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BOARD # 441: RFE: Trust but Verify: The Use of Intuition in Engineering Problem Solving

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RFE: Trust but Verify: The Use of Intuition in Engineering Problem Solving

We all have moments when we are struck by a "gut feeling" or a "sixth sense" about something. It could pertain to a relationship or task at work. That sense can be broadly termed intuition. Intuitive decision-making is an essential characteristic of individuals who have attained a certain level of expertise [1]. The development of expertise [1, 2] and intuition [3, 4] are heavily influenced by experience. Intuition is a skill used by professionals in specialized skills such as nursing, business management, law, engineering, and other STEM fields [4-8]. Engineering intuition is defined as an experience-informed skill subconsciously leveraged in problem solving by engineering practitioners when under pressure from constraints such as lack of time [4]. Practicing engineers use and develop intuition regularly on-the-job, but the use of intuition is often discouraged in undergraduate education. The disconnect between intuition's use in engineering practice and in education, coupled with our limited knowledge of the relationship between intuition, expertise, and experience, presents an important gap in our existing understanding of engineering problem solving and future workforce preparation. Through this Research in the Formation of Engineers (RFE) grant, we seek to address this gap by examining the application of intuition by engineering practitioners to generate knowledge that promotes professional formation and development of a stronger engineering workforce through four research questions.

RQ1: How does the application of intuition manifest in engineering problem solving?
RQ2: How does the application of intuition vary when approaching "ill" versus "well" structured engineering problems?
RQ3: How does the domain of practitioner expertise influence the application of intuition when approaching "ill" versus "well" structured engineering problems?
RQ4: How does prior engineering experience influence the application of intuition when approaching "ill" versus "well" structured engineering problems?

Theoretical Grounding and Relevant Literature

The crux of our work rests on the shoulders of extant literature regarding expertise development, which denotes progressions in efficiency [9], skill acquisition [1, 10, 11], and proficiency [12, 13] through experience. Intuition has emerged as an underlying and essential characteristic that drives one's ability to develop their expertise. Such development can be linked to speed and automaticity [14], processing of information [15], and storage of information [16].

Several studies have shown key differences between novice and expert problem-solving approaches [17, 18]. Experts are known to have greater working memory to devote to problem solving, which reduces the cognitive load of storing information and allows for greater information processing capacity [19]. This greater processing capacity allows experts to approach a problem in a reactionary, rather than systematic, way that engages intuitive processes to navigate the decisions of problem solving [20].

One might assume that such abilities begin to develop while attending formal education, but development of these abilities is largely attributed to professional experience [4]. The importance of professional experience to intuition development may stem from the gap that exists between the kinds of problems professional engineers and engineering students typically solve. Jonassen [21], Jonassen [22] provides a typology of problems to clarify different problem types using eleven categories: a) logical, b) algorithmic, c) story, d) rule-using, e) decision making, f) troubleshooting, g) diagnosis-solution, h) strategic performance, i) case analysis, j) design, and k) dilemma. The problems at the beginning of the typology (e.g., logical and algorithmic) represent problems typically encountered by engineering students. These problem types are often lumped together as well-structured, well-defined, or transformation problems and can generally be characterized as less complex [23-25]. Professional engineers, on the other hand, solve complex, open-ended, ill-defined, non-routine, and wicked problems [24, 26-28], which appear in the latter half of the typology (e.g., decision-making, troubleshooting, and design problems). These types of problems present vague initial and goal states with no definite process to move from one state to the other [29].

Jonassen also notes that each type of problem calls for different skills exhibited by the problem solver [21, 22]. For example, students are rarely exposed to ill-structured problems in the classroom leading to a certain set of skills needing to be used. Efforts have been made to shift the landscape of engineering education toward greater opportunities for ill-structured problem solving [30], but well-structured problems remain prevalent in most engineering curricula.

Research Design

The goal of our research design is to collect and analyze data on how engineers solve problems. Since we are particularly interested in observing the use of intuition in problem-solving, our target sample population includes engineers at two experience levels: 1) participants whose primary experience with engineering is their undergraduate education (senior undergraduate students or those with less than a year of experience), and 2) participants who are current engineering practitioners with 6-10 years of on-the-job experience. Those with less experience are subsequently assumed to have limited intuition development, while those with greater on-the-job experience are expected to have developed intuition over time within their domain.

We elicit participant knowledge through Cognitive Task Analysis (CTA) interviews. CTA is a method that to our knowledge has not previously been applied to engineering education research but has a strong record of success in social science research, particularly in studies of expert task completion. Per best practices, our approach mixes CTA methods (Simulation Interviews, Critical Decision Method, and Knowledge Audit Method) to support robust data collection [31].

The final version CTA interviews will first engage participants in a Simulation Interview*,* which will be an observational "think-aloud" protocol [32, 33]. Participants will work on two well-structured tasks and one ill-structured task, i.e., the simulations or scenarios. The ill-structured question will present a contextualized engineering design task. Embedding the task experience in the interview will enable us to provide participants with a shared context from which to reflect on their problem solving. The Simulation Interview will be followed by a Critical Decision Method (CDM) interview where a timeline of problem-solving decision points is co-created with the participant through a series of four interview "sweeps" or stages. The CDM interview is supplemented with additional probing questions informed by the Knowledge Audit Method (KAM) designed to elicit what knowledge or skills were used in navigating decision points for each task.

We tested our methods prior to full-scale data collection through pilot interviews to ensure that the data collected are suitable for answering our research questions [34]. Successful protocol development was ensured during our first round of pilot interviews where we did not include the Simulation Interviews. Instead, we requested that participants (three current academics who recently transitioned after 10+ years in industry) come prepared with a problem from their own industry experience to discuss. This approach placed initial focus on the development of the CDM and KAM protocols.

CTA data is analyzed through deductive coding that leverages the Leveraging Intuition Toward Engineering Solutions (LITES) codebook, which operationalizes engineering intuition [4]. The codebook was applied with some flexibility to allow for open coding to identify potential emergent themes not captured in prior work [35].

Preliminary Results and Next Steps

Analysis from the pilot interviews further supports the applicability of the LITES codebook to engineering problem solving. All participants chose to describe ill-structured problems in which they, as the problem-solver, needed to gather information, collaborate with domain experts, and ultimately exercise their judgment to take action. Past experience emerged as a strong guiding force in each participant's problem-solving approach and was often credited for how they "knew what to do" more readily. These findings align with what is known about engineering intuition and are an important first step towards demonstrating its direct use in engineering problem solving.

The pilot interviews also suggest new emergent codes that have the potential to add further nuance to our current understanding of engineering intuition. For example, reflection emerged as a new code to be explored further by the research team. These initial efforts are providing seeds for further refinement of the LITES codebook definitions, which will be a useful next step for ensuring other scholars are able to apply emergent codes as intended. Refining definitions in the LITES codebook and assessing new potential emergent codes are the team's immediate focus as we seek to transition from pilot interviews to full-scale data collection efforts.

Broader Impacts

Intuition has emerged as a critical skill in expertise development but is also seen as secondary and less important to data when solving an engineering problem. Findings from this work will shine a light on intuition, while providing a foundation for the explicit application of intuition in engineering problem solving within industry and educational settings. This foundation will: 1) bridge the disconnect between classroom and real-world engineering practices, 2) inform the design of educational interventions that promote intuition development, and 3) provide an understanding of how early intuition development can help level the playing field for all students regardless of individual background, including socio-economic status, demographics, or past engineering experiences. The expected outcome is a leveling of the playing field resulting from a decoupling of intuition development from a reliance on co- or extra-curricular experiences [36-38]. Developing intuition also creates a pathway to expertise development which in turn promotes metacognition [20]. Increasing metacognition can result in adaptive expertise development [39] and improved problem-solving approaches [40], which directly benefits students from underrepresented groups whose expertise is more likely to be dismissed [41, 42]. This effort combined with our prior work identifying a positive link between intuition and confidence [4, 43, 44] will reduce overall student attrition [45-47], which disproportionately effects underrepresented groups. A greater focus placed on intuition development may serve as a means for boosting student confidence and expertise, ultimately supporting greater retention and workforce development.

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