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Update on is it Rocket Science or Brain Science Developing an Approach to Measure Engineering Intuition

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I am an early-career engineering education scholar and educator. I hold a B.S. in Chemical Engineering (with Genetics minor) from Iowa State University, and an M.S. and Ph.D. in Chemical Engineering from The Ohio State University. My early Ph.D. work focused on the development of bacterial biosensors capable of screening pesticides for specifically targeting the malaria vector mosquito, Anopheles gambiae. As a result, my diverse background also includes experience in infectious disease and epidemiology, providing crucial exposure to the broader context of engineering problems and their subsequent solutions. These diverse experiences and a growing passion for improving engineering education prompted me to change career paths and become a scholar of engineering education. As an educator, I am committed to challenging my students to uncover new perspectives and dig deeper into the context of the societal problems engineering is intended to solve. As a scholar, I seek to not only contribute original theoretical research to the field, but work to bridge the theory-to-practice gap in engineering education by serving as an ambassador for empirically driven educational practices.

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Update on is it Rocket Science or Brain Science? Developing an Approach to Measure Engineering Intuition

The engineering workforce is increasingly relying on engineering judgement as engineering problem solving becomes more complex and reliant on technology. This increased reliance has driven a need to place greater emphasis on developing the judgement skills of engineering students to help ensure that students are able to critically analyze solutions. Our work focuses specifically on engineering intuition and its role in helping the next generation become better problem solvers. We are exploring four research questions:

RQ1: What are practicing professional engineers' perceptions of discipline specific intuition and its use in the workplace?

RQ2: Where does intuition manifest in expert engineer decision-making and problem-solving processes?

RQ3: How does the motivation and identity of practicing professional engineers relate to discipline-specific intuition?

RQ4: What would an instrument designed to validly and reliably measure engineering intuition look like?

These four research questions are summarized by the two major goals of this project: 1) characterize expert engineering intuition (RQ1, RQ2 and RQ3), and 2) design an instrument to measure engineering intuition (RQ4). Work undertaken and completed on this project over the first two years has characterized expert engineering intuition using interviews of practicing engineers and led to the design of a survey instrument to measure the engineering intuition of engineering students.

Background

Literature from the fields of nursing [1], management [2], and expertise development [3] suggest intuition plays a role in both decision-making and expertise development. Academic models to date in engineering education fall short of defining or describing how to develop intuition.

Expertise has been defined as years of experience or an accumulation of knowledge [4]. Research into expertise in specific domain areas suggest expertise can be developed [5-8], learned through external and internal feedback [7], and used to form associations or run mental simulations [9].

Intuition is embedded in several expertise development models. Patel and Groen [6] suggest advancement from novice to expert occurs in three stages: 1) forming content knowledge, 2) differentiating between relevant and irrelevant information in a problem, and 3) efficiency. The progression to efficiency corresponds to the idea of intuition as a key characteristic of expertise development. The Dreyfus Model [3, 10] more explicitly describes expertise development through five-levels from novice to expert. Intuition is explicitly stated necessary as a characteristic to becoming an expert. Chi's model [5], adapted from Hoffman [11], instead offers a proficiency scale from naïve to master with expert as the sixth of seven stages. Only those who reach mastery can rely on their intuition. These models describe the importance of intuition in developing expertise, but do not define or suggest how intuition is developed.

Intuition is observed to be complex and discipline-specific in how it is used to make judgements and decisions. For example, the field of nursing characterizes expert nurses as having an "intuitive grasp" of situations or a holistic view that allows them to accurately assess and respond to a situation [12], while business management has shown business managers make faster decisions by leaning on intuition when information is missing [2, 13]. We have shown in a cross-disciplinary study of nurses, business managers, and engineers that expertise and intuition used by professionals has generalizable attributes aligned to elements developed through personal experience [14]. 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 [15], processing of information [16], and storage of information [17]. The current and future engineering workforce requires expertise in many domains, which is by nature developed through experience and marked by intuition. This knowledge led to our initial definition of engineering intuition as *an ability to assess solution (or response) feasibility and predict outcomes and/or options within a scenario*.

Past, Present, and Future Work

Our team has been working on addressing the first three research questions through a series of interviews with engineering practitioners at various stages in their careers. Our qualitative analysis has revealed that practicing engineers denote their gut feeling as being based on past knowledge gained over time through experiences [14]. Practicing engineers note a clear role for intuition in helping them navigate their engineering responsibilities and that intuition is developed through experience that allows a practitioner to fill in logical gaps when faced with uncertainty in decision making [18]. This has led us to evolve our definition of engineering intuition to *the ability to leverage past experience to efficiently assess the present and predict the future*. This definition is supported by such cognitive theories as System 1 [15], experiential processing [16], gist trace [17], domain general knowledge [19], and heuristic processing [20].

Analysis of skills reported – technical or professional – and ownership of expertise – passive or active – have provided additional platforms for further explorations [21]. These include: 1) assessing practitioners with varying years of on-the-job experience – new (zero to one year), early-career (two to six years), and mid-career (six to 10 years), 2) exploring gender differences, 3) analyzing the impact of role changes, particularly managerial positions, and 4) understanding the influence of problem type – well or ill-structured.

Our qualitative findings have also provided the foundation for our quantitative assessment of engineering intuition among engineering students. Our team has been addressing our final research questions through the creation and development of the Predicting and Evaluating Engineering Problem Solving (PEEPS) survey designed to measure engineering intuition. PEEPS leverages questions obtained from available concept inventories to provide respondents with an opportunity to solve a problem, predict an outcome, and judge the feasibility (or sensibility) of the solution or outcome [22]. This instrument was tested in Spring 2021 and re-deployed in Fall 2021 using the Concept Assessment Tool for Statics (CATS) [23] as the base. We had 88 complete responses in Spring 2021 and 130 in Fall 2021 comprising primarily of participants who identified as male and majoring in aerospace engineering (31 in Spring 2021 and 63 in Fall 2021).

Broader Impacts

Our overarching goal with this project is to inform the creation of classroom practices that improve students' ability to develop, recognize, and improve their own engineering intuition. Knowledge generated has and will continue to provide a foundation for: 1) bridging the disconnect between classroom and real-world engineering practices, 2) designing educational interventions that promote intuition development, and 3) understanding 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.

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