Smartness in Engineering Culture: An Interdisciplinary Dialogue

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Abstract
This theory paper contributes to the study of smartness in engineering culture from different disciplinary perspectives. We are interested in the construct of smartness, which is a powerful, yet implicit, driver of students’ experience in engineering education. Smartness in engineering culture can be linked to both the broad narratives and norms that overarch engineering at a societal level (e.g., engineers are smart) as well as the more specific, individual beliefs that individual students hold about the nature of intelligence (e.g., fixed vs. growth mindset). However, the construct of smartness at these different levels is operationalized differently and is informed by theory from different disciplinary fields such as psychology and anthropology. Studying a complex social construct, such as smartness, from a single disciplinary frame is common; each frame has its advantages and limitations. We use this paper to foster an interdisciplinary dialogue and to motivate the importance of an interdisciplinary approach to studying smartness and its role in the culture of undergraduate engineering education.

We ground our dialogue in the scholarly literature from psychology and anthropology, and leverage two co-authors’ prior work in each of these research frames respectively. From these vantage points, we discuss our own observations of the affordances and limitations of the single disciplinary perspectives. We then motivate and discuss the features of an interdisciplinary research agenda, including challenges associated with blending the assumptions and epistemologies of the two different disciplinary frames. We offer an idea of leveraging the unifying construct of beliefs as a way to facilitate interdisciplinary research on the complex construct of smartness. Theoretical implications of interdisciplinary research in this vein include new approaches to other educational constructs that span both individual mental and collective social dimensions. We note that the interdisciplinary study of smartness in engineering culture also has practical implications, such as for inclusive classroom design.

1. Introduction
The construct of smartness and the field of engineering are inextricably linked. While the public often has limited understanding of engineering as a profession [1-3], one central theme is the belief that engineering, with its emphasis on math and science, is difficult [4, 5]. As with any societal narrative, there is a gap between the public perception of engineering as a profession and the reality of engineering work. For example, we see this in emphasizing the importance of math and science skills while ignoring key engineering characteristics such as creativity, teamwork, and communication. The collective emphasis on merit has perpetuated the narrative that engineering is “not for everyone,” a narrative that has particular impact on underrepresented demographic groups [6]. Relatedly, 40% of girls believe they aren’t smart enough for their dream career by the time they enter high school [7]; women remain among the demographics
underrepresented in engineering. Recent ethnographic work has clearly demonstrated how the belief that ‘not everyone is cut out for engineering’ is salient and problematic in engineering classrooms [8].

While society perpetuates a cultural narrative about engineering, intelligence is typically framed in purely individualistic terms. This is in stark contrast to the argument that intelligence cannot be understood outside of its cultural context because culture influences what constitutes intelligence and intelligent acts [9, 10]. Indeed, conceptions of “smartness” in school often cater to analytical abilities, while ignoring other types of intelligence, such as creative or practical abilities [11]. This emphasis on analytical abilities is magnified even further in engineering school, where math and engineering science dominate the curriculum. This cultural norm of valuing analytical intelligence above all else reflects white, middle class constructions of intelligence. This reality contributes to the exclusionary narratives about who belongs in engineering as the qualities that are revered in academia (e.g., brilliance, rigor, seriousness, rationality, objectivity, etc.) are all traditionally linked with masculinity [12]. Extant research has demonstrated that the belief that a field requires innate intelligence predicts lower participation of women and underrepresented racial minorities in that field [13]. This context motivates our desire to study smartness in engineering through interdisciplinary collaboration.

Societal and cultural constructions of smartness create the backdrops from which students make individual choices about becoming engineers. Because of the alignment between academic measures of competence and stereotypes about engineers, it is predominantly those students who have been tracked or conferred as “smart” (e.g., through Talented and Gifted programs, Advanced Placement track, National Merit Scholar, etc.) who matriculate into engineering programs [14]. When comparing the composition of engineering students at the first author’s home institution, students in the college of engineering have slightly higher ACT and SAT composite scores than students campus-wide, and are more likely to have been in the top 25% or 10% of their high school class. While the SAT is often regarded as an “objective” measure of intelligence, it is also noted to contain language, cultural, and socioeconomic bias [15, 16]. Given this backdrop, students with less cultural capital or demographic normativity in STEM assume they need to work even harder to compensate for the required “brilliance,” and they feel less included and less inclined to persist with engineering [17]. Thus, smartness has a major role in institutional priorities, individual experience, and engineering culture that necessitates a nuanced and holistic research agenda.

1.1. Prior Empirical Work on Smartness Relevant in Engineering Education

Despite evidence that smartness is interwoven into disciplinary practice and implicated in issues of equity and inclusion, there is a limited amount of critical dialogue about it in our community. Some extant work has concluded that intelligence beliefs are linked to self-efficacy and the use of active learning strategies and knowledge building behaviors [18]. A study considering how young African American students construct perspectives of science and school related to their
own identity showed that students conceptions of science and self are influenced by their socialization both in and out of school; they primarily construct smartness as holding a large amount of knowledge [19]. Similarly, another study investigated elementary and middle school science classrooms and found that classroom culture matters because how we teach a content area directly influences the identities that are celebrated and who can hold a position of scientist/engineer [20]. A parallel study involving constructions of smartness and inclusion in elementary classrooms found that many students identified “smart engineers” in ways that were more broad than the ways in which they defined “smart students” [21].

The previous work of the first two authors has corroborated the salient role of smartness for undergraduate engineering students. While they often identify as smart, they also feel the pressure that they must continuously prove that they are smart enough. This reality has implications for their experiences and trajectories as learners. First-year engineering students provided the following quotes when prompted by Dringenberg to reflect on their own experiences with smartness.

“I grew up being told time and time again, you are so smart or how did you get a B on that test? You’re supposed to be smart.”

“In general, when it comes to intelligence, I believe that I am above average compared to other majoring students but when it comes to engineers I believe that I am below par...Hopefully, I can prove to myself that I am as smart as the average engineer and that my strengths can set me ahead to do great things.”

“I used to refrain from asking for help because I was embarrassed and thought I was too smart to ask for help.”

In Secules’ ethnographic research, students noted ways that smartness is constructed and functions within engineering classrooms. The following quote is a student’s response to an interview question about how he notices how students are doing in the class; his response reveals how keenly aware students are of the classroom actions that help communicate competence and smartness:

“The professor will ask a certain question and someone will have their hand up and they’ll answer it and give them-- or ask a very in-depth question that shows not only do they have the grasp of the knowledge, but they are very far ahead. Um, also there's certain attitudes that I think a lot of people put on-- like-- it's the way they sit-- there are certain people in the class who are leaning forward with their pencil and looking at their board, cause they want to know everything that's going on, they're hanging on the professor's every word; and there are certain students who are kind of laid back and will just call shots.”
If engineering classes become spaces to project smartness, it creates conditions for students to receive a message about a lack of smartness in themselves or to deliver such a message to others. Another student from this course concluded in his post-interview:

“I just don’t think I have the brain for programming.”

Thus, ours and others’ prior empirical work suggests that smartness is a salient and complex aspect of the student experience of engineering education. In spite of this promise and initial contribution, the terrain of smartness remains contested and taboo, with strong traditions and camps on either side of a disciplinary divide. In the next sections we explore psychological and anthropological approaches to investigating smartness.

2. Background (Disciplinary Divide)
While smartness is a phenomenon and a construct that is embedded in everyday experience, the extant approaches to studying smartness demonstrate a stark disciplinary divide. When focused on personal beliefs about smartness, growth or fixed mindsets, and individual motivation, we can see beliefs about intelligence through a psychological lens as an individual cognitive state. Alternatively, when focused on the cultural definitions of smartness, broad disciplinary narratives, and pedagogical or interactional norms in an educational setting, we can see smartness through an anthropological lens as a social and cultural construction. While we each conduct productive research from our current respective lenses, we are in agreement that these lenses are related and interactive, as theorized in Figure 1. We begin providing background for an interdisciplinary dialogue by providing more detail about each of these disciplinary approaches to understanding smartness.
2.1. Example of Psychological Lens—Overview of Dweck’s Mindset Theory

A psychological lens to studying smartness focuses on the stable beliefs an individual holds about the nature of intelligence. Pioneered by Carol Dweck, significant work on student motivation resulted in her Mindset theory. The theory posits that individuals possess implicit beliefs that tend towards believing that a person’s intelligence or ability is 1) static (fixed mindset), or 2) malleable and can change with effort (growth mindset) [22]. It is assumed that these beliefs are accessible through survey items that prompt learners to self-report their level of agreement or disagreement with statements such as, “You have a certain amount of intelligence and you really can’t do much to change it” [23]. These intelligence beliefs, held at the individual level, have been shown to correlate with the types of learning goals people are motivated to achieve (e.g., look smart or learn), their views on effort (e.g., it is a sign of low ability and futile or it is required for learning), and the ways in which they respond to challenges (e.g., with helplessness or with a mastery orientation that results in persistence) [24].

2.2. Strengths and Limitations of Growth Mindset as a Framework for Studying Smartness

As with other psychological theories, growth mindset is a productive lens built on a large body of empirical work demonstrating the links between an individual’s beliefs about the nature of intelligence and their academic achievement. For example, Blackwell and colleagues [24] found that a mindset intervention before the transition into middle school for students who initially demonstrated a fixed mindset showed increased motivation and an upward trend in math achievement as opposed to those in the control group. A growth mindset intervention used to mitigate stereotypes threat for African American college students resulted in greater academic achievement, engagement and enjoyment [25]. Additionally, increased persistence in the face of failure was shown in college students who were given a growth mindset intervention [26]. Specifically within an engineering context, first-year students given an open ended problem to solve showed less of a change towards fixed mindset compared to peers not given such an opportunity [27], and students with growth mindset beliefs were more likely to engage in active learning and knowledge-building behaviors [18]. The simple framing and proven results have made mindset theory and the psychological lens attractive and popular, especially in K-12 education. The existence of valid and reliable survey items [23] allows educators or researchers to measure these powerful beliefs for a given individual in a rather simple and straightforward way. Finally, the idea of being able to change each individual’s intelligence beliefs to align with a growth mindset can appear as a fix-all for motivation, persistence, and achievement in school and in life. Despite these attractive aspects of studying smartness through individual beliefs, there are limitations to this approach.

Educators are often encouraged to promote a growth mindset through praising effort, but Dweck has warned against an oversimplification of the theory of intelligence beliefs when translating the theory to practice. Her early work demonstrated that a sociocognitive approach is useful because when predicting behavior with mindset as an internal state, the outcomes are moderated
by other things, such as confidence in present ability [28]. She emphasizes that an individual’s intelligence beliefs are, in fact, contextual and dynamic, and that the adoption of her theory is often oversimplified [29, 30]. Of course, content area also matters—an individual may have a growth mindset about their mathematical ability, but a fixed mindset about their artistic ability, for example. Furthermore, intelligence beliefs were found to vary by culture, citizens of the United States were less likely to believe that everyone has the potential to become highly intelligent than individuals from India [31]. This aligns with other researchers who argue that intelligence simply cannot be understood without consideration of culture [9]. After all, cultural beliefs about intelligence vary—in a study of participants from both Anglo-American and various immigrant groups, researchers found that only Anglo-American parents focus mostly on cognitive abilities, while other immigrant families prioritize social skills to be just as important [32]. A survey of mindset items on a Chilean census revealed that mindset is not equally distributed across groups of different socioeconomic status [33]. In this same vein, researchers have demonstrated that intelligence beliefs do not directly predict achievement or belonging, but instead are moderated by the academic environment [34].

While some research found that mindset remained stable for three years in college students [35], other research has documented changes in mindset just during a single year of college [36]. In the first author’s own work, she has also recognized the limitations of intelligence beliefs being measured without consideration of the cultural context. For example, she engaged first-year engineering students in a semester-long, in-depth, mindset intervention and analyzed student reactions qualitatively. A key takeaway was that students recognize that one cannot simply flip a switch and harness a growth mindset, but rather it requires constant vigilance depending on context and culture in order to embrace challenges as learning opportunities and persist through difficulty by maintaining growth mindset beliefs [37].

While the beliefs that an individual holds about intelligence are something that exist and are important, in order to understand engineering education culture with respect to smartness, we need to look beyond the individual and study the construct of smartness at grain sizes larger than the individual or student. In other words, a limitation of using the psychological lens to study the construct of smartness as it operates in engineering culture is limited by the inability of the psychological lens to account for the role of context in the construction of smartness. In the midst of recognizing these limitations in her own scholarship in this area, Dringenberg reached out to Secules to better understand his academic approach to studying smartness (or ability) in engineering education, which is described next.

2.3. Example of Anthropological Lens—Overview of Cultural Scholarship on Inequity
In the latter half of the 20th century, a group of scholars from anthropology and sociology of education were developing tools to examine root causes of inequity in education. Borrowing from other social sciences, these scholars uncovered the cultural and structural roots for the
reproduction of educational inequity, including socioeconomic, gender, and racial dominance [38-40]. Anthropologist Ray McDermott first engaged in this work through interrogating laboratory psychometric tests designed to assess students’ cognitive function, investigating the tests’ validity in new environmental and cultural settings [41, 42]. In reexamining this work over the decades, McDermott and collaborator Herve Varenne developed an influential critical framework for the primary ways educational problems are explained [43, 44]. Educational problems include problems encountered by individual students in classrooms as well as broader societal educational inequities.

In Stage 1 of McDermott and Varenne’s (2006) framework, the educational problem is located in the individual, perhaps including their motivation, their affect, mental state, or their cognitive abilities. Educational scholarship has often noted that explaining educational problems such as persistence in terms of an individual results in a deficit framing, blaming the individual for a personal shortcoming. Although many in the psychological literature might focus on the individual positive framing—explaining particular success, persistence, or hard work through individual traits such as growth mindsets or grit—the reverse logic inevitably comes true as well. McDermott suggests an equally unsatisfying logic, labelled as Stage 2, which is to locate an educational problem only in the different-but-not-worse background, socialization, and unique culture of an individual. While both individuals and home cultures are at play, he suggests a frame (Stage 3: cultural construction) investigating the educational culture and system that creates the problem in the first place. One might say in that Stage 3 the focus is on the context, conditions, actors, and system that make producing a given negative educational outcome likely and predictable. While Stage 3 holds more explanatory insight, Stages 1 and 2 remain prevalent because they implicate less of the institutional system and thus appear easier to solve.

2.4. Strengths and Critiques of Cultural Scholarship on Inequity
The cultural construction approach has been adapted to investigate the construction of competence in K-12 mathematics education [45] and literacy education [46]. In higher STEM education, Kevin O’Connor has examined the ways particular institutional trajectories, instructor discourse, and course culture contribute to constructing categories of “Calculus-ready” [47, 48]. Secules investigated the cultural construction of “not cut out for” engineering in an introductory programming course for electrical engineers [8]. Many of these studies make important insights about the subtle and unintended impacts of culture on students, even in courses with evidence-based pedagogy and well-intentioned instructors. These important insights have been more often explored in K-12 education than engineering higher education, suggesting the importance of this paper’s effort. Nevertheless, a few prominent or implicit critiques of cultural construction motivate some of the particular ways our project will leverage the framework.

One critique of cultural construction is that it is tautological and presupposes the problematic culture it hopes to interrogate. In recent work [49, 50], Secules has become curious about certain
beliefs about engineering culture, for example, “real engineering needs to be high pressure and competitive.” These beliefs seem to be brought into the classroom rather than purely constructed and reinforced, and they seem to have consequences for the classroom culture that students and instructors co-create. By interrogating the roots of certain cultural beliefs, cultural construction scholars may gain greater clarity into the perpetuating of oppressive culture. Recognizing the importance of cultural beliefs as complementary to individual beliefs from a psychological lens resulted in our selection of beliefs as a unifying construct. This is discussed further in Section 4.1.

An additional critique of cultural construction and cultural reproduction approaches is that a solitary focus on marginalizing culture is unable to make proactive recommendations for change. Secules approached this limitation once the study concluded by making practical recommendations to the collaborator instructor and to readers [8]. Rather than leveraging critiques only against broad culture, specific classroom practices that recreate broad culture for the local setting are identified and shifted. A related body of work prominent in science education, has looked not only at the culture and structures influencing the reproduction of inequity, but also at the environmental and cultural affordances contributing to the production of new forms of culture supporting equity and inclusion [51-53]. These are proactive and solution-oriented approaches, perhaps more in line with the goals of educational psychologists but with an appreciation for contested cultural meanings and interactional complexity.

Because of our agreement that the role of smartness is critical to how individuals experience engineering education and directly related to the challenges of engineering to be diverse and inclusive, we are motivated to engage in interdisciplinary collaboration to conduct research that provides a more holistic understanding of it. Cultural construction, with a focus on a problematic system composed of cultural beliefs is in contrast to growth mindset, which highlights the role of students’ individual beliefs in their persistence and achievement. We aim to blend these two frames, despite their differences, as a way to allow them to complement one another and provide a more holistic approach to understanding how to shift engineering education to be more inclusive through continued careful study of smartness and its role in engineering culture.

3. **Challenges of Interdisciplinarity**

In approaching interdisciplinarity we note that the disciplinary divide cuts quite a bit deeper than camps. Challenges of interdisciplinarity include epistemological outlook and goals.

3.1. **Epistemological Assumptions and Pragmatism**

Mindset can be viewed as essentially a post-positivist paradigm in the sense that the theory assumes that there is an objective reality, and that individuals hold beliefs that are ‘true’ and relatively stable. Therefore, mindset researchers posit that they can measure individuals’ beliefs through survey items, and that we can build evidence for understanding or changing beliefs
through looking for quantitative differences in individual beliefs. Although mindset scholars acknowledge that beliefs can be contextual, those beliefs are nevertheless often sampled at a limited number of points in time and then (typically) generalized as stable.

Cultural construction, on the other hand, is a critical cultural paradigm. It assumes that we can only see reality through our cultural lenses, including educational stakeholders and researchers. Although there is no reason to expect students are not being ‘true’ in their survey responses, any survey would be thought of as a communication in a certain context from a certain speaker to a certain audience. The response may be indicating a stable thought or belief, but it may also be indicating an answer that has been socialized to be thought of as correct by prior experiences or within a specific cultural context such as a research study or an engineering classroom. Since these aspects cannot be separated, anthropologists focus on understanding students’ experiences, social interactions, and how to interpret them.

Thus, interdisciplinarity is fundamentally difficult because the epistemologies underlying psychology and anthropology represent core ontological and epistemological commitments that cannot be easily blended or synthesized. Nevertheless, the theories (and the researchers themselves) do not have to remain locked in a duel about the nature of reality in order to come to useful insights. We need not limit ourselves to our unique disciplines and have our ‘silod heads explode’ at the thought of meaningful interdisciplinary work [54]. More than a theoretical discussion, we, the co-authors, want to help teachers be able to theorize about what is happening within their own classrooms and related to their own pedagogy (both implicit and explicit). We are hoping to generate more holistic and pragmatic theory for understanding the role of smartness in engineering teaching, learning and research. We might ask of both theories—what works to improve student experiences? How do individual beliefs and the cultural construction of smartness create more inclusive and holistic learning environments? We suggest that such an interdisciplinary pragmatism allows a way of combining approaches from both traditions without resolving all underlying disagreements.

3.2. Goals and Orientations
As an additional corollary to these pragmatic solutions to the theoretical disciplinary divide, we should consider the ontologies associated with the goals of the research and the meanings associated with the intended outcomes of each. Here, mindset researchers focus on producing environments and interventions that support growth mindset in students. Critical cultural education research, on the other hand, analyzes power dynamics and inequities in order to create more equitable and inclusive educational environments. These goals aren’t mutually exclusive, but they also aren’t precisely the same. An additional set of questions for interdisciplinary research might be: In what ways do beliefs about intelligence actually address inequities? How do inclusive educational environments contribute to growth mindset?
3.3. Ontologies of Knowledge and Learning as Clarifying Divergence

Educational psychologists Murphy, Alexander, and Muis [55] suggest an additional divide and associated interdisciplinary coordination may come around the following questions that all educational research implicitly or explicitly addresses: Where is knowledge located? In the mind or in the environment (in participation in a culture, etc.). How does learning happen? Individually or socially? In their framework, which can be used to locate disciplinary practice based on their assumptions, cognitivists and constructivists assume that knowledge is fundamentally constructed in the mind, and that learning is an individual process. Behaviorists also assume that learning is an individual process, but that the best evidence of knowledge is in the individual’s behaviors (i.e., in the environment or social world). A sociocultural researcher assumes that learning is a social rather than an individual process, and also assumes that the best evidence of knowledge is in one’s full participation in a society or culture (e.g., learning via apprenticeship in a community of practice [56]). Finally, social constructivists assume that learning is a social and cultural process but that evidence of knowledge is in the individual, for example, that individuals learn by interacting with stimuli within their cognitively appropriate zone of proximal development [57]. We have utilized this framework as a tool to help acknowledge differences in orientation while seeking common goals. At the same time, we recognize that this tool is an oversimplification when represented as dichotomous. The framework is useful for thinking about differences in emphases rather than as a statement about reality.

4. Building Towards Interdisciplinarity

Our desire for and challenges with interdisciplinarity are not new, we note that other scholars have provided models for studying complex interactions between an individual and their surroundings, such as Bronfenbrenner’s ecological model for human development [58]. The resolution of different philosophical assumptions was significant during the development of mixed methods research during the 1970s-1990s, but this debate has been partially answered by a focus on pragmatism and explicit attention to the different paradigms for both quantitative and qualitative methods within a given study [59]. Based on our motivation of studying the construct of smartness specifically, we focus on beliefs as a unifying construct for our respective lenses and then discuss social norms as a potential example of how to bridge the disciplinary divide.

4.1. Beliefs

We scope our aim of investigating smartness in engineering education culture to establishing concrete ways in which to understand beliefs about smartness specifically. In our extended conversations about studying smartness, the construct of beliefs was a reoccurring theme. We found it useful to consider our assumptions about beliefs, much in the same way that Murphy and colleagues [55] discussed disciplinary assumptions about knowledge and learning. Beliefs can refer to any assumption about how the world works; they can be implicit or explicit, and they are rules that inform behavior. At some level beliefs are held personally, but people typically
hold beliefs that stem from their understanding of shared experience. Their experience of the cultural and social world has been co-constructed with many others outside of themselves. Thus, beliefs are often individually held, socially constructed, and have an impact in the social world beyond the individual as displayed in Figure 2.

![Image of Figure 2: Theoretically Interdisciplinary Location of Beliefs]

4.2. Social Norms
The concept of social norms provides a useful illustration of how the operationalization of and assumptions about beliefs can span across disciplines including both what exists in an individual’s mind and what is constructed culturally. While individuals certainly hold personal beliefs that inform their behavior, they are also influenced by their beliefs about what is normative in a given setting [60]. Social norms have been operationalized as two distinct types of beliefs that reside in an individual: 1) descriptive beliefs—beliefs about what others are doing, and 2) injunctive beliefs—beliefs about what others want you to do [60]. This operationalization of beliefs is aligned with a psychological lens—accessed through direct questioning, often in the form of survey items or semi-structured interviews. However, we see this as a potentially productive extension of beliefs strictly operationalized as growth or fixed mindset because it captures not just what a person believes personally, but also what they think is expected in a given context or culture. For example, a student may personally believe that effort leads to increased intelligence, but they may demonstrate contradictory behaviors because they believe their professors only care about how well they do on exams. Indeed, this dynamic and complex reality is possible based on our previous findings that even though students see the value in a growth mindset, they feel the culture of school and society more broadly sends fixed mindset messages [37].
Additionally, social norms have a place in anthropological research approaches. When anthropologists define social norms, they focus on the behaviors of dominant social groups. Specifically, they seek to reveal the behaviors that are so commonly enacted in a disciplinary setting that individuals in that setting don’t have to think about them. Of course, there are many educational social norms, many of which are less relevant to issues of inequity (e.g., the norm for students to sit in seats facing a standing instructor), so anthropologists often look towards the social and cultural norms that seem to have a consequence for experience and inequity. For example, in Secules’ prior work, the student norm that on a team pair the student who knows how to do the work already was the one doing most of the work had serious consequences for students learning and equitable participation. Social norms, operationalized in this way, are more concerned with the enacted habits and implicit assumptions embedded in a culture. As such, they are accessed primarily through observations rather than direct questioning to participants, which is more typically used to follow-up or confirm social norms documented through observation.

These overlapping definitions of social norms may provide a useful starting point for the classroom, where the anthropological lens identifies and problematizes the cultural realities of a given setting, and the psychological lens validates the extent of students’ shared views of those cultural realities.

4.3. A Working Interdisciplinary Methodological Framework to Investigate Smartness

In exploring psychological-anthropological interdisciplinarity, we have leveraged pragmatism to think flexibly about the role of smartness in engineering education culture and the data with which we interrogate them. We propose that the following approach might be useful as a starting point for an interdisciplinary research agenda on smartness. First, we must think creatively about familiar methods for data collection and analysis and determine how the combined data sources help explain smartness and its salient, yet implicit, role in engineering education in ways that can lead to concrete recommendations for increasing the inclusivity of engineering at the classroom level.

4.3.1. Classroom observations and video can look for the ways that classroom environments reinforce certain beliefs or send messages to students about smartness. Field note protocols might blend orientations towards culture (e.g., How is ability being made salient?) with orientations towards triggers for beliefs (e.g., How are growth or fixed mindset beliefs being promoted or reinforced?). In order not to overwhelm a field note researcher looking with both lenses simultaneously, a list of phrases and words could help identify growth/fixed mindset triggers [29], while a more expansive field noting process could help capture the cultural process of smartness. McDermott and collaborators wrote about these methodological approaches in foundational and more recent papers [42, 61], while Secules et al. [8] adapted these
methodologies for an engineering educational context. A preliminary example of a combined observation protocol is displayed in Figure 3.

**Anthropological and Psychological Combined Observational Protocol**
The purpose of this combined observational protocol is to allow for field noting that captures the role of smartness in an anthropological sense, which provides a real context for further data collection to understand the role of smartness in engineering classrooms. At the same time, the observation protocol can allow the researcher to capture cues from the environment that have been established as promoting either growth or fixed mindset beliefs. In addition, future interviews with students can be contextualized.

**Setting:**
- What is the classroom set up (i.e. how are desk arranged, where is the instructor standing)?
- Think about your five senses (is there a sight, sound, touch, smell, or taste to the classroom, etc.).
- What is ordinary or unusual about the setting (in terms of cultural expectations for engineering classrooms, etc.)

**Participants:**
- Describe the participants (students, instructor, teaching assistants).
- Create a shorthand for participants and instructors and a seating chart for their arrangement.
- Account for traditional and non-traditional demographics and population groups (e.g., apparent race, gender, rank, students who speak up a lot, etc.)
- Regularly shift gaze between key participants. Think about their respective reactions to class events to generate evidence of their perceptions.

**Chronology of events:**
- Describe the chronology of events and activities in (at least) 10 minutes intervals.
- If “nothing” is happening in the class, describe the nothingness.
- With your orienting observation questions in mind, write constantly. Capture the primary events of the classroom.
- Indicate coordination with instructional material when this material can be resourced separately instead of copied down word for word into the notes.
- Break down high level intuitions (e.g., the student is sad) to their low-level evidence (the student has slumped shoulders, furrowed brow, and just put their head on their desk).
- Right after (or within 24 hours after) a classroom observation event set aside time to translate your shorthand into full sentences and elaborate details with more information.

**Keep your eyes and ears out for items of interest:**
- Who is positioned as capable or incapable in this setting?
- How is one’s “ability” becoming public in this setting?
- What are the consequences (of ability) for participants’ self-perceptions? Source [29]
- What are the consequences (of ability) for opportunities for learning?
- **Key interview participants and their experiences (also what may be significant for them in the future)**
- How does the instructor provide encouragement to students?
  - When responding, is the instructor cueing growth or fixed mindset (see figure)?

**Figure 3: Sample Observation Protocol**

4.3.2. **Interviews** can investigate students’ beliefs about self and the nature of intelligence and then continue to explore what course context and culture has impacted or helped form that belief.
We are expecting that the belief is somewhat existing based on prior socialization, but also malleable and informed by on-going experience. Dringenberg’s interview protocol approach is to interrogate beliefs about intelligence through soliciting feelings and ideas about the three parts of a growth mindset framework introduced in Section 2.1: types of learning goals, beliefs about effort, and reactions to challenges. She then consistently prompts for students to elaborate with examples (e.g., critical incidents) and clarifications. Crafting questions that focus on the three parts of the growth mindset framework was shown effective in a study exploring the role of implicit theories of intelligence in adolescents students [24]. Secules’ interview protocol begins by asking something that initiates thinking about ability (e.g., class performance, keeping up), and then to ask why/how they think that. Secules continues asking follow-up questions about interactions and culture that come from that. While we have started from different places we see a shared strategy of “tiptoeing”-- to ask the easy question and then move to the more challenging questions.

In a shared interview protocol, we might ask students to convey their own beliefs and perspectives, but also press for them to provide explanation or rationale for those beliefs based on examples in a given classroom. This would allow us, as researchers, to situate their co-constructions of beliefs within the interview to a concrete and observable classroom reality in order to better understand the interactions between beliefs at the individual level as well as the cultural level. This blends the strengths of both the psychological and anthropological approaches to studying smartness. A preliminary example of a combined interview protocol is displayed in Figure 4.

### Anthropological and Psychological Combined Interview Protocol

The purpose of this combined interview protocol is to have a detailed discussion with the participant about their beliefs about the nature of intelligence. The discussion will inform our understanding of the perceptions of engineering students and will help future decisions about the undergraduate engineering experience and how it can be improved for all students. We want to hear the participants own thoughts and perceptions—there are no ‘right’ or ‘wrong’ answers.

Throughout the interview, remember:

- Respond with “that’s interesting” rather than “that’s good”
- Use “tell me more about that” “can you give me an example of when that happened?”
- Make connections, “why do you think that’s important in terms of…?”

#### Sample Questions:

1. Tell me about how class xxx is going for you.
2. Follow up with respect to the following themes:
   a. Motivation for learning goals (looking smart vs. learning)
   b. Beliefs about effort (necessary to improve or futile)
   c. Response to challenges (helplessness or mastery)

### Goal Orientation/Motivation

3. In this class, what sorts of things do you find motivating?
   a. What do you prefer to work on and why?
4. Say you have to choose a professor for a core course required for your major. There are two options: 1) A professor where it is more difficult to succeed but you are likely to learn a lot, or 2)
A professor where it is easier to succeed, but you likely won’t learn as much. Which one would you choose? Why?

Beliefs about Effort
5. Tell me about how much effort you’re putting into this class?
   a. How did you feel about that?
   b. How does this compare to your other courses?
   c. How does your effort level compare to other students in this course?
   d. Describe a student who puts in a lot of effort in this course? What does that tell you about how smart they are?

Responses to Challenges
6. In this class what’s challenging for you?
   a. How are you responding to this challenge?
   b. How does this make you feel?
   c. Are you learning anything from this experience?

Figure 4: Sample Interview Protocol

4.3.3. **Surveys** can be tools to look at the impact of classroom culture and interactions, where rich data helps explain a change in survey findings. Surveys can also be tools to investigate why certain cultural practices are so intransigent (i.e., students come in with pre-existing beliefs about the nature of engineering and of education). In growth mindset studies, we would give the following four items as Likert-style items, as validated by Dweck [23], average them, and take that as indication of the individual’s tendency towards growth or fixed beliefs about the nature of intelligence:

- Your intelligence is something very basic about you that you can't change very much
- You can learn new things, but you can’t really change how intelligent you are
- No matter how much intelligence you have, you can always change it quite a bit
- You can always substantially change how intelligent you are

To truly uncover meaning, an anthropological survey may tend to be open-ended or to find creative ways to uncover cultural meaning. Since interviews had found that asking the question “is engineering competitive or not?” was difficult for students embedded in engineering culture to make sense of, a prior survey asked a comparison question, with a slider between current class and prior class (also part of the observational study)– which course is more competitive/collaborative? Open-ended survey items might also consider larger questions to look for students’ constructions of engineering learning and smartness:

- What does it mean to you to learn engineering?
- What can someone do to be a good engineer? What are the characteristics of a good engineer?

Both belief surveys and one-on-one interviews can be reexamined as communicating within and about a cultural context. The survey and interview are communications/interactions contextualized within a given cultural setting. The findings may be telling us what the “right” answers are in engineering culture. They may be telling us a students’ established ways of being throughout their socialization. They also may be shifted by a very recent interaction on their
mind. Again, by combining the data collection strategies of both the psychological and anthropological approaches, we believe we can develop a more holistic and contextual understanding of the ways in which beliefs, held at both the individual and cultural level, provide insight into the role of smartness in engineering education culture.

5. Conclusion and Future Work
The work of interrogating smartness in education can seem like a vast and impossible challenge. When isolating one portion of the phenomenon of smartness, such as students’ beliefs about intelligence, we find that several other portions of the phenomenon (cultural narratives, instructor messages, grading systems, student interactions) are overlapping and superseding it. When isolating another portion, such as the cultural interactions of a classroom, we find that student preconceived beliefs are helping create those cultural interactions. Anthropologists identify the messy, intertwined nature of culture as an “always already there” [8]—we cannot look at a phenomenon apart from the context and culture it is set in because that culture is always already present. In education, as in engineering, smartness is an always already there. Even in publishing this paper, we as researchers must leverage certain forms of eloquent (“smart”) arguments in order to have our arguments related to smartness be seen as legitimate in the academic arena [54]. We must recreate smartness in order to deconstruct it.

Despite the challenge of researching smartness, we believe that the interdisciplinary paradigms provide a great deal of promise. At both fundamental theoretical and pragmatic levels, an interdisciplinary approach allows us to interrogate the function of smartness as a way to systematically exclude individuals and magnify existing societal inequality within our own profession, classrooms, and engineers. Our approach is to understand beliefs located at both the individual and social level and created both individually and socially and to find creative ways of merging data collection and analysis approaches. We plan to pursue this interdisciplinary research agenda in future collaborations.
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