Discovering Upper-Division Students' Cognitive Engagement across Engineering Courses—An Interpretive Phenomenological Analysis Approach

Key words: Cognitive engagement, Student engagement, Interpretive Phenomenological Analysis, Undergraduate, Qualitative

Abstract

Background: STEM education research has consistently purported that student cognitive engagement is tied to learning outcomes and can be influenced by pedagogical strategies. Yet, there is little research describing the experience of students as they engage with their courses, and what shapes this engagement.

Purpose/Hypothesis: Our research seeks to understand how upperclassman civil engineering students are engaged across their engineering courses, and the factors most salient in how they have come to engage in such a manner.

Design/Method: Five engineering students participated in a semi-structured interview where they were prompted to discuss their engagement generally throughout college, and specifically in their engineering courses from the previous term. We utilized interpretive phenomenological analysis (IPA) to make meaning of each participant's engagement experience; themes were drawn from analysis of each participant's individual transcript, and further meaning made from themes across participants.

Results: Primary themes from the IPA analysis showed that participants 1) established behavioral engagement values that remained constant across courses 2) used future goals to deepen cognitive engagement within the discipline 3) adjusted cognitive engagement to mirror the engagement stance of instructors and 4) blended influences to determine effective and efficient engagement strategies.

Conclusions: Findings indicate that students are future-minded in their decisions surrounding engagement, yet are still malleable to engage in more or less meaningful ways based on their

instructors. This work builds evidence for the importance of instructors utilizing evidence-based instructional practices, as well as assisting students in exploring and developing career goals.

Introduction

Recent calls to active learning in STEM education have encouraged instructors to make modifications to their courses to generate higher levels of engagement among their students (Prince, 2004). Fundamental to generating student engagement is understanding the construct itself. Engagement is often considered a meta-construct (Appleton, Christenson, Kim, & Reschly, 2006), and is frequently conceptualized as being constructed of multiple components. One popular conceptualization by Fredricks et al. (2004) states that scholastic engagement is comprised of behavioral, emotional, and cognitive engagement components. They indicate that of these, cognitive engagement is the least observable to instructors and therefore must be indicated by behavioral proxy or survey instrument.

Research has continued to develop both proxies (Chi & Wylie, 2014) and instruments (Appleton et al., 2006; Greene, 2015; Zhao & Kuh, 2004) as a means of assessing student cognitive engagement. Instruments to better understand how students respond to instructional practices (DeMonbrun et al., 2017) and interact with course material (Authors, In Review) have also been developed. Such research emphasizes the importance of cognitive engagement to student learning, and the crucial role instructors play in influencing it. As instructors move towards more cognitively engaging classrooms, they may realize their classroom is indeed made up of individual students with complex histories, interests, and abilities that influence how he or she cognitively engages in that particular course. The inherently difficult-to-observe nature of cognitive engagement may leave instructors further confused on how their students are responding to their teaching practices. Current literature offers little insight as to what might be going beyond what is observed in students: the driving forces that shape students' cognitive engagement within engineering courses is currently under-researched. While it would be near impossible to unpack the stories of all

engineering students, we suggest understanding what shapes the cognitive engagement of a few upper-division engineering students provides a starting point.

In this study, we recruited five upper-division civil engineering students to participate in semi-structured interviews regarding their cognitive engagement in engineering courses. Interpretive Phenomenological Analysis (IPA), an in-depth approach to analyzing qualitative data, allowed for the organization of themes surrounding participants' cognitive engagement experiences. Results show that participants' perceptions, values, and contextual course features all shaped their cognitive engagement within engineering courses. We anticipate this study will be useful in building foundational understanding of what shapes student cognitive engagement in engineering courses. This is not because our sample is representative of population, but because it allows for the nuanced, personal nature of cognitive engagement to be presented.

Background

The background is intended to frame the study's work around cognitive engagement of students across their engineering courses. To do so, we briefly discuss engagement broadly, with an emphasis on cognitive engagement and how it is conceptualized and measured. This is followed by a presentation of our conceptual framework where we argue that the reality students experience in their courses is a valid field of study, and our purpose statement where we present the relevance of our research question.

Student Engagement

Student engagement has long been viewed as a multi-dimensional construct, of interest in part due to its relationship with enhanced student learning (Reschly & Christenson, 2012). Beyond this, student engagement can be seen as the glue that links the important contexts of home, schooling, and community together in working towards positive learning outcomes (Reschly & Christenson, 2012). One prevalent conceptualization of student engagement breaks it down into

dimensions of behavior, emotion, and cognition (Fredricks et al., 2004). These dimensions help explain how engagement is tied to particular learning outcomes: behavioral engagement has been associated with academic achievement, emotional engagement has been shown to keep at-risk students in school, and cognitive engaging has been correlated with synthesis and deep-level understanding (Fredricks et al., 2004).

Ties to positive learning outcomes have catalyzed the development of measurement schemas along all three engagement dimensions. Some dimensions of engagement are more readily observable, such as behavioral engagement displays of effort, persistence, and attention (Sinatra, Heddy, & Lombardi, 2015); or emotional engagement displays of interest, happiness, and anxiety (Fredricks et al., 2004). Self-report metrics such as the Motivated Strategies for Learning (Pintrich, Smith, Garcia, & McKeachie, 1991) and National Survey of Student Engagement (Kuh, 2001) assess engagement and related factors in broader terms. Yet, cognitive engagement has remained difficult to both define and measure (Sinatra et al., 2015). One persistent difficulty in doing so is the lack of clear boundaries between where cognitive engagement ends and behavioral or emotional engagement begins. In fact, one well-cited framework of student cognitive engagement relied on overt *behaviors* to infer underlying cognitive states (Chi & Wylie, 2014). The intent of this framework, known as the ICAP framework, was to assist educators in evaluating the success of implementing active learning strategies in their own classrooms (Chi & Wylie, 2014), yet it has proven difficult for educators to develop and implement curriculum targeted at particular modes of cognitive engagement (Chi et al., 2018).

Conceptualizations of engagement (i.e. ICAP) provide insight into how a body of students may be engaging with course material at a given point in time. Survey instruments to measure cognitive engagement (Authors, In Review) are more aggregate in nature, providing insight to

students' experience with course material over a greater period of time (entire lecture period, week, term, etc.). It is only deep inquiry with individuals provides insight as to what shapes cognitive engagement at a personal level. No work was found in the literature that provided deep exploration of the personal factors that influence cognitive engagement in STEM students. Such work would provide foundational understanding as to the ways in which students are malleable and responsive to their contextual course features.

Conceptual Framework

Critical to exploring how cognitive engagement is shaped within a student is the conceptual framework with which the researcher approaches the task. Where worldviews such as post-positivism have their place in measuring theory, and pragmatism in practice-based problem solving, constructivism lends itself useful to theory generation and understanding multiple participants' meaning (Creswell, 2014). Constructivism suggests knowledge is self-constructed, and influences assumptions on how such knowledge ought to be disseminated in the classroom (Hutchinson & Huberman, 1994). More specifically, social constructivists believe that individuals develop subjective meanings from the worlds in which they live, work, and interact with others (Creswell, 2014). Social constructivist researchers ought to formulate a pattern of meaning from inquiry targeted at understanding the conditions in which individuals make meaning (Creswell, 2014). Thus, research on how individual students make meaning and decisions surrounding their engagement from their experiences in a classroom is inherently social-constructivist in nature. Researchers need not seek out an objective reality of a classroom, or how a student should respond to a particular set of teaching practices; rather, such research should seek to uncover the student's experience in a broad sense, and how particular course factors influence their engagement. Furthermore, such research ought to acknowledge the role of the researcher in making meaning of the students' lived experience.

Rational

Educators are continually called towards creating active learning environments. We have seen that active learning does indeed *work* (Prince, 2004), but we have yet to address who active learning works *for*, and in what ways. For example, problem-based learning and collaborative learning both result in learning gains (Dard, Lison, Dalle, & Boutin, 2010; K. A. Smith, Sheppard, Johnson, & Johnson, 2005), yet, others have gone on to say the impacts of problem-based learning and collaboration differ along gender, ethnicity, and individuality within students (Stump, Hilpert, Husman, Chung, & Kim, 2011). Other research has shown it is much more complex an issue than to simply state that it is better to learn together (Nokes-Malach, Richey, & Gadgil, 2015). Teachers are left to sift through pushes towards implementing active learning practices and questions on how students benefit. Linked to positive learning outcomes (Chi, 2009), cognitive engagement is one key to understanding how active learning is working for students. It therefore becomes important that, as researchers, we seek to develop theories that explain how cognitive engagement is shaped within individuals in different contexts.

We note the inherent difficulty in separating cognitive engagement from the meta-construct of engagement. In discussing dimensions of engagement, Fredricks et al. (2004) states:

> Defining and examining the components of engagement individually separates students' behavior, emotion, and cognition. In reality these factors are dynamically interrelated within the individual; they are not isolated processes. Robust bodies of work address each of the components separately, but considering engagement as a multidimensional construct argues for examining antecedents and consequences of behavior, emotion, and cognition simultaneously and dynamically, to test for additive or interactive effects.

We therefore see a need not to isolate cognitive engagement when studying student engagement; cognitive engagement ought to be studied in light of the *antecedents and consequences* of behavior and emotion. We seek to study cognitive engagement by first developing a holistic understanding of students' engagement experiences, then focusing in on cognitive engagement specifically.

Theory generation and practical knowledge gains can emerge from qualitative research, so long as there is transparency and rigor in the methodology. Our methodology is based in Interpretive Phenomenological Analysis (IPA), an approach for understanding experience of students in engineering courses (J. L. Huff et al., 2015; Kirn, Godwin, Cass, Ross, & Huff, 2017). IPA is useful when seeking to understand a lived experience, such as how a student experiences engagement in engineering courses. Here, we rely heavily on the philosophical commitments of IPA as outlined by Smith et al. (2009), and look to others who have applied the methodology in engineering education contexts for further guidance (J. Huff & Clements, 2018; Kirn & Benson, 2018). IPA allows us to make meaning of the particular, that is the experience of the individual's engagement, while connecting meaning to themes common to a set of participants. Such results are uniquely situated to bring insight to the individual's experience, while poising us to interpret what changes might bring benefit to the broader setting in which the individuals are situated. It is the hermeneutic circle of interpretation that allows for meaning to be shared from participant, researcher, and reader: when prompted with an interview question, a participant makes meaning of it as they respond. The researcher makes meaning of their response through a careful series of analysis. Finally, you, the reader, make meaning of our interpretations presented in written word. This analysis allows us to present themes to answer the research question: *What shapes cognitive engagement in engineering courses of upper-division civil engineering students*?

Methods

In collecting and analyzing data, we followed an IPA approach: a small sample of students was recruited to share their experiences related to cognitive engagement in their engineering courses. The following methods further detail how participants and data were recruited,

interviewed, and analyzed in alignment with IPA methodology. We seek to be transparent in our methods to allow the reader to make informed meaning of the results.

Recruitment and Sampling

Participants were initially recruited via a related study, in which a large number of courses were asked to deploy an instrument to measure cognitive engagement within a course (Authors, In Review). Students were asked if they would be interested in participating in a follow-up study to discuss their cognitive engagement as it related to their engineering courses. Students were also told there would be a monetary incentive for their participation. Of the 170 student participants in the previous study, 33 indicated interest in participating in the follow-up. Only upper-division students who were enrolled in the Civil and Construction Engineering program at a single Pacific Northwestern university were contacted. We therefore had a *purposefully selected* sample (Creswell, 2014), intended to allow the research team to focus on the phenomena (i.e. cognitive engagement) by minimizing confounding factors (e.g. major, academic level, institutional culture). From this initial round of recruitment, five students scheduled an interview with our team. The sample size is within the range suggested by Smith et al. (2007), and of similar magnitude to that which was seen in other similar studies (e.g. J. Huff & Clements, 2018; Kirn & Benson, 2018). In **Table 1**, we show brief demographic information on each participant and the pseudonym they are referred to henceforth.

Table 1: Demographic of participants

Pseudonym	***Grade Level***	***Major***	***Sex***
Bruce	Senior	Civil Engineering	Male
Alisa	Senior	Civil Engineering	Female
Zach	Junior	Civil Engineering	Male
Cole	Senior	Civil Engineering	Male
Kara	Senior	Construction Engineering	Female

Data Collection

Participants were asked to interview approximately two weeks after the completion of the winter academic term. This was intended to allow participants to reflect on their engagement from the previous term while minimizing external stressors (e.g. end-of-term projects, start of new classes). Participants were invited to a research meeting space in a familiar building, where a semi-structured dialogue lasted approximately one hour. The interview schedule was followed loosely, with the participant guiding the interview towards important facets of their engagement that may or may not have been specified in the schedule. The focus of the study remained cognitive engagement: the interviewer lead students to broadly discuss all facets of their engagement, and probed more deeply as cognition was discussed. It was during data analysis that cognitive engagement was explicated from other forms of engagement.

The interview schedule began with the researcher offering a short explanation of the research, explaining to participants that answers to all questions were voluntary, the nature of their qualitative responses would not be directly communicated to their instructors, and all data would remain anonymous. Additionally, the researcher offered participants a brief definition of the meaning of cognitive engagement in the context of the study: "*cognitive engagement can be thought of as how hard you are thinking, your mental effort, or your focus on course material"*. Interview questions began with asking participants to describe how they entered into engineering, how they would typify their engagement in college, its evolution over time, and major factors in how they engaged (interview ***Part 1***, as seen in **Table 2**). The intent was to allow participants to openly discuss salient factors in their engagement and identity within engineering, which would guide the remainder of the interview. Using this knowledge, the researcher then asked participants to discuss engagement as it related specifically to a course, specifically their engineering courses from the previous term (***Part 2***, as seen in **Table 2**). Participants were asked to reflect on the

courses they engaged most deeply with and those they did not, and why they chose to engage in such a manner. Finally, participants were asked to give advice to both instructors and engineering students on strategies that would lead to successful engagement, specifying what steps instructors might take to lead to more meaningful student engagement (***Part 3***, as seen in **Table 2)**. In responding, participants illuminated further a piece of their engagement stance—the ways in which responsibility for engagement is divided and shared among instructors and students.

Table 2: General interview schedule used during data collection. The schedule was followed loosely, with each part covered using questions similar to those listed below.

Part 1	How did you get into engineering? What was your purpose and/or goals?
	When you think about your engineering courses, how would you characterize your cognitive engagement? Why do you engage in this way?
	In what ways has your cognitive engagement evolved over time? What were some of the biggest factors in its evolution?
Part 2	How would you describe your overall cognitive engagement with this course? What were some key factors that engaged you in this manner?
	How useful do you perceive this course being to your career? How does that influence your engagement?
	In what ways did you perceive the instructor trying to engage you? How effective were they?
	What were the biggest factors limiting your engagement with this course?
Part 3	What are steps that instructors take that are the most cognitively engaging? The least engaging?
	What advice would you give another student about their engagement? What advice would you give a faculty member seeking to engage their students?

Data Analysis

Following data collection, each interview was externally transcribed and internally reviewed. Review of the transcript included re-listening to audio recordings while reading transcripts to gain familiarity with the participant's voice and its conveyance through written word. Cases were analyzed sequentially, with the researcher immersing herself in the data of a single participant and undergoing analysis before moving on to the next case. Per the IPA methodology(J.

A. Smith & Osborn, 2007), each transcript was first annotated with descriptive, linguistic, and conceptual comments. These annotations formed the basis for participant-based emergent themes.

Emergent themes were centered around participant cognitive engagement, with the meta-construct of engagement used as contextualization. As participants discussed their engagement in broad terms, we honed in on the themes that related to the shaping of their cognitive engagement. To do so, we relied on the definition of cognitive engagement suggested by Fredricks et al. (2004): *[cognitive engagement] incorporates thoughtfulness and willingness to exert the effort necessary to comprehend complex ideas and master difficult skills*. Themes were generated from the data to tell the story of how a given participant came to cognitively engage in a given manner within engineering courses.

As emergent themes developed in each case independently, the researcher began to connect these themes together first within the case, and finally across the sample. Crucial to this process was the *dynamic bracketing* suggested by Smith et al. (2009). Dynamic bracketing, the process of continually setting aside interpretations to remain grounded in the data, allowed each segment of data (i.e. each participant) to speak for themselves. While remaining grounded in the data, the researcher played an interpretive role in generating themes to tell a story across participants. This process developed a schema for answering the primary research question of *what shapes cognitive engagement in engineering courses of upper-division civil engineering students*? Four super-ordinate themes were developed and are discussed in the Results below.

Credibility and Trustworthiness

We acknowledge it is not simply adherence to a methodology that ensures credibility and trustworthiness, rather it is the clarity with which the reader can view the analytic process that allows them to accurately assess quality themselves. Therefore, we seek to clarify the ways in

which credibility and trustworthiness were pursued, and acknowledge the positionality of the researchers in this process.

The ways in which phenomena are accurately represented, and how consistent the representation is with participants' experiences is defined as credibility (Whittemore, Chase, & Mandle, 2001). Per IPA methodology, we sought to immerse ourselves in a single participant's interview and dataset, bracketing off preconceptions and shallow interpretations. Yet, we acknowledge that each researcher brings their positionality to all interactions. Both authors are engineering education researchers trained in civil engineering, with the lead author a student to the second author. The lead author guided interpretations and analysis, while the second author offered ongoing feedback and review of the results. Authors were both trained in civil engineering, adding to the initial rapport with participants and adding to the credibility of the interpretations of their experiences (Berg & Lune, 2014; Guba & Lincoln, 1989). In previous work, authors had spent considerable time focusing on the experience of cognitive engagement in engineering students, and questioned what might play a significant role in shaping how a student engaged. Both authors had conducted extensive qualitative research prior, and were familiar with interviewing and extracting themes from qualitative interview data. Credibility was ensured through the researchers utilizing IPA as a tool to generate, refine, reconsider, and present themes to represent student experiences with engagement.

Trustworthiness is defined as the degree to which findings are represented honestly and evidence for such findings is sufficiently documented (Creswell, 2009). We report our findings, guiding the reader towards interpretations we see as meaningful through multiple participant quotes. We aim not to present the *true* meaning of the participants' words, rather we suggest that

we provide a trustworthy interpretation that may be helpful as we consider the ways in which students engage in engineering courses.

Results

Our results show that an interconnected, and sometimes contrasting, set of behaviors, values, and cognitions can be used to answer the research question: *What shapes cognitive engagement in engineering courses of upper-division civil engineering students*? Here, ideals and enactments of participants are consolidated into four super-ordinate themes, with occurrences within participants used as supporting evidence of how the theme applies on an individual level (i.e. to the particular). We present a summary of themes in **Table 3** to guide the reader through the results; ***Descriptions*** indicate the ways in which themes build upon one another, and ***Example Quotes*** offer a poignant example of the theme within a participant.

Table 3: Summary of themes addressing what shaped the cognitive engagement within participants.

Theme	*Description*	*Example Quotes*
Established behavioral engagement values that remained constant across courses	Participants used self-awareness and early college experiences to create a set of personalized behavioral engagement values that they applied in their courses, largely irrespective of external influences.	*I've never not turned in an assignment* *I pay for it, I'm gonna sit there whether I pay attention or not, so yeah. I don't skip unless I'm seriously sick or have a doctor's appointment, or something*
Future goals used to deepen cognitive engagement within the discipline	Behavioral engagement values were associated with a vision for participants' futures, from which they developed meaningful cognitive engagement strategies for deep learning.	*And then in the future, I know we're not gonna do some of the exact same stuff, like we're not gonna be doing steel design technicalities to the T, but I know that the concepts and theories are still really important for the future.*
Cognitive engagement adjustments to mirror the engagement stance of instructors	Both cognitive and behavioral engagement strategies were brought to the classroom by participants, where instructors played a primary influencing role in how students adjusted their cognitive engagement on a course-by-course basis.	*As a student, like, I'm in this one class right now and the professor is totally engaged and writes all the stuff, it's just very genuine that it's his work, and it's so easy to learn from. Last term I had some professors that were using other materials and they didn't know how to do the homework assignments, they kind of just reading off the slides and it's just really difficult to learn that way for me*
Blended influences to determine effective and efficient engagement strategies	Participants looked to develop effective and efficient engagement strategies that reasonably aligned with their behavioral values, future goals, and the stance projected their instructors.	*That's when I'm just going to have to fall back onto this is just part of the step, part of the process, these are the fundamentals from which I'm trying to lay a foundation for the future. But it's a good reminder that even when you're in those types of [technical] classes and you're kind of burrowing deep, it's that you're not in a vacuum, this all exists in the real world and these have consequences*

Theme 1: Established behavioral engagement values that remained constant across courses

The backdrop of participants' engagement patterns was their entry into the engineering discipline. Participants were not students who had grown up wanting to be civil engineers; rather, they represented a group of high-performing, successful high school students who found themselves in civil engineering due to a mix of family and social pressures. Upon entering college, these students leveraged their capital to switch majors to find the "right" fit (Alisa and Kara), join the honors college (Zach), find a dual-enrollment master's program (Bruce), participate in a sorority (Kara), and/or take a co-op internship (Cole). Though varying, these somewhat disparate

experiences instilled similar self-awareness among participants that shaped their behavioral engagement values.

Participants discussed their behavioral engagement values such as attending class, completing homework assignments, and passing tests/courses in terms of absolutes. Bruce repeatedly mentioned that he had "*never not turned in an assignment*," even if sometimes those assignments were completed with "*not maybe having the best academic integrity*." Bruce alluded to a common theme among participants: behavioral engagement values are constant, but cognitive engagement values are dependent on contextual course features. For Bruce, the behavioral value was turning in assignments, closely associated with his identity as a successful student. Yet, the mental effort or exertion he put into his assignment (whether or not he cheated) was dependent on contextual course features (e.g. a homework assignment seen as unnecessarily burdensome). Alisa similarly was absolute in her description of her behavioral engagement pattern of attending class: "*I pay for it, I'm gonna sit there whether I pay attention or not, so yeah. I don't skip unless I'm seriously sick or have a doctor's appointment, or something."* The language Alisa associated with cognitive engagement depicted little certainty: "*whether I pay attention or not, so yeah."* Throughout her interview, Alisa discussed the contextual course features that might result in her paying much attention and those that resulted in her just simply "*sit[ting] there,*" but remained unwavering in her behavioral engagement values.

Underscoring participants' behavioral engagement values was a drive for successful completion of a course. For Bruce, Cole, and Zach, there was an awareness of their past successes and a belief that their established behavioral values would continue to lead them to successful outcomes. Zach framed it as "*my brain is kind of suited to the system that we've created to educate students and it usually works out for me in the end*." Zach was not only aware of the education

system in which he was a part, he used this awareness to predictively indicate his future successes based on continued enactment of his behavioral engagement values. Kara and Alisa emphasized more heavily the role their past engagement failures played on their current behavioral values. Both participants discussed a dramatic shift in their engagement after failing courses early in college. Alisa believed she "*wasn't doing college right*" when she was failing classes. She later developed values that helped her succeed: "*'Okay this makes more sense, what I'm doing is helping me.' That was when I started to go to office hours, and actually engaging with the material. More than just writing down the answer*." Alisa moved from an abstract version of how to do college "*right*," to a set of personalized behavioral engagement values that she carried with her through her courses (notably going to office hours when she needed help).

The drive for successful completion of a course committed students to their behavioral engagement values despite circumstances they viewed as unfavorable. For Kara, contextual course features were enough to cause her to mentally disengage from a course, but remained committed to passing:

> I didn't actually withdraw from the class, but mentally I was putting it on the back burner because I wasn't doing great, but it wasn't engaging. It wasn't super exciting subject to me. So I didn't really… I just did what I had to do to get past the class.

Kara's commitment was not simply to pass the class but to "*get past the class*." In order to do so, a particular level of cognitive engagement was required of her. It was in this way that behavioral engagement values shaped the cognitive engagement values of participants: cognitive effort was put forth in order to remain in alignment with behavioral engagement values. Cognitive engagement *beyond* the level that ensured alignment with self-imposed behavioral engagement values remained contextually dependent on course features.

Theme 2: Future goals used to deepen cognitive engagement within the discipline

As seen above, participants attached their behavioral engagement to a short-term goal (e.g. quickly completing a homework assignment, passing a course); it was participants' long-term future goals that deepened their cognitive engagement within their chosen engineering discipline. For Cole, his future goals included becoming successful in his career to the point of owning his own company: "*I know, I want to probably own my own company, or take over someone else's company, I don't know*." Cole's desire to be in management was echoed in all participants, yet, like Cole, these participants often used uncommitted language when discussing their future goals. It was therefore not the assurance of a particular future that resulted in participants deepening their cognitive engagement, rather it was their perception of the skills needed to fill the projected future role. When Cole enrolled in an engineering planning course that related to finance and business, his cognitive engagement notably deepened. He put forth cognitive effort to develop personalized strategies (in this case, watching videos) for deeper learning and mastery of the material:

> I liked that one a lot. I feel like it also has to do with my interest, though, because I really like finance, and figuring out how all of that works, and how money works, so that was really interesting to me. And outside of the class, I watched more videos on how interest rates and all of that worked, so-

Cole uses language such as "*figuring out how all of that works*," indicative of the meaningful cognitive engagement associated with material he found interesting and relevant to his future. Furthermore, Cole put effort into learning from videos as a result of his independent interest and investment, beyond the behavioral engagement established in response to his values. Participants' cognitive engagement similarly deepened across courses and subjects they deemed relevant to achieving their future goals.

Interconnectivity between cognitive engagement and future goals was further exhibited in the way participants often failed to generate meaningful cognitive engagement with courses they

perceived held little relevant to their future. Kara became notably disengaged when her perceived future job did not require skills being taught in her course:

> You're never going to have to design temporary shoring, whatever for a building. And it's, okay so that in the back of my head I'm in the class and I'm never going to have to actually calculate and punch these numbers. Yes, it's good to actually know if I walk into a construction site I'd be, 'Oh I know what that is'. That's more so where it's nice and I'm okay, I'm able to go in and talk the talk and be familiar with things. But then when it's the math, so I just have to like, I'm not going to be crunching numbers all day long, putting into equations like that. So that's kind of a trade-off for the conceptual stuff. I'm, okay good, I need to know this. Versus the actual math, it's ehh, someone else, it's not my job.

Kara's inner battle was between a firm belief that certain things she learned in class were "*not [her] job*" and a hesitancy to dismiss a subject or course as holistically inapplicable *("Yes, it's good to actually know if I walk into a construction site*"). Thus, Kara aligned herself with her behavioral engagement values of attending a course to ensure exposure to material, but minimized her cognitive engagement based on a perceived lack of usefulness in achieving her future goals.

The future goals of participants were not attached to an unchanging reality, and were therefore negotiated as participants interacted with internships and course material. Participants indeed were more influenced by their beliefs about their future goals than the real-world experiences that related to them:

> It's more helpful to know how what you're learning in class applies to the real world, or like what you'll actually be using in the real world, but I feel like they don't really pertain to each other, really at all. I mean, they kind of do, but not a lot. I was very surprised on how little I actually used, but I feel like it'll be a lot different when I work for the private company, because they're a lot more design side of things, and I feel like that's kind of like what we learned in class more. (Cole)

Cole actively sought to connect his learning to his future, as he started off saying "*It's more helpful to know what you're learning in class applies to the real world*," yet remembered experience taught him otherwise—the classroom was different than his experience of the workplace. In the midst of

this dissonance, Cole concludes that there is likely more connection between his learning and future career coming just over the horizon in his job with a private company. Cole thus generated more meaningful cognitive engagement with the intent of applying acquired knowledge a future job.

Cognitive engagement within components of course material was similarly responsive to participants' beliefs about its usefulness to their future; the general strategy of participants was to engage meaningfully when examples were done in class, and pay little to no attention to the supporting theory or proofs (only as much as was perceived as useful to the future). This was, in part, due to participants believing their future job needs would mimic the needs of the present. Alisa exemplified both when she said:

> So yeah, obviously homework's the first thing on my mind, so I'm like, "All right, if I pay attention now I'll be able to do the homework easier, and not wanna cry every time I look at a homework assignment. And then yeah, once again... So like taking the FE, I knew a lot of questions would be similar to the FE, and I know that the PE will probably be somewhat similar to what we're seeing. And then in the future, I know we're not gonna do some of the exact same stuff, like we're not gonna be doing steel design technicalities to the T, but I know that the concepts and theories are still really important for the future.

Alisa presents the duplicity present in participants' view of their future; homework, the FE (Fundamentals of Engineering exam), the PE (Professional Engineering exam), and a job were all important futures to which course material must apply to be engaged with deeply. The ongoing negotiation between an uncertain future and a commitment to focusing on learning what was applicable to that unknown future, resulted in participants cognitively engaging to build connections between their coursework and future. It was apparent that these connections were self-generated or influenced by personal internship experience; instructors were not cited as a source of connecting participants to future goals.

Theme 3: Cognitive engagement adjustments to mirror the engagement stance of instructors

While values guided participants' behavioral engagement (Theme 1) and future goals shaped their cognitive engagement within the discipline (Theme 2), instructors/instruction played a significant role in shaping participants' cognitive engagement with a particular course. Kara was motivated to cognitively engage with courses that were interesting and applied to her, but the depth and persistence of her cognitive engagement was shaped largely by her instructors. Beyond this, she exhibited willingness to meaningfully cognitively engage with a course solely because of the instructor's engagement:

> He did all these good just life stories that he talks about but also was another teacher like you could tell he wanted you to do well in the class. And so I was, okay, I do want to understand this and I do, it is, it's again, it's nothing super, I'd really use it. It's, oh it was a lot of math stuff. It's not really what I'm going to use in my lifetime. But because of him I was, okay, I feel I needed to. So I, I went to his office hours, probably every time we had a homework assignment due four or five, six homework assignments and stuff. I went all the time and would just sit in there and I'd work on it before if I got stuck and then I'd go to him and be, okay, what am I doing wrong? I keep, and then we just work through it step by step and I was, he's also probably one of my favorite teachers I've had in college. (Kara)

Kara substantially adjusted her engagement based on the engagement of her instructor. Her mirroring of her instructor's engagement went beyond behavioral—she talked about "*wanting to understand*" and seeking to learn what she had done wrong while attending office hours, signs of meaningful cognitive engagement. For Kara, it was the importance of her instructors caring and wanting her to do well in the course that deepened her cognitive engagement with the course despite a lack of interest or relevance at the onset.

For all participants, there was a clear correlation between how much they cared and how much the instructor cared—participants mirrored the value of the course as determined by the instructor. This mirroring would go as far as to conflict with the future goals students professed; high quality of instruction, as seen with Kara, could result in creating a new interest with a subject,

whereas poor instruction of a course led participants to disengage regardless of relevance to their future goals. Zach emphasized both, saying:

> I think that perception of whether a professor cares, whether or not they necessarily do about any individual or not, makes a difference. So like, I really like structures and last term, my structures one, because I would say he has challenges showing that he cares, but it comes through that he does care about the students and making sure people succeed. And same for fluid mechanics last term, even though it was disorganized, she really cared about the students and really did want everybody to learn, whereas, like geotech where I was kind of in that middle ground, it was a bigger lecture, and it was just kind of like, he was just kind of there filling in his notes and questions. I know he does care, but there is kind of an aloof perception that maybe like, "Well if you don't care about this, why the hell should I care about this?" So whether or not he did or not, I think that would make a difference

Zach points to a distinction in how instructors care and its result on his engagement—some it "*comes through*" whereas with others (e.g. his Geotech professor), the perception was that he was "*just kind of there filling in notes.*" Zach stated clearly a theme which echoed throughout participants: "*Well if you don't care about this, why the hell should I care about this?*" It was not that Zach believed instructors some did not care, instead he was primarily interested in the caring he could observe and mirror in his own engagement. Across participants, there was similar belief that instructor care should not exist in an abstract sense, but should be demonstrated in ways that could be perceived and mirrored. The ways in which instructors were perceived to care was nuanced and went beyond simply the behaviors. For Zach, his fluid mechanics instructor's behaviors were not engaging, rather it was her "*want[ing] everybody to learn.*" In this sense, participants were seen to mirror the cognitive state of *wanting to learn* more so than simply instructor behavior.

Time in college had developed in participants a deeply-held set of beliefs through which they perceived the level of care of their instructors. Bruce, immediately when discussing his engagement at the opening of the interview, brought up difficulty learning from instructors who

used materials they did not develop. Bruce went on to repeatedly reference how difficult, frustrating, and uninspiring these professors were, and how his own engagement and learning reflected the investment of his instructors:

> As a student, like, I'm in this one class right now and the professor is totally engaged and writes all the stuff, it's just very genuine that it's his work, and it's so easy to learn from. Last term I had some professors that were using other materials and they didn't know how to do the homework assignments, they kind of just reading off the slides and it's just really difficult to learn that way for me.

Bruce starts off talking about "*as a student*," but curtails the thought and then begins to describe how his instructor was "*totally engaged*" and "*genuine*" in his work; it is as if Bruce uses the engagement of his instructors to justify his own engagement within the course. This extends to instruction Bruce does not find engaging—particularly instructors utilizing old material. If the instructor "*didn't know how to do the homework assignments*," Bruce concluded that neither should he. Other participants similarly had qualities of instruction they mirrored for positive cognitive engagement: Alisa cognitively engaged in classes that were challenging, Zach when use of a projected document camera allowed him to see more clearly as a colorblind student, Cole with hands-on learning, and Kara when instructors made connections to the "*real-world*."

While instructional practice preferences were somewhat unique to participants, a common set of practices emerged that resulted in the deepening of cognitive engagement. Clear and concise presentation of material minimized cognitive dissonance in participants, and resulted in deep thinking over material as they translated it into notes for their personal use. The organization, enthusiasm, and effort participants perceived in their instructors was mirrored in their cognitive engagement with course assignments. Zach went as far as to describe organization as the "*best thing*" instructors can do to engage their students: "*With the faculty, the best thing you can do is to have clear blocks and don't make them super long, like make a lecture that actually lasts 50*

minutes, or lasts even 45 minutes and take questions at the end." Cole struggled to put to words exactly how instruction impacted his engagement, stemming from a strong interconnection between his own response to instructional practices and the practices themselves:

> I feel like the teaching style, or just their personality, or energy, if they're very monotone, just like a robot, it's very hard to pay attention in class. But if they're excited about what they're teaching, and they're ... They like ... I don't know, I feel like you can just tell that they want you to learn, kind of thing. I don't know.

Cole could "*just tell"* that instructors wanted him to learn as a result of his own belief that he needed to learn. The connection between Cole's cognition and that of his instructors was so strong that he in fact described *their* engagement when asked how an instructor influenced *his* engagement. Other participants similarly referenced an elusive understanding that their instructors wanted them to learn, and built their own desire to learn upon it. The shared set of instructional traits deemed engaging by participants indicated their responsiveness to best practices, and their willingness to abandon their own deep cognitive engagement in the absence of effective instruction.

Even though their cognitive engagement was dramatically influenced by their instructors, participants were hesitant to abandon their behavioral engagement values in response to instructional practices. Viewing instructors as human and cultivating their own values of engagement remained critical even in the mirroring of engagement participants exhibited. Cole showed how his behavioral engagement value of taking notes intertwines with the instructional practices in a course:

> It really depends on how the teacher is actually teaching, though, because some classes, I can't really take notes, or I don't know what information is important to write down. If they have all the information's on the slide, like they just have a slide full of words, I don't really know what information is important, so that's why it helps me when they actually solve out problems, or they write ... They actually just write out on the board the important points or something like that.

Cole's repeated use of "*actually*" indicated his comfort when his value of notetaking aligned with instructional practices of "*actually solv[ing] out problems*" or "*actually just writ[ing] out on the board*." Cole was at odds with instructors who did not clearly communicate information that was important on crowded slides. Cole was unable or unwilling to mirror the shallow cognitive engagement (i.e. presenting material with no manipulation) in his notetaking, leaving him with conflict between his engagement values and those of his instructor. Across participants, the greatest dissonance in their engagement occurred when their behavioral engagement values conflicted with the cognitive engagement projected by their instructors.

Theme 4: Blended influences to determine effective and efficient engagement strategies

As seen above, instructional practices could stand at odds with participants' own beliefs about engagement. Participants were seen to minimize the dissonance between these sometimes-conflicting influences on their engagement by moving towards effective and efficient strategies in their learning. We previously discussed how Alisa came to see office hours as a way for her to effectively learn material; while visiting office hours was a behavioral engagement value of Alisa's, it was also indicative of a deeper movement towards effective and efficient cognitive engagement in her education. Alisa no longer struggled with assignments on her own or took on the financial burden and extended time in college of failing classes.

The strategies for effective and efficient learning varied among participants: Kara took courses with a friend, Bruce turned to YouTube when struggling on assignments, and Cole typically worked alone as opposed to collaborating with peers. Cole stated that he worked alone because it was "*easier*" and "*more time efficient*." It was observed that when Cole did struggle, he would employ a broader range of effective and efficient learning strategies. His sequence was as follows: attempt work on his own, seek additional guidance from YouTube, ask his friends for help, and finally go to office hours with the instructor. Cole employed these strategies primarily

because they were efficient and effective, not because they were most closely associated with his values, future goals, or impressed by the instructor. Bruce noted a conflict between his behavioral engagement values when he described telling himself at the start of every term he would read the textbook before lecture; the behavior never occurred because he "*seem[ed] to get by without having to*." These simplified engagement strategies allowed students to continue moving through their coursework without becoming cognitively overwhelmed or overburdened by their or their instructors' ideals.

Frustration emerged in participants when courses continued to demand their behavioral engagement, but required minimal cognitive engagement: "*But if a teacher is just reading word for word off of a slide, that's where it's like 'do I really need to be here? I could teach myself this right now"*" (Kara). Kara described a classroom that was no longer the most effective or efficient means for her to learn the material. Participants were vividly aware of their ability to engage with material beyond what was presented to them in the classroom; YouTube, Khan Academy, texting with peers, and notes made available online by the instructor were all cited by multiple participants as notably meaningful ways they independently cognitively engaged in their learning. These "beyond the instructor" learning mediums were utilized most heavily when instructional practices reflected levels of cognitive engagement below their own values or interest due to future goals.

Kara showed signs of her varying engagement strategies to effectively learn the material in various contexts:

> And if it's a topic, it's okay, I can kind of figure this out on my own. That's probably one I will not show up. But if it's one, like have an 8am right now with 15% of the grade is participation. So it's okay, I got to show up and all of that. And then also again, if I really like my teachers that's going to get me to go more, or if we're doing group projects, that's going to get me to go more because I don't want to be the slacker in my group. And so I'm okay, I'm here. Let's do what we gotta do.

Kara adapted her behavioral engagement strategies (e.g. not wanting to show up for early-morning lectures) to those of her instructor (e.g. the weight assigned to participation) when it was effective and efficient for her to do so. As stated above, Kara no longer wanted to fail courses and therefore was looking for the most efficient way to pass (provided the instructor was not inspiring deeper cognitive engagement). Kara knew when her behaviors could be modified and still result in her passing; her behavioral engagement was adjusted accordingly: "*When I can figure it out on my own. That's probably one I will not show up*"

Though all participants were persistent in the development of cognitive engagement for their personal benefit, contrasting ideals often led them to engage in the most efficient and effective manner possible. Zach projected minimizing dissonance when taking a technical course that would likely not interest him or align with his future goals:

> That's when I'm just going to have to fall back onto this is just part of the step, part of the process, these are the fundamentals from which I'm trying to lay a foundation for the future. But it's a good reminder that even when you're in those types of [technical] classes and you're kind of burrowing deep, it's that you're not in a vacuum, this all exists in the real world and these have consequences both in the very day to day level, in the fact that you get to just sit here in a classroom and be comfortable, relatively speaking doing that, and also in a grand scale of the meta in civil engineering, infrastructure, all that stuff that I'm interested in (Zach)

While Zach was often more reflective of the broader consequences of his engagement than other participants, he presented a theme that was common among them: sometimes it is was getting through and taking the next step forward that resulted in effective achievement of participants' values, goals, and course experiences.

Discussion

Inherent to IPA research is attention to the particular; the results of this work are intended to be representative of the lived experiences of participants in this study. We see a critical need for

research attentive to the particular to inform the community's broader understanding of the student experience. Here, we outline the ways in which we see this work aligning with, and contributing to, the growing body of knowledge on student engagement, research-based instructional practices, and research on phenomena relevant to engineering education.

Alignment with Previous Research

Our results suggest that four themes can be used to frame the cognitive engagement of our upper-division, civil engineering student participants. Under *Theme 1*, participants were seen to establish behavioral engagement values that were consistent across their learning contexts. Other research has proposed that students' learning is shaped by their context and culture (National Academies of Sciences Engineering and Medicine., 2018a), aligning with our findings related to the personal stances and values we observed to influence engagement. We used the behavioral engagement values observed in *Theme 1* as foundational to understanding cognitive engagement in later themes, which is supported in research on strategy use and self-regulation as important aspects of understanding cognitive engagement in science (Greene, 2015). *Theme 2* suggests that future goals impacted the cognitive engagement pattern of participants, which aligns with the previously established relationship between future goal orientation and cognitive engagement in courses (Appleton et al., 2006; Greene & Miller, 1996). *Theme 3* indicates that instructors indeed play a meaningful role in engaging their students, as participants were seen to mirror the engagement of their instructors. Such results suggest that Conclusion 7-4 of *How We Learn* is applicable in the engineering education context: purposeful teaching is critical to students developing deep understanding (National Academies of Sciences Engineering and Medicine., 2018b). Furthermore, this echoes the findings of Heller et al., who note that students report it is something about their instructor's presence that makes their courses engaging (2010), and Chi et al., who found that instructors could generate learning gains by developing learning activities

targeting deeper cognitive engagement (2018). Finally, *Theme 4* suggests that it was a blended influence of personal values, future goals, and instructional practices that led participants to make effective and efficient engagement decisions. Hickey and Granade proposed that reconciliation between individuals and their knowledge communities occurs as students internalize values and undergo sociocultural influence (2004). We found such reconciliation to be similarly true in our sample—it was through this reconciliation of sociocultural influences that participants came to effective and efficient engagement strategies in their later college courses. We reiterate the conclusions of Chen et al., who state that engagement is a *joint responsibility which relies on the attitudes and behaviors of both students and faculty*, but emphasize the importance of considering the critical role of faculty in the engagement experience (2010).

Implications of Sample and Methodology

While our work aligns with and supports previous research, there are implications unique and innovative to this work. Here, we leveraged the usefulness of the IPA methodology in understanding the lived experience of a group of upper-division, civil and construction engineering students—specifically what shaped their cognitive engagement within engineering courses. IPA allowed us to come to themes representative of the participants, then connect them to previous work. Connecting findings to previous work suggests that our sample is representative of a larger group's experiences (i.e. engineering students), while also provides insight into experiences unique to the sample (e.g. Zach's deep self-reflections, Kara's working through failing courses, etc.). As suggested by Huff (2015), the IPA methodology may be adopted by a wide variety of engineering education researchers seeking to study experience related to a wide array of phenomena of interest to engineering educators. We see ongoing need for participant experience focused research even within our own area of study (student cognitive engagement), as the experience of many remains underexplored; that which shapes the engagement of underrepresented, underperforming, first-

generation, and nontraditional students is critical to addressing the continuing question of *who* active learning works for and *in what ways*.

Implications for Practice

We see a linchpin of our results to be that faculty indeed influence student's engagement in meaningful ways Earlier we noted other studies provide evidence of such a relationship; the results of this study unpack the nuanced ways in which participants tended to mirror the cognitive engagement they perceived in their instructors. Importantly, participants had both the ability and means to acquire knowledge gains on their own—indeed, they often cited internet resources as information enough to allow them to align with their values and reach their future goals. It was therefore the *quality*, *effectiveness*, and *efficiency* of instruction that prompted participants to meaningfully engage and thereby learn from their instructors. Practically, results suggest that instructors need to clearly communicate to students that they themselves see the course material as worth cognitively wrestling with for understanding. Conversely, results suggest that poor instruction may result in substantial detriment to the cognitive engagement of students in the classroom; while highly motivated students (such as the participants in this study) may seek out other meaningful forms of engaging with learning material (e.g. the internet), it remains to be seen if unmotivated students choose to meaningfully cognitively engage at all.

Beyond the instructor, it was participants' future goals that largely shaped their meaningful cognitive engagement with particular course material; when participants saw a connection between what they were learning in class and an achievement of a future goal, their cognitive engagement increased. Though participants exhibited lack of certainty in regards to their future, they based important engagement decisions on a narrow view of their future career. Our results suggest that students may require a broader view of their future goals in order to generate more meaningful cognitive engagement with a larger range of course material. Instructors may seek to present

students with evidence for their probable career changes, and indicate how course material is useful for achieving goals that may seem less obvious (e.g. structural engineers may seek to be conscious of pipe flow constraints during design). Furthermore, instructors may seek to address the ways in which patterns of meaningful cognitive engagement may lead students to futures beyond what they currently envision for themselves.

Limitations and Future Work

The attention to the particular in this study is inherently limited. We seek to understand the experience of an admittedly narrow group of students as foundational work to understand the broader experience of students' cognitive engagement. Our findings are useful insofar as the interpreter (i.e. the reader) is thoughtful about the context in which they are making their own meaning. Data suggests that participants were not financially limited (i.e. they could fail a course and continue their studies), had access to social networks, and were supported by mentors/parents. Our participants therefore had access to the resources necessary reflectively considerer their engagement, its benefit to them, and adjust when previous attempts had failed. Participants were also largely successful, high-achieving, and self-identified as good students. We see a need for future work to begin to develop an understanding of varying student experiences within engineering. Participants in this study showed improvement and overcame obstacles over time; less is known about the students who do not improve. Furthermore, participants in this study had internship experience that led them to an understanding of their future goal and what might be required to achieve them. More work is needed to understand how students who do not have internship experience develop their future goals, and how instructors might elicit meaningful cognitive engagement with course material related to their indeterminate future.

While studying high-achieving students may initially seem counterintuitive, we suggest that it is indeed a useful metric for instructors seeking to better understand their classrooms. Results

suggest that instructors might gauge their practices as they see the reflection of cognitive engagement in their high-achieving students. We also hope to inspire educators to thoughtfully consider their own engagement and its impact on their students, because even the most motivated students are influenced by their instructors' engagement. While it is often inferred that active learning will simply lead to deep student cognitive engagement, we have begun to see that engagement is influenced by a variety of factors. As instructors design their courses, we see a need to think in broader terms of how students are learning—not to seek out one-size-fits-all models of engagement. Further study is needed to explore the phenomenon of student cognitive engagement in diverse groups, with particular attention to low-achieving students who are at risk of leaving the discipline. Questions remain about students who have not developed behavioral engagement values that lead them towards meaningful cognitive engagement: what motivates these students, and at what capacity do they choose to meaningfully cognitively engage?

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