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Work in Progress: Research on Engineering Students' Epistemological Beliefs in Design Decision Making; Conceptual Issues and a New Methodological Approach

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(WIP) Research on Engineering Students' Epistemological Beliefs in Design Decision Making: Conceptual Issues and a New Methodological Approach

This work-in-progress paper reports on an approach to examining students' epistemologies in the context engineering design. Studies of students' epistemologies suggest a gap between their professed epistemologies (i.e., their stated beliefs about knowledge) and their enacted epistemologies (i.e., what one might deduce about their beliefs from their behaviors). This research examines that gap in the context of design problem solving. We conducted focus groups in which we asked students to (a) discuss their responses to a paper survey (professed epistemologies) and (b) evaluate engineering concepts, as well as the rationales behind the concepts, in a set of engineering vignettes (enacted epistemologies). Preliminary findings suggest students often expressed hesitance for dominant epistemologies in engineering, rejecting the normative ubiquity of math and science, when responding to surveys. However, when evaluating ideas, students elevated math, science, and technical rationality and objected to ideas supported by engineers' prior experiences or cultural knowledge.

Keywords: epistemology, design thinking, mixed methods research

Introduction and Background

Existing research indicates students' epistemological beliefs, defined as one's belief about the limits, certainty, and sources of knowledge, are particularly important in ill-structured problem solving, such as engineering design [1-2]. For example, Jonassen described students' epistemologies as important in ill-structured problem solving since students' epistemologies inform (a) how they understand design problems, (b) how they generate and evaluate ideas, and (c) the types of knowledge claims they value or devalue during the ideation and decision-making processes [1-2]. Thus, understanding students' epistemologies in the context of solving design problems is an issue of importance for engineering design teaching and learning.

However, the ways that scholars have examined students' epistemologies in higher education research are fraught with conceptual and methodological challenges, leading to gaps in knowledge about the role of epistemologies in students' learning and design problem solving. For example, one conceptual issue centers on the domain-generality of students' epistemologies. While early studies of college students' epistemologies viewed students' personal epistemologies as domain-general (i.e., that epistemologies are fixed across academic contexts), more recently, studies have examined students' epistemologies in the context of specific academic disciplines (i.e., domain-specific epistemologies) [3]. These studies posited that one's beliefs about the nature of knowledge in one academic domain (e.g., history) need not align with beliefs in other academic contexts (e.g., engineering) [3-5]. As such, studies examining engineering-related epistemological beliefs have become more common in the empirical literature [5].

Other conceptual and methodological challenges have had implications for engineering education research related to the role of students' engineering-related epistemologies. For example, in a study of engineering students' beliefs about problem solving, McNeill and colleagues [6] used the Reasoning about Current Issues Test (RCI), a domain general measure examining reflective judgement, as a measure of engineering students' personal epistemologies.

While other studies have utilized domain-specific instruments to measure students' engineering-related personal epistemologies, these instruments are often unsupported by strong statistical evidence (e.g., inadequate sample size, poor internal consistency). For example, Carberry and colleagues [7] validated the Epistemological Beliefs Assessment for Engineering (EBAE) using a sample size of 43 first-year engineering students, a sample size the authors acknowledged was insufficient for rigorous validation techniques. Similarly, Faber and Benson [5] examined the Engineering Related Beliefs Questionnaire developed by Yu and Strobel and found that one factor in the scale had an internal consistency measure (i.e., Cronbach's alpha = .48) well below established minimum values. Consistently, attempts to measure students' personal epistemologies have exhibited conceptual, methodological, and statistical shortcomings.

This begs the question: Why have epistemologies been so difficult to measure in quantitative educational research? Several scholars have posited explanations for the challenges in empirical research on personal epistemologies in education broadly, and engineering education specifically. Richardson [8] pointed to the evolving ways epistemologies have been conceptualized (e.g., unidimensional versus multidimensional, domain-general versus domain specific), and the implications such conceptualizations have for empirical research. Others have pointed to social influences on epistemological beliefs, such as the influence of dominant disciplinary ideologies on students' beliefs about knowledge [9-10].

This research began from the premise that one reason survey methodologies for measuring students' engineering-related epistemologies frequently exhibit statistical shortcomings lies in what Louca and colleagues [11] referred to as the difference between *professed* and *enacted* epistemologies. That is, that one's epistemologies are not necessarily stable beliefs. Rather, professed epistemologies (i.e., the views about knowledge one states in the abstract, such as in survey responses) might differ from one's enacted epistemologies (i.e., the manifestations of one's epistemological beliefs manifested in one's behaviors) [11]. They suggested that different epistemological resources are activated in different contexts (e.g., "the hubbub of the classroom versus the reflective calm of a clinical interview") (p. 59). In this research, we presuppose that answering survey questions about one's abstract beliefs about knowledge (i.e., professed epistemologies) might activate different epistemological resources than evaluating engineering concepts and rationales in practice amongst other engineers (i.e., enacted epistemologies). As such, we hypothesized that students' responses to survey questions and their rationales for their responses might differ markedly from their behaviors in practice while evaluating engineering ideas. This research sought to answer the following research questions: (1) What are the characteristics of students' professed and enacted epistemologies? (2) How are students' professed and enacted epistemologies manifested in their evaluations of engineering ideas in design contexts?

Data Sources

This work-in-progress paper reports on preliminary analysis of semi-structured focus groups designed to elicit students' (N= 8) responses about engineering ideas and rationales. Each focus group proceeded in three segments and entailed two instruments. In the first segment, to examine students' professed epistemologies, students were asked to respond to an engineering-related beliefs survey using paper and pencils. We administered a survey instrument designed to measure students' beliefs about the role of scientific objectivity, value neutrality, and depoliticization in engineering (e.g., "Engineers should rely on math and science when defending their ideas." and "If engineers follow mathematical and scientific principles, they will always find the best solutions."). These survey items, which were developed by the study team, were measured on a five-point Likert scale (i.e., 1 = Strongly disagree, 2 = Somewhat disagree, 3 = Neither agree nor disagree, 4 = Somewhat agree, 5 = Strongly agree). After students recorded their answers to survey questions individually, we asked them to discuss their responses aloud, as well as explain their choices and rationales.

Second, to examine students' enacted epistemologies we used a set of engineering vignettes. In each vignette, an engineer is responding to a design dilemma—whether to implement tires or continuous tracks in robotics design project (Figure 1). We asked students to evaluate the rationales of five different engineers in written commentary by responding to three questions: (a) Do you think the engineer provided appropriate support for their opinion? Why or why not? (b) Were there any parts of their rationale that you thought were particularly convincing? What made their rationale convincing? and (c) What advice would you give to the engineer to make their rationale more effective? Finally, students were asked to discuss which engineers provided the most and least appropriate rationales, and which ideas warranted further consideration.

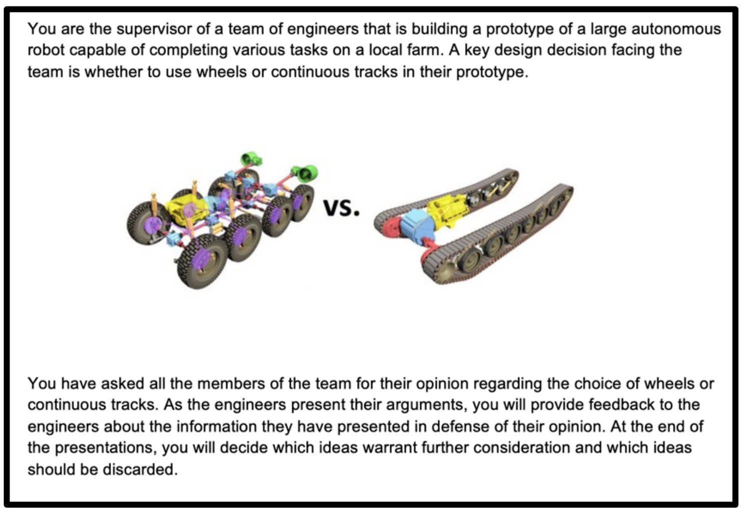

Figure 1. Introduction to engineering vignettes for the second portion of the focus groups.

Findings

This paper reports on analysis of two focus groups with first-year engineering students. Specifically, this paper draws on (a) transcripts of students' discussions following the survey segment, (b) students' written responses to the engineering vignettes, and (c) transcripts of students' comments during the focus group discussion evaluating each engineering vignette.

Students' Professed Epistemologies: Tentative Support for Scientific Objectivity

While existing research suggests engineers tend to elevate the "technical realm" of engineering (e.g., technical knowledge, mathematics, science), participants in this research routinely expressed tentative support for the idea that math and science were the best ways to communicate and defend ideas, often pointing to social issues, human factors, and personal values as caveats to such beliefs. For example, while reflecting on responses to the survey questions, one student discussed how the questions were difficult to answer given the number of contextual factors that might inform their beliefs about engineering knowledge:

> I said strongly agree, just because initially, in the start I was like engineering is math and science, of course, you use math and science to defend something that you are doing in engineering, but then as [other participant] said, when they got to the end, I was like thinking about the social justice and the social aspect of it when I was looking through it but then it like brings up like maybe there are some reasons to not use just math and science.

Similarly, others expressed an awareness of the ubiquity of math and science in engineering, but noted caveats and exceptions to those beliefs:

> I think generally when we think of engineering, we think of just the straight numbers and actual calculations of things, which, there's no need for personal bias to be involved in that. But when you extend the lens further into engineering communities and engineering as a whole, humans are involved. So it doesn't make sense to not include personal bias, because it's just a fact of life.

This research suggests students hold tentative views when responding to surveys about their engineering-related epistemologies due, in part, to their understanding of the broader implications of their engineering work. However, we acknowledged that these views may not align with their evaluation behaviors in practice. As such, we turned to the engineering vignettes, asking students to evaluate engineering ideas and rationales to assess whether and how students enacted particular epistemic beliefs and values in practices.

Students' Enacted Epistemologies: Strong Enactment of Technical Rationality

While students expressed tentative support for the ubiquity of technical knowledge in engineering while responding to survey questions (i.e., professed epistemologies), the role of technical knowledge in their evaluation approaches was apparent. For some students, their professed support for scientific objectivity and technical rationality hardened when evaluating solutions. For example, one student, who agreed that math and science are the best ways to defend ideas, and supported the claim knowledge in engineering is objective, objected to all but Engineer 3, who presented an equation and citation. When asked if Engineer 3 provided appropriate support, this student wrote:

> Yes. The engineer fully supports him/herself by quoting the opinions in research papers and giving theoretical deductions…The conclusions from the research papers and theoretical deductions [were most convincing]. These materials are evidence and experiment-based proofs that is [sic] highly reliable to be used as support.

Still, students' professed epistemologies did not always align with their evaluations of ideas and rationales in practice. For example, one student, who had disagreed with the idea that technical knowledge was the best way to defend ideas in engineering, as well as the idea that cultural beliefs, human emotions, and personal experiences should be left out of engineering work, objected to Engineer 2 due to the lack of "data and engineering thoughts":

> The engineer brought up a very good point, however it was basically based on their personal experience…No engineering concept was used to support their opinion, and it weakened the point they made…Personal cases are really good to clarify an idea…I'd say they [need] to bring data and engineering thoughts that help their argument be very strong.

Discussion and Future Work

Louca and colleagues [11] argued that differences between students' professed and enacted epistemologies are a function of context, where different epistemological resources are activated in different contexts (e.g., the classroom vs. a one-on-one interview). If it is true that students activate different epistemological resources in different academic and social contexts, then the implications for research on engineering design, teamwork, and team-based design processes are immense. For example, students in the study appeared to more readily indicate that ideas from engineers who drew on personal experiences or cultural knowledge did not warrant further consideration during the design discussion. In team-based design settings, the tendency to discard ideas based in personal experiences or cultural knowledge might disproportionately impact students of color [9, 12]. Existing research suggests students of color are likely to seek opportunities to discuss their cultural knowledge and socially situated goals in engineering [12], but that opportunities to do so are limited in engineering education. This research suggests that one reason such opportunities are limited is due to the dominant enacted epistemic culture of the discipline, which elevates technical knowledge from the engineering sciences and marginalizes other sources of knowledge (e.g., cultural knowledge, personal experience). This might be why, for example, Cech and colleagues [9] found that Indigenous students reported the difficult work of reconciling or suppressing their epistemological beliefs in science, engineering, and health fields. Our future work will examine how characteristics such as race/ethnicity and gender inform the gap between students' professed and enacted epistemologies.

Similarly, the general belief that engineers should divorce their personal values from their engineering work, while tentative in the professed epistemologies, appeared to guide students' thinking while evaluating ideas. Scholars have routinely called for engineering education to center the importance of the "social realm" of engineering (i.e., the ways that engineering shapes, and is shaped by, non-technical issues), calling for curricular reforms and pedagogical practices that foster students' sociotechnical thinking [13-15]. This work suggests that, while students generally acknowledge the importance of the social realm of engineering (i.e., professed epistemologies), they still tend to elevate the technical realm in their thinking and decision making. This work suggests that efforts to change students' ways of thinking about engineering and engineering work must move away from the theoretical realm and into the practical realm in engineering education. Thus, our future work will begin to develop interventions that position students to enact the epistemic values they profess in the specific context of design projects.

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