, & Kohn, 2011). As such, the general focus of this work was to uncover aspects of team problem solving and design.

This work in particular explored the often-dynamic nature of the design process, which manifests through unexpected changes in goals or constraints. For instance, a client might drastically change a set of specifications after solving begins, or a competitor may introduce a new technology or feature. Such unexpected changes are likely to require the team to perform some amount of redesign, ultimately decreasing the overall efficiency of the design process. Thus, the guiding question that drove this research was: 'How does a design

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team respond to drastic changes in the design task, and how can a team be made more resilient to these changes?'

For the purposes of this work, a change is drastic if the post-change problem requires a mental model or representation that is substantially different from that associated with the pre-change problem. In responding to a drastic change, a team must potentially overcome a variety of obstacles. One such obstacle is design fixation, defined as premature adherence to a design concept that impairs conceptual design efforts (Jansson & Smith, 1991). Fixation is relevant to this work because bias towards past solutions can be detrimental when responding to a change. This is particularly true if the problem is changed in such a way that drastically different solutions are required. A second obstacle is the effort required to simply become acquainted with the new problem representation. Still another is the selection of an adequate representation of the new problem, which must be done on-the-fly in a dynamic problem. Selection of a new representation impacts the extent to which knowledge can be transferred from the initial problem (Kotovsky & Fallside, 1989).

In this paper, two hypotheses were explored. First, we hypothesized that *teams that excelled in responding to change would display underlying problem-solving processes that differed from teams that responded slowly or poorly*. To explore these differences, a cognitive study was designed that tasked small teams of undergraduate engineering students with the design of a truss structure. Midway through the study, a fundamental aspect of the original design problem was changed. Shortly thereafter, a second modification was made to the original design problem. A complete record of the design team's efforts was collected through a computer interface, allowing problem-solving strategies to be fully reconstructed for analysis. Differences in problem-solving processes could result from the inherent variability of the individuals composing the team. The role of individual traits in addressing unexpected change at the team level was explored in several studies (LePine, 2003; LePine, 2005; LePine, Colquitt, & Erez, 2000). It was demonstrated that individuals' cognitive ability, goal orientation and openness to change are critical factors in predicting post-change performance (LePine, 2003; LePine, 2005; LePine et al., 2000). Expertise is another phenomenon that can affect performance in engineering design, and leads to different solution strategies (Cross, 2004). Since expertise may take years to develop (Ericsson, Krampe, & Tesch-Römer, 1993), it is unlikely that *true* expertise was encountered in this work. However, students generally display varying levels of familiarity and experience on any given subject. Therefore, individual-level domain experience could lead some individuals to perform more like experts than others, inducing team-level differences. The work presented in this paper randomly assigned individuals to design teams, making no attempt to control for such factors to homogenize the teams. Therefore, between-person variability was expected to induce a wide variety of problem-solving strategies at the team level.