# Reasoning About Uncertainty and Efficient Decision-making in Engineering Design

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## Introduction

Engineering design has been defined as a systematic, iterative and reflective process by which engineers understand a problem, generate potential solutions, evaluate them, and refine the ideas for solving users' needs while satisfying a given set of constraints (Dym et al., 2005). It uses design thinking, a complex process that learners often struggle with (Dym et al., 2005). Core characteristics of design thinking include tolerating ambiguity, maintaining a systems perspective, handling uncertainty, effective decision making, working in a team, and communicating design ideas effectively (Dym et al., 2005). My prior work suggests that when middle school students are primed with a suboptimal design and are then asked to solve an ill-structured engineering design challenge, they engage in various disciplinary practices and design thinking to take effective design decisions (Dasgupta, 2015). This research also suggested that uncertainty may have promoted learning about the disciplinary practices and scaffolds like the suboptimal design may have helped students manage uncertainty while they were taking effective design decisions.

Uncertainty likely plays an important role in facilitating content learning by creating opportunities for knowledge construction and transition of tacit understanding to normative understanding (Jordan et al., 2012). Further research is needed to develop a good understanding about the mechanism of efficient decision-making under uncertainty and the nature of appropriate scaffolds needed in the learning environment to support robust design thinking during the process. My current research focuses on this gap and draws on prior research in the fields of Learning Sciences, Engineering Education, Human-Computer Interaction and Neuroscience research.

## Literature review

Prior research has demonstrated that there are various interpretations of uncertainty. Uncertainty can occur due to lack of a well-defined problem, lack of knowledge about the problem, incomplete information, abundance of conflicting information, inadequate understanding, presence of undifferentiated alternatives which often lead to conflict, and doubt between team-members (Lipshitz, & Strauss, 1997; Radinsky, 2008). At a very broad level, two categories emerge from this prior work – content uncertainty and relational uncertainty. Content uncertainty arises while solving an engineering design problem where all the criteria are seldom specified completely and one rarely has enough knowledge to solve the problem right away (Ullman, 2001; Jonassen, Strobel & Lee, 2006). Relational uncertainty arises out of a cognitive feeling of doubt between team members, discomfort about the unknown, and lack of a well-defined social position in the team (Jordan & McDaniel Jr, 2014; Radinsky, 2008). Learners employ various strategies to manage such uncertainties – reduce uncertainty, acknowledge uncertainty, suppress uncertainty, maintain uncertainty, and even increase uncertainty (Jordan & McDaniel Jr, 2014; Lipshitz, & Strauss, 1997; Ullman, 2001). Further research is needed to understand the mechanism by which learners reason about each type of uncertainty and the scaffolds and feedback processes that might be helpful in supporting the strategies thereby promoting efficient decision-making and robust design thinking (Dym et al. 2005).

## Emerging research agenda

My research focuses on the following three strands- (a) designing *learning environments* for effectively priming and anchoring learners' design thinking and decision-making process under uncertainty, (b) understanding the *mechanism* by which learners reason about uncertainty and take informed design decisions, and (c) developing *feedback processes* (with and without technology) by which teachers can effectively promote productive decision-making under uncertainty and ensure that learners are engaging in robust design thinking.

### Learning environments for supporting decision-making under uncertainty

I am working on developing a framework for characterizing various types of uncertainties, investigating how they are introduced in an engineering design problem-solving environment and how we can sustain them during the design activity by embedding various types of scaffolds in the learning environment to maximize the learning opportunity. I also investigate the role of the teacher when learners are engaged in managing

uncertainty and how teachers can support the decision-making process effectively. This strand draws from seminal research on scaffolding complex learning (Reiser, 2004; Quintana et al., 2004).

### Mechanism of reasoning about uncertainty and taking informed design decisions

This strand focuses on characterizing various strategies used by learners for managing each type of uncertainty in an engineering design problem-solving environment. I focus on unpacking the mechanism of how learners reason about the uncertainty, the learning that happens from such engagement and the role of the activity, context and culture in which the learning occurs; thus, taking a situated learning perspective (Lave & Wenger, 1991).

Here, I take a multimodal analysis approach using electroencephalography (EEG), electrodermal activation sensors and eye-tracking in addition to audio-video data for drawing inferences about what and how learners are learning (Worsley, 2017). This approach enables me to explore the translation of neuroscience research (e.g., Kounios & Beeman, 2009) and investigate the neurological mechanisms underlying design thinking and apply findings about how the brain works to design learning environments and also refine theories of learning (Johri, 2011).

### Feedback processes for promoting effective decision-making under uncertainty

Formative feedback is essential for making sustained progress towards the learning goals in a classroom environment. This line of research draws from Shute's framework for providing formative feedback (Shute, 2008) and focuses on identifying appropriate technology and understanding the process for providing effective formative feedback to the learners while they are engaged in managing uncertainty.

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