WIP: Intuiting Intuition through First-Year Interviews

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Abstract

This work-in-progress paper discusses themes that have appeared during preliminary interviews of first-year engineering students on their perceptions of engineering intuition. We believe that developing a student's intuition is an important aspect in engineering education, but the construct itself remains vague. As part of a larger project on defining engineering intuition, this paper focuses on how first-year engineers perceive the construct of intuition. With less than a year of experience in engineering, these students currently lack the experience and knowledge required to develop robust intuition, but they have interesting insights into what they, as novice engineers, consider intuition and how it is developed. In future work, we will compare first-year student perceptions of the construct with those of practicing engineering (representing experts) to capture similarities and differences across novice and expert perceptions on intuition.

Background

Intuition is a slippery construct which often means dissimilar things to different people. Developing a thorough and encompassing definition of intuition can be complicated. Intuition is thought to be the gut reaction to a solution, the quiet thoughts that guide the brainstorming of a design, and the idea that gives an engineer pause when they realize something may be wrong. In this work, we define intuition as a process of feeling-based problem solving that views a problem and solution holistically (Sinclair & Ashkanasy, 2005). This definition of intuition focuses on solutions based around a problem-solver's gut feeling of what is right.

No matter how intuition is defined, there is evidence that intuition and expertise are closely intertwined. The Dreyfus Model of skill acquisition labels intuition as a key identifier that someone has reached expertise within a skill (Dreyfus, 1980). On the other end of his scale, Dreyfus states that a novice in a skill is rigid in their thinking. They are set in strict processes. Unlike an expert, the novice cannot intuit how a process, solution, or idea can be used in a context other than how it was taught to them. Dreyfus does not comment how a novice's intuition is or can be developed through the stages of expertise development.

Kuhlmann and Ardichvili agree that novices lack the flexible thinking of a master (Kuhlmann & Ardichvili, 2015). In their exploration of expertise, they reiterate that beginners, or "non-experts", learn through developing problem solving processes but can become dependent on these "routine solutions". For example, students that recently learned about derivatives may be able to easily take the derivative of given equations but may not be able to understand what the equations represent in the real-world. For students, being unable to see connections in subjects, ideas, and processes can make new problems especially hard to understand and solve.

This difference in flexibility of thinking manifests in several ways in novice vs. expert problem-solving. When answering general design idea questions, experts and those with high levels of intuition tend to have more "gist" (bottom line) based solutions while novices tend to go into more precise detail of their answer. A beginner is expected to get caught up in details rather than being able to convey the overall idea of their design (Corbin, Reyna, Weldon, & Brainerd, 2015). Because beginners tend towards overly in-depth solutions, their first idea constrains their design space, limiting the final product unnecessarily.

While non-experts are slowed down by a focus on details, experts spend time while solving problems to check their answers as they work (Simon & Simon, 1978; Miskioglu & Martin, 2019). Experts are able to focus on big picture solutions by trusting their well-developed intuition to check if their design is a reasonable solution and if smaller details and problems that may bog down a beginner need to be explored further. Non-experts need to spend more time developing their solution because they do not have the experience that experts are able to pull from. Because of this, experts are able to use analogical problem solving while non-experts must treat each problem they are met with as something new and unique.

In order for beginners to access their intuition and avoid being overwhelmed, engineering problems need to be carefully structured to remove the novices from their rigid design processes and to avoid "noise". Noise is the extra information and distractions that someone may be bombarded with while working out a solution. Okoli, Weller, and Watt found that intuition helps a problem solver to more easily ignore noise (Okoli, Weller, & Watt, 2015). Avoiding complicated problems should help to keep those with low levels of intuition focused and away from confusion. Noise can easily overload beginners, distracting them from their purpose and leading them towards overly complicated answers.

As engineering students graduate from college, they transition from the structured and controlled environment of the classroom into the unstructured and uncontrolled workforce where engineers are routinely confronted with unexpected and never-before-seen problems. During their education, students practice many problems of a similar nature and become accustomed to the patterns and consistencies they see in these problems. Without the development of a strong intuition for correct solutions, student engineers can lack the ability to self-check once faced with more complicated real-world problems.

Methods

In order to access a student engineer's understanding of intuition, we conducted interviews that would encourage students to think critically about an engineering question and then explain the role they felt their intuition had taken in the process. We gave the students a design question focused on the first steps of the problem solving process as intuition takes a large role in these first steps. This engineering question served as a way to open up discussion into expertise and intuition. The students' design could then be used to support a discussion on the role of expertise and intuition in their work and their design processes.

Design Problem

The design problem students were given was a worksheet with the prompt "Design a steering wheel for a person with only one arm." The worksheet also contained a large blank space for students to write and sketch their solution. This prompt was designed to be open ended with many possible solutions. Because all three participants were familiar with driving and able-bodied, the question would address something they knew well, as well as the more unfamiliar element of designing for a differently-abled person.

This prompt was developed by building on a previous study (Cunningham, Martin, & Miskioglu, 2019). In the previous study, students were asked to design a way to cross a river with only the materials they would find by a wooded river. These students were assessed on their answer's creativity. The problem given in that study put several constraints on the designer (materials they could use, location, machining ability) but failed to mention the depth or width of the river. In contrast, the problem used in this study had no constraints but clearer operating conditions, meaning that the designer needed to use their engineering intuition and experience to develop their own design space rather than a simple answer of, "just jump over the river."

Participants

Participants were selected through a survey distributed to the "University 101" class at a small, private southwestern university targeted to engineering majors. All engineering students are required to take this class during their first semester at the university. University 101 gives students a basic overview of different kinds of engineering majors offered by the university, common processes students perform (building a four year plan, adding and dropping classes, etc.), and helps students to transfer successfully into their newly focused studies. Students that elected to take the survey submitted their major, noted how long they had been attending college-level classes, and completed an engineering identity survey (Godwin, 2016).

Nine of the students (less than 3%) in the University 101 class completed the survey. This poor turnout may be due to a lack of incentive to fill out the survey or because of the timing of the survey distribution (three weeks before final exams). While the survey only took a few minutes to fill out and the following interview would take less than half an hour, students may have not wanted to commit additional time to a research project so close to finals. Presenting the opportunity to participate multiple times through the student's first semester, or within the first month of their second semester may help increase our participation in the future.

Students were eligible to participate in the interview if they were engineers in their first semester at the university and had spent no more than two semesters studying at another university. Of the nine students who filled out the survey, one student was not eligible because they had enrolled in another university as a full time student for more than two semesters. Three of the remaining eight students were selected for both their availability and their representative range of engineering identity score. One student had one of the highest average identity scores of the nine replies, one student had one of the lowest average scores, and the third student's score fell about half way between them.

Interview

The interviews were conducted by a single researcher shortly before the end of the semester. When students arrived, they signed an informed consent form, and the interviews were recorded using Zoom.

Interviews began with general questions (i.e., What is your major? How are you liking your classes?) to build rapport. The student was then given the design problem on a worksheet and given about five minutes to work on their design. The five minute limit was created to encourage the students to quickly develop and write down the first idea their intuition led them to. After the five minutes given for design, the students were asked to explain their idea. The interviewer asked follow-up questions (Can you explain your design? What improvements do you believe professors or professional engineers would offer? Do you feel this design is intuitive? Would your professors/professional engineers feel this design is intuitive?) designed to assess the student's use of intuition in the design process and to probe the choices that the students made and why they made them.

The student's design was used as a jumping off point and a reference while discussing their thought process. The interviewer assessed the student's ideas concerning intuition and expertise using a combination of preplanned and on the spot (Did you consider a modification to an existing steering wheel? Was this designed for someone right handed or left handed? What was your inspiration for including this feature?) questions. On the spot questions were based on the design the student produced and were used to help focus students on the intuition they used in design rather than the intuition a user would need to use it.

Results and Discussion

While the preliminary survey was distributed to all first year engineering students, all respondents were male. Two of the students who participated were white and one was Asian. The enrollment of the university is predominately white males (around 75% male and 67% white). As part of the preliminary participant survey, students took the engineering identity survey which asks the participants to rate how well they agree with thirteen given statements of identity affirmation on a scale of 0-6 (strongly disagree to strongly agree). These rankings were all averaged to give the student's Total Engineering Identity Score. Godwin categorizes the thirteen questions into three categories: Recognition, Interest, and Performance/Competence (Godwin, 2016). The rankings in each section were averaged to give the student's category specific scores. The student's engineering identity scores and GPA can be found in Table 1.

Scott, Dave, and John[1] are all high achieving engineering students. Their first-semester GPA's reflect their success in their first 5-7 university courses, and they all were enrolled in University 101. Scott and Dave were also enrolled in a Matlab focused computing course, and John was enrolled in an introductory physics course.

Table 1: Student Participant Data

Name	Total Engineering Identity Score	Recognition	Interest	Performance / Competence	GPA
Scott[1]	4.31	4.5	4.67	4	4.0
Dave[1]	5.08	4	6	5.33	3.92
John[1]	5.23	5	5.67	5.17	4.0

All students' solutions were based on existing items they were familiar with. Scott and Dave both provided solutions that were relatively simple attachments or modifications to a typical steering wheel. Scott's design made use of a knob on the wheel and Dave included several knobs and ridges in his design. Scott and Dave both transferred in physics class credit and were not enrolled in physics at the time of the interview. Having this prior experience, they both used technical language. When asked to explain their idea, both students went into deep detail on the physics of how they believed their designs would work. They both mentioned "Normal Force"

[1] Student's names have been changed to ensure their anonymity.

and Scott continued with details on the wheel's "friction" when asked to explain their design. Scott and Dave's interviews may show that students who do not identify as experts, but who have a base understanding of a subject, may use overly technical terms to gain the trust of their listeners and prove that they possess necessary knowledge of the subject by mimicking the words they have heard previous instructors use.

Scott and Dave's engineering intuition guided them towards similar answers to the problem they were presented with. Both based their design on something familiar, a steering wheel. They choose to add attachments or modifications to the design rather than try to invent something themselves. Scott and Dave both mentioned that they believed the hardest thing for someone with one hand while driving would be a turn that would require rotating the steering wheel several times. Their solutions were designed to solve this problem.

John's design was also based off of a subject that he had a prior familiarity with and an interest in, a fighter pilot's control stick. He commented that anything that is usually controlled by knobs and levers may be difficult for someone without a second hand or to use. John offered the solution of controlling these functions with buttons on the control stick. Contrary to Scott and Dave who have more experience with physics, John had not yet learned kinematics concepts in his physics class. However, John's design was inspired by his previous interests. All three students found design inspiration in something familiar to them. For Scott and Dave, this inspiration came from the standard two-handed steering wheel and their study of kinematics in physics courses while John's inspiration was derived from his personal interest in aeronautics.

Intuition is subject specific (Miskioglu & Martin, 2019). These students showed the use of their engineering intuition in the face of an unfamiliar problem. Instead of trying to create something new and untested, all three students built a design around something that they knew worked and that they felt in their gut would be able to solve the problem they were presented with.

To better understand the link engineering intuition may have with the student's experiences in engineering, we used the students' identity scores. Scott has the lowest Interest, Performance/Competence, and total scores. These scores indicate low self confidence in the area and difficulty seeing himself as a capable engineer. Dave had the lowest score for Recognition, but the highest scores for Interest and Performance/Confidence. Because he does not feel he is recognized as an engineer, Dave may feel that he needs to prove his potential through his Interest and Performance/Confidence in the subject. Scott and Dave's reluctance to stray from the traditional wheel design of a steering wheel showed that they wanted to provide an easily acceptable and recognizable design. Their engineering intuition may have guided them to a solution that would be familiar to users and to their interviewers. Because they wanted their design to be accepted and respected, they may have added the design constraint of making their solution recognizable as a steering wheel.

John scored the highest in the Recognition category of the engineering identity survey. Because he feels that he has been recognized as an engineer, he may have been more willing to take the risk that his design may not be accepted by others and follow a less traditional design path. This may have allowed his intuition the freedom to guide him to something that was still familiar but was a more unique solution to the problem statement.

After students explained their designs, the interviewers engaged them in discussion of expertise and intuition. To characterize how students believed intuition was developed, they were asked about the intuition of two groups: professors and practicing engineers in industry. Knowing how students believe intuition is developed and how much intuition they believe different professionals have can shed light on the steps they believe a person should take to be an expert in their field.

When asked how they believed professors would define intuition, the students viewed professors and experts as more rigid in their ideas and processes than students. Scott said that he felt his professors would say “don’t do [something] because of a feeling” though his definition of intuition had been “based off of feeling”. This connection implies that Scott viewed intuition as something used by beginners rather than developed while gaining knowledge and expertise. This implication is exactly opposite of the Dreyfus Model’s belief that experts develop high levels of intuition to aid decision making while beginners are stuck in rigid processes. The students also differentiated professors from practicing engineers and did not see their professors as experts in a field as compared to practicing engineers. The students viewed professors as the most rigid in the engineering field. Students are most accustomed to teachers and professors who teach through repetition of like questions and problems. The students’ view of their professors may be a product of the way that they have been taught. We believe that if students are taught how to manipulate the concepts and encouraged to explore how concepts apply to different subjects, students would have viewed professors as much less rigid.

Conclusion and Future Work

These interviews have shed light on preliminary connections that can be made between a student’s engineering identity survey results, intuition, definition of intuition, and engineering design process.

The three interviews that have been discussed are the preliminary interviews for this research. The results of these interviews will guide the protocol for the future. We plan to ask the students to expand on their background in engineering as well as the problem’s design space (i.e., Do you have a personal connection to someone with a physical handicap? Have you ever had an engineering internship?). With these questions, we will better understand what may have influenced and inspired their answers. We also hope to recruit a more diverse pool of interviewees through outreach to more classes, organizations, and groups on campus.

During the next phase of this work, we intend to interview more first-semester students and gain a better understanding of their level and definition of intuition. With a larger group of interviewees, we hope to be able to confirm our preliminary connection of the student’s average engineering identity score and rating in one category of the engineering identity survey with their level or understanding of intuition. Using these preliminary interviews, we will begin to work on creating a codebook for this research to help us find patterns in the responses.

A student’s ability to identify engineering intuition and develop their own will be integral to their success as a practicing engineer. Identifying how most first-year students understand intuition is the first step in achieving this goal.

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