WIP: Experts' Perceptions of Engineering Intuition

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Introduction

This work in progress paper describes preliminary findings from interviews intending to develop a definition of and method for measuring "engineering intuition." Engineers are asked regularly in their profession to judge situations and predict or estimate results in order to minimize the potential for error. The need for this ability has been amplified with the pervasiveness of computer-aided problem solving in engineering. It is now mandatory for practicing engineers to quickly and accurately evaluate software results as part of the problem-solving process. We hypothesize that the ability to undertake such actions is heavily influenced by discipline-specific intuition, which has been previously explored in the disciplines of nursing and business management.

The following work in progress study presents preliminary results attempting to define the construct of "engineering intuition," specifically focusing on the establishment of our interview protocol. Semi-structured interviews with practicing engineers, nurses, and business managers were conducted using: 1) implicit discussion around intuition informed by literature, and 2) critical incident technique [1], i.e., explicit discussion around the concept of intuition. Each interview sought to identify practitioner decision-making and problem-solving processes on the job. The combined dataset and supporting literature are planned to be used as the basis of our future work, which ultimately aims to develop a psychometrically tested instrument capable of accurately measuring engineering intuition. Dissemination of these preliminary results are intended to elicit feedback on our methodologies and findings before moving to the second phase of our research study.

Background

Studies of intuition outside of engineering rely on expertise and decision-making literature to support the existence of such a construct. Expertise is recognized among scholars as more than simply an accumulation of knowledge or years of experience [2, 3]. Research on specialized domain knowledge suggests expertise may be developed through experience [4-7] coupled with an ability to learn from internal and external feedback [4] and a strong ability to build associations or run mental simulations [8]. These traits of expertise for experts are contrasted with novices, i.e., individuals at the beginning of their quest for specialized knowledge within a domain [9, 10]. Models for expertise development argue for the importance of intuition in developing disciplinary expertise, but do not describe how intuition may be developed [6, 7, 11, 12].

Studies of intuition have predominantly examined the disciplines of nursing and business management. Skill acquisition in nursing is modeled by Benner's Stages of Clinical Competence [13], a five-stage model that maps directly to the model proposed by Dreyfus [14]. An expert nurse is characterized as having an "intuitive grasp" of situations and a holistic view that allows them to accurately assess the patient's situation and respond appropriately [15]. Nurses who trust their intuition can positively change the outcomes of their patients [16] and describe intuition as an autopilot task that can be learned [17]. Studies in business management are similar to nursing

having shown that business managers make faster decisions and lean on their intuition when they are missing information [18, 19]. Executive management even notes that intuition is as important as analysis when making decisions [20]. The majority of these managers cite experience, feelings, and emotions as the most common descriptions for what it means to make decisions using intuition.

Research in both nursing and business management indicates that intuition can lead to faster and more accurate decisions [19, 21]. Decisions made by practicing nurses and managers may vary, but share a heavy reliance on being high-stakes and time-constrained. Decision-making in the field of engineering has this in common with nursing and business management. Several studies comparing novices and experts in engineering have identified additional connections to problem-solving, motivation, and identity [22-26]. A review of the management literature on intuition in decision-making as it relates to engineering education was also recently completed by Dringenberg and Abell [27], which identified the need to integrate intuitive reasoning as defined by Zeidler and Sadler [28] into the engineering curriculum.

The observed similarities and differences in the nursing, business management, and engineering literature strongly suggests the importance of discipline-specific intuition in decision-making and development of expertise. Significant gaps remain in how to define and describe the development of intuition and how this may differ across disciplines. These gaps are the motivation for our work to define and ultimately measure discipline-specific intuition in engineering. We also aim to build upon existing theories in expertise development and dual cognition, as well as leverage literature from nursing and management, to build a theory specific to engineering education [29].

Methods

Phase I seeks to generate a better understanding of and definition for engineering intuition using interviews with practicing engineers, nurses, and business managers. Our findings from Phase I are designed to inform the development of a tool to measure engineering intuition during Phase II. This work in progress presents our preliminary efforts, or Phase 0, used to develop and implement our interview protocol.

The specific aim of Phase 0 work is to develop and test our interview protocol. The initial interview protocol was developed using a semi-structured approach. Focus was placed on the development of individual expertise and decision-making. Intuition is not explicitly mentioned until a related idea (e.g., "gut-feeling") naturally arises. Intuition is introduced as a concept after a set time has passed for cases where intuition has not naturally arisen.

Sample

The sample population for preliminary interviews consists of practicing engineers, registered nurses, and business managers selected using convenience sampling. The disciplines were selected to represent our target population (engineers) as well as the disciplines in which prior work in discipline-specific intuition is available (nursing and business management). A sample of convenience consisting of individuals within these disciplinary backgrounds and known to the

researchers was used to allow for an initial basis of comparison with the literature and further supports the credibility of our future work focused in engineering [30]. Each interview also provides insight into the best possible interview protocol for our study. All participants had a minimum of five years of experience in their respective field.

Interview Procedures

Interviews are conducted, recorded, and auto-transcribed using the video communication tool Zoom. Each transcription is verified manually and then reviewed and analyzed using: 1) analysis of interview "flow" to suggest improvements to the protocol, 2) analysis of emergent themes [31, 32], and 3) identification of critical incidents [1]. Direct feedback on the interview experience was also solicited from the Phase 0 interviewees.

The first set of interviews (one nurse, business manager, and engineer) were conducted by a single interviewer with the remaining members of the team observing and saving questions for the end. The second set (one nurse, business manager, and engineer) interviews were conducted in a similar fashion with one notable change; observing team members used the videoconferencing private chat window to share thoughts and questions in real-time with a single interviewer conducting the interview to maintain a one-to-one conversation. This structure allowed for a more natural flow of questions during the interview experience. Initial development of the interview protocol concluded after the second set of interviews and following a review by the project's supporting advisory board members who were satisfied with the convergence of interview responses. Phase I interviews focused solely on practicing engineers will follow these initial sets of testing.

Interview (Semi)-Structure

Our semi-structured interview protocol follows four main points of discussion: 1) general background and experience, 2) development of expertise, 3) decision-making on the job, and 4) use of intuition.

The initial set of questions on background and experience (e.g., schooling, current job, etc.) were used for future analysis and as a simple gauge of how participants respond. For example, when asked about their schooling, some participants gave detailed verbal descriptions of their academic history, while others listed their degree type, institution it was awarded from, and year earned. Participants who responded in the latter form tended to also provide less detail for other questions, and subsequently required more active follow-up questions from the interviewer.

Discussion of expertise and decision-making begins by asking participants to describe their typical day-to-day experiences on the job, including roles and responsibilities. This question tended to lead to follow-up questions on decision-making or expertise. The interviewer took an approach to focus the conversation on whatever topic was most natural. Transitions like, "we are also interested in how you define your expertise," were used to ensure all topics of interest were discussed.

The term intuition is not used by the interviewer unless it arises naturally, either explicitly or implicitly, during the discussions of expertise and decision-making. Any mention of intuition or an adjacent concept was used to transition the discussion to focus on intuition. The semi-structured approach allowed for a transition at any point in the interview. The protocol was also designed with a failsafe in the event that intuition does not arise naturally. The introduction of intuition is performed in a way to avoid biasing participants using a simple inquiry on how they define intuition, i.e., "our research team is interested in the idea of "intuition," when we say "intuition" does this term have meaning for you? If so, how would you define it?" This line of questioning is followed by questions of whether they believe intuition is used in the workplace, i.e., "do you think you use intuition in the workplace? If so, how? If not, why not?"). Participants are asked if they believe we have missed anything in the discussion of their expertise development, decision-making, or perceptions of intuition before ending the interview.

Limitations

The primary limitations placed on this study concern participant sampling and the lack of prior interviewer experience. The participant sampling was one of convenience. The participants were known to the interviewers and do not represent a diverse sampling within the given fields of expertise. Interviews conducted of these participants were performed by the authors of this paper. Two of the three authors are transitioning from discipline-specific research into engineering education. The preliminary interviews included the dual purpose of serving as a tool to develop interviewing experience under the guidance of an expert and developing the interview protocol. The authors would also like to note the potential role our positionalities and epistemological commitments may have played as part of this research. This work is being undertaken because we believe engineering intuition exists and plays a major role in the decision making of engineering learners and practitioners. These held beliefs combined with our goal to ultimately measure engineering intuition have the potential of impacting how interviews were conducted and the data that resulted from these interviews.

Results and Discussion

The preliminary interviews yielded some notable disciplinary similarities and differences in the development of expertise and perceptions of intuition, including definitions of intuition, the role of experience, beliefs around whether intuition and skills were learned or innate, decision-making processes, and transfer of skills.

Defining Intuition

Intuition related ideas that arose in interviews included gut-feeling, "spidey" sense, knowing what to do, and less hesitation. These descriptors were used by all participants when asked to define intuition explicitly. Participants credited experience with giving them the additional sense to make more rapid and confident judgements.

Experience in Expertise Development

All interviewees described experience as being essential for the development of their specific skillsets, in particular their decision-making. The nursing and engineering participants gave credit to schooling for developing their baseline of skills. This education was also described as insufficient but closely aligned with their expertise. The business manager participants considered themselves experts in people rather than any given content area. They described the baseline skills that allowed them to be successful in their roles as innate but enhanced with experience.

Developing Intuition

The theme of learned versus innate also appeared in how members of each discipline viewed intuition. The idea of intuition arose naturally in interviews with engineers and nurses, but did not with managers. This discrepancy may be because descriptions of expertise development tended to focus on describing experiences, which managers did not view as developing their intuition. Alternatively, this discrepancy may also arise from the specific areas of expertise. Managers self-described themselves as "people experts" and presumably have a longer history of informal experience in their area of expertise compared to nurses and engineers. The introduction of intuition into the interview after a designated period of time revealed that managers resonated with this construct and saw the importance of intuition in their roles.

Decision-making Processes

Discussions about decision-making led engineers and managers to describe intuition as sometimes in conflict with data or facts. This conflict did not arise in nursing likely due to the complexity and variability of working with patients. Addressing situations where data conflicts with intuition introduced the idea of relative risk during the decision-making process. One business manager participant cited being more likely to follow their intuition in low-risk scenarios and rely on the data in high-risk situations. This participant also acknowledged that this may be a personal preference, and that others may engaged differently in the process.

Transfer of Skills

Changing specializations for one nurse (e.g., emergency room, neonatal intensive care unit, etc.) was in many ways starting from zero as the patients, time-scales, and prioritization protocols were so different. Specifically, the nurse participant noted that their previously learned and accurate intuition was in conflict with their new role. Managers and engineers described skillsets as more transferable when moving into new roles, perhaps because those roles occurred within similar contexts.

Conclusion

All participants described experience as an essential component when developing expertise despite differences in perceptions of whether intuition can be learned. Participants also described improvements in their judgement, including the speed and accuracy of decision making, through

experience. Terms such as "gut-feeling" were used to describe how their current judgement and decision-making compares to their earlier career selves. These results are well-aligned with the literature on expertise and decision making, which can be used to identify the role of engineering intuition in future interviews. Our work going forward will be sure to keep in mind alternate explanations to our existing and future data and seek to understand the definition and context-specificity of engineering intuition.

Future Plans

Our next step is to finalize the interview protocol in response to analysis of the completed interviews and begin conducting interviews strictly with practicing engineers (Phase I). The Phase 0 interviews presented in this study have helped us better understand the potential directions each interview may take as we apply existing literature to the discipline of engineering. We will use this information to guide our future interviews and data analysis.

Phase I we will continue to conduct semi-structured interviews and build a strong foundation for studying engineering intuition that includes using: 1) parallel grounded theory [33], i.e., implicit discussion around intuition informed by literature from other disciplines, and 2) critical incident technique [1], i.e., explicit discussion around the concept of intuition. This information will be used in Phase II to create a tool to measure engineering intuition.

Acknowledgement

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