STUDIES IN ENGINEERING EDUCATION

Barlow, A., & Brown, S. (2020). Discovering Upper-Division Students' Cognitive Engagement Across Engineering Courses—An Interpretive Phenomenological Analysis Approach. *Studies in Engineering Education*, 1(1), pp. 58–73.

EMPIRICAL RESEARCH

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

Allyson Barlow and Shane Brown
Oregon State University, US
Corresponding author: Allyson Barlow (barlowal@oregonstate.edu)

Background: Engineering 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 nuanced experience of students as they engage with their courses and how context plays a role in shaping this engagement.
Purpose/Hypothesis: Our research seeks to understand how upperclassman civil engineering students are engaged across their engineering courses. We use the experience of individuals to explain how the sample made contextual decisions of engagement.
Design/Method: We used Interpretive Phenomenological Analysis (IPA) as the overarching guide when designing the study, collecting data, and interpreting findings. We recruited an appropriate sample of five engineering students to participate in a semi-structured interview. To explore participants' engagement context and experience, we used prompts to discuss engagement generally over time. The interview progressed to a discussion of engagement specifically in their engineering courses from the previous term. In analysis, we generated themes from each participant's individual experience. As these themes coalesced, we developed super-ordinate themes that connected the experiences of individuals to the larger whole.
Results: Through analysis and interpretation, we developed the following super-ordinate themes: *Behaviors for Engagement Opportunity*—actions that created more or fewer chances for deep cognitive engagement, *Engagement for the Future Self*—looking to the generated future self to determine meaningful and applicable curriculum, and *Engagement in Course Context*—adjusting cognitive engagement to mirror the engagement stance of instructors.
Conclusions: We view our findings as indicative of the malleable nature of student's cognitive engagement, particularly in relationship to authority figures such as instructors. While personal values and future goals were indeed factors in participants' engagement decisions, all participants were impacted by their classroom context. This work builds evidence for the importance of instructors utilizing evidence-based instructional practices to cultivate learning environments that maximize students' engagement potential.

Keywords: cognitive engagement; student engagement; interpretive phenomenological analysis; undergraduate; qualitative

Introduction and Background

Upon establishing that active learning indeed does *work* (Prince, 2004), the engineering education community continues to push educators to create more active learning environments. Unfortunately, educators have been slow to implement changes in their classroom, for reasons including perceived student resistance (Henderson & Dancy, 2011). Even when well-established active learning instructional styles such as problem-based and collaborative learning are implemented and result in learning gains (Bédard, Lison, Dalle, & Boutin, 2010; K. A. Smith, Sheppard, Johnson, & Johnson, 2005), impact on students differs along gender, ethnicity, and individual experience (Stump, Hilpert, Husman, Chung, & Kim, 2011). Researchers now acknowledge it is a much more complex issue than to simply state that it is better to learn together (Nokes-Malach, Richey, & Gadgil, 2015). Cognitive engagement, the mental effort put forth towards understanding, is one key to understanding how active learning is working for students (Chi, 2009). It therefore becomes important that, as researchers, we seek to develop theories that explain how cognitive engagement is shaped within individuals in different contexts.

Broadly, 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. Behavioral engagement can be thought of as the participatory actions students take towards their learning (e.g., following the rules, participating in a classroom discussion, etc.). Emotional engagement is the reactive feelings of students towards classroom stimuli including excitement, boredom, and anxiety. Cognitive engagement emphasizes the self-regulatory investment of students their learning such as working hard or effort towards learning and comprehension. These dimensions are used to explain how components of engagement are 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 engagement has been correlated with synthesis and deep-level understanding (Fredricks et al., 2004). As an indicator of higher-order thinking, cognitive engagement is particularly important for engineering students to cultivate in order to achieve authentic understanding of scientific practices (Sinatra & Chinn, 2011).

While previous work advances measurement of cognitive engagement (see Appleton et al., 2006; Chi & Wylie, 2014; DeMonbrun et al., 2017; Greene, 2015; Zhao & Kuh, 2004), it does not explore how students have come to cognitively engage at shallow (rote, mechanical) or deep (complex, knowledge-building) levels. The driving forces that shape students' cognitive engagement within engineering courses are currently under-researched. As engineering instructors are called to create increasingly engaging learning environments, it becomes important to understand the responsiveness of students to these instructional practices.

We suggest that germane to understanding student response to instructional practices is holistically exploring how student cognitive engagement is shaped at an individual level. To do so, an exploration of a relatively homogenous sample is required. A sample of students that share the same institutional, departmental, and curricular experiences will highlight personal responsiveness to contextual classroom experiences. In this study, we seek to explore what shapes the cognitive engagement of upper-division engineering students; our guiding purpose is to provide educators with a foundational understanding of students' engagement positionality and responsiveness to instructional practices.

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 collecting and analyzing qualitative data, served as the overarching guide for the conceptualization and carrying out of the project. Notably, IPA guided the organization of themes surrounding participants' cognitive engagement experiences. Results show that participants' engagement opportunities, conceptualized future self, and contextual course features all shaped their cognitive engagement within engineering courses. We anticipate this study will be useful in building a foundational understanding of what shapes individual students' cognitive engagement in engineering courses as we allow for the nuanced, personal nature of cognitive engagement to be presented.

Student Engagement

As aforementioned, 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 has three distinct dimensions: behavior, emotion, and cognition (Fredricks et al., 2004). Though each component of engagement is associated with unique learning outcomes, the three components of engagement are inextricably tied to one another. In discussing dimensions of engagement, Fredricks et al. (2004, p. 61) 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.

It is therefore appropriate to look holistically at engagement, even if the phenomenon of interest is one component of engagement; for example, cognitive engagement ought to be studied in light of the *antecedents and consequences* of behavioral and emotional engagement.

It is specifically cognitive engagement that has historically remained difficult to both define and measure (Sinatra, Heddy, & Lombardi, 2015). This is perhaps because other dimensions of engagement are more readily observable and therefore accessible: behavioral engagement displays of effort, persistence, and attention (Sinatra et al., 2015); emotional engagement displays of interest, happiness, and anxiety (Fredricks et al., 2004). Researchers have suggested that cognitive engagement is closely related to psychological effort, a state in which students put forth effort to understand (Sinatra et al., 2015) and investment, a willingness to put forth effort for comprehension (Fredricks et al., 2004). Simply stated, cognitive engagement is closely tied with mental effort or exertion towards learning. Much research has relied on work suggesting that students can cognitively engage at deep or shallow levels (Craik & Lockhart, 1972). Shallow cognitive engagement is associated with rote, mechanical processing whereas deep cognitive engagement is associated with intentional creation of complex knowledge structures through the integration of new material (Greene, 2015).

Previous work provides conceptualizations of cognitive engagement that offer insight into how a body of students may be cognitively engaging with course material at a given point in time via observational schema (Chi & Wylie, 2014). This means an instructor could critically observe their students and develop a gross understanding of the cognitive engagement that exists in their classroom. The literature also provides survey instruments to measure cognitive engagement (Barlow et al., 2020) that 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.). Yet, neither observation nor survey capture the entire picture of student cognitive engagement. Anecdotally, we hear of classes that are disengaged despite instructors utilizing the same curriculum, or classes that are simply a good group. The nuance that explains these phenomena must be captured within personal experiences of students.

No work was found in the literature that provided deep exploration of the personal factors that influence cognitive engagement in STEM students. Interviews where participants share the nuances of their own experience are an effective means to capture these personal factors. While interviews are inherently limited by how the participant perceives their own reality and conceptualize the phenomenon being discussed, we suggest study of the personal, or particular, will, in time, help make sense of the whole. Here, we research what shapes student cognitive engagement in an effort to gain better understanding of STEM students' response to contextual course features, specifically the ways in which their cognitive engagement is malleable to instructional practices.

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 our research approach, positionality, how participants were interviewed, and data 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. As a part of this transparency, we include the ways in which validity was considered and prioritized throughout the study. This research was approved by the Oregon State University Institutional Review Board (IRB #6922).

Research Approach

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 that has been used for understanding experience of students in engineering courses (J. L. Huff et al., 2015; Kirn, Godwin, Cass, Ross, & Huff, 2017; Kirn, Huff, Godwin, Ross, & Cass, 2019). 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). In the engineering education discipline, "IPA has allowed us to richly explore the lived experiences of engineering students in ways not documented in the literature and develop innovative ways of teaching, fostering, and mentoring students" (Kirn et al., 2019, p. 319); we look to contribute to this growing body of literature by providing insight on the cognitive engagement of engineering students.

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 analyses. 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?

Researcher Positionality

Within qualitative research, the project is meaningfully informed from conception to completion by the positionality of the researchers. Here, we seek to present our positionality and background, providing readers an opportunity to view the findings through the lens of the researchers as they make their own meaning of the work. Both researchers align with a constructivist worldview, which suggests knowledge is self-constructed, and influences assumptions on how such knowledge ought to be disseminated in the classroom (Hutchinson & Huberman, 1994). More specifically, we identify with social constructivism—the belief that individuals develop subjective meanings from the worlds in which they live, work, and interact with others (Creswell, 2014). As social constructivists, we sought to formulate a pattern of meaning from targeted inquiry focused on understanding the conditions in which individuals make meaning (Creswell, 2014). Thus, we did not seek out an objective reality; rather, we sought to uncover the student's lived experience, focusing on how particular course factors shaped their engagement. In conducting and analyzing this work, we note our own role in making meaning of the students' lived experience, extending beyond our worldview positionality and into our individual backgrounds. Both authors were educated in the field of civil engineering and could relate at some level to the experience of participants. The lead author, a graduate student at the time of the research, had taken similar courses to those participants discussed in the interviews. This allowed the author to build rapport, connection, and meaning with participants, adding to the credibility of the findings (Berg & Lune, 2014; Guba & Lincoln, 1989). We also employed extensive bracketing (described in the methods below) to allow for the participants' own experience to stay at the forefront of our analysis. Both authors had experience researching student engagement, with the lead author having participated in the development of a student cognitive engagement measurement instrument and the second author having conducted over 15 years of education-related research, including extensive work on student engagement in engineering courses.

Recruitment and Sampling

Smith et al. suggest "IPA studies are conducted on relatively small sample sizes, and the aim is to find a reasonably homogeneous sample, so that, within the sample, we can examine convergence and divergence in some detail" (2009, p. 3). We accomplished this by recruiting via a related study, in which a large number of courses were asked to deploy an instrument to measure cognitive engagement within a course (Barlow et al., 2020). 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).

Participant Demographics

We seek to *make visible* (Pawley, 2017) the demographics of our participants by not only including information about their gender, race, and academic rank, but a brief discussion on relevant beliefs that are likely informed by their socioeconomic status and personal backgrounds. Below, we provide profiles of each participant, aiming to capture details that help frame their cognitive engagement as individuals; these individual stories form the basis of the results. We note that the lack of ethnic diversity in our study, which included only White participants. This work is only a starting point based on the availability within our sample; we strongly advocate for the continuation of this work on to address cognitive engagement in different racial and socioeconomic groups.

Bruce—White male, civil engineering senior

Bruce was not passionate about engineering; rather he made a logical choice to pursue a career that would result in a job. Bruce worked hard, as he paid for his own schooling. Once, he failed a class during his sophomore year and in the interview, Bruce reflected on how his decisions in the course cost him a lot of money. In general terms, Bruce noted that his engagement decreased over time, particularly after he was accepted into a master's program in a related discipline at his undergraduate university. Slowly, he transitioned from a student who worked ahead and studied in advance to one who found the most efficient means to complete tasks.

Throughout the interview, Bruce returned to the strong opinions he held about the role of professors in the engineering classroom. He mentioned on multiple occasions an extreme distaste for professors who copied their lecture materials from previous professors, saying it was obvious when the train of thought was not their own. He believed that organization was key to engaging students. Professors who used previously developed material, did long proofs with no purpose, or were enthusiastic but made mistakes were all barriers to engagement. He saw a professor's ability to engage their student as a function of their personality. Citing that professors likely taught how they wanted to be taught as students, he assumed that professors did their best to engage students in the way that made the most sense to them. Bruce was hesitant to speak disrespectfully of his professors and believed they had much knowledge to share.

Alisa—White female, civil engineering senior

Alisa presented as a very self-motivated student. She had switched into engineering from another degree. After doing so, she performed poorly in some classes, at which point she realized she would need to modify her approach to become successful in college. Office hours were a key facet leading to her success. Often working on her own (not with peers), Alisa would reach out to professors when she got stuck. She wanted to learn, she said, and it was up to her to do it. She notably said that it was not up to the professors, but up to herself to "take hold" of the engaging environment. Alisa was paying for her schooling, motivating her to show up for class—even if she was not going to pay attention.

Alisa expressed a continual tension between wanting a challenge, wanting to learn, wanting to prove nay-sayers wrong, and some days "not feeling like it" or tuning out information that bore little relevance. Alisa seemed to know what material would matter for her future, but then quickly noted that no one knows what the future holds. She moved into engineering, particularly civil engineering because both of her parents were in the discipline. Yet, she cited her parent's work as "boring". Tension existed between the deep desire to be challenged by "proving others wrong", and not wanting professors to be rude or unhelpful. Alisa showed great faith in her instructors and their knowledge, stating with surety that instructors held information that would be of benefit to her.

Alisa was continually motivated to engage by the same things: maximizing the benefit of her financial expense, proving to others that she was capable and competent, and learning for her future career. Alisa was not particularly motivated by grades—though she did mention her focus on "beating" her dad's GPA.

Zach—White male, civil engineering junior

Zach took an approach to his courses that was different than most of his peers. Instead of engaging for grades or even a future career, he was notably disciplined in how he spent his time. Splitting his time between dual majors of Spanish and engineering, Zach also worked a variety of on-campus jobs for both personal development and money. Zach was not particularly passionate about civil engineering in the traditional sense. He described himself multiple times throughout the interview as a "civil engineer masquerading as a social scientist". He was a member of the honors college and surrounded by peers who were also heavily involved students and reinforced both positive and negative engagement patterns.

Zach was focused and intentional. He attended all of his courses, seeking to learn from them. He utilized tools provided for him, but indicated frustration when those tools were not useful to a future version of himself. Notes pages that were far too detailed and notes pages that were not attuned to the course pace decreased his engagement. Zach used journaling as an outlet when disengaged; he viewed sleeping or being engrossed in his phone as a waste of resources. Instead, he would journal, which allowed him to occasionally pause, look up, and take in his contextual course surroundings. Engagement and disengagement emerged from a central concern over the pacing of the course; Zach seemed willing to learn about most topics as long as they were presented well and appropriately paced.

Cole—White male, civil engineering senior

Cole was a motivated student who performed well in his courses, regardless of the instructor's teaching style. Cole was a part of an internship co-op program at his university where he worked on internships over the summer (and had an upcoming internship upon completion of his coursework). The program served as a social network of sorts for Cole; the friends he worked with in class, his motivation to continue to do well in school, and his comradery in the program all stemmed from the co-op program.

Cole indicated that he accepted that every instructor had their own style, but also had his own preferences. He indicated that he was a very "hands-on" learner and wanted the experience of solving an example problem. Cole stated he always took notes in his courses, but mentioned that courses where PowerPoints were "overwhelmed" with material discouraged him from taking good notes. Cole said he was most engaged in a course that used an effective combination of examples worked out on the board and PowerPoint with supporting theory (with slides posted).

The energy of the instructor and interest in the material were the primary factors in Cole's choices surrounding engagement. Energetic instructors that he could "tell" wanted him to learn encouraged him to be engaged. There was tension in how Cole viewed instructors who did not appear excited; he stated that "they don't care... well they do care, they just have a different style." Cole seemed accepting that teachers would have different styles of teaching, and that this may benefit students other than himself. When prompted, he was not able to provide specific evidence in his engineering courses that his counterparts were learning from unenthusiastic instructors, rather he cited examples of some being better at memorizing musical lyrics than he was. He again mentioned that hands-on learning was important to him, but that may not be the case for all students.

Cole appreciated group work, finding working with pairs most helpful when he could explain to someone who didn't understand (for his personal learning benefit), or could work through a problem on his own and learn from peers' alternate solutions.

Kara—White female, construction engineering senior

Kara was not a highly engaged student. Early in college she was admittedly more focused on her sorority and social life than she was on her academic pursuits. She entered into college as a chemical engineer because her father noticed in high school that she was "good at math and science." She never felt the major was a good fit; she failed multiple classes multiple times. While she took ownership of her choices to not put the full effort into her coursework, she also externalized some of her failures. Kara mentioned her academic advisor's lack of "push" to think critically about whether or not the degree was a good fit for her. Once Kara switched her degree to civil engineering (temporarily), she was motivated by her desire to get into pro-school—the discipline-specific latter two years of engineering school that require acceptance—at her university.

Kara was disengaged with theory and mathematical bases for solving problems. She admittedly was more interested in the business aspect of her degree, and soon switched to construction engineering. As a construction engineering student, she was engaged with conceptual courses where she could learn from professors with real-world experience. Kara mentioned multiple times the importance of a professor being able to tie examples and experiences to the real world. Additionally, Kara wanted her professors to have a sense of humor. She seemed to desire a level of entertainment from her courses and was disinterested in professors who simply read material.

While Kara was not motivated by grades for a job, scholarship, or appearance, she was motivated to do the minimum needed to succeed. She attended courses in which a participation grade was awarded—but attended only the amount needed to do passably. Kara was also influenced by her friends. She noted that her friend and roommate would often convince her to go to class. She mentioned she was fearful of raising her hand, but was able to learn well from group work assignments (even if she did not always like them).

Data Collection

Smith et al. provide clarity on data collection in IPA studies: "Data collection is usually (but not necessarily) in the form of semi-structured interviews where an interview schedule is used flexibly and the participant has an important stake in what is covered" (2009, p. 3). In alignment with IPA, we developed a loosely structured interview protocol to guide our discussion of cognitive engagement with participants.

In this study, we conceptualize cognitive engagement to be the mental effort a student puts forth as part of the learning process. We sought to uncover the participants' experience of putting forth different levels of cognitive engagement across their courses. We were not seeking an absolute or objective reality that corresponded to particular assessable outcomes, as has been done in previous studies on cognitive engagement. Instead, we looked to the participants to share their experience of what lead to differences in depth of their engagement in different course contexts. We therefore believe our phenomenon of interest (cognitive engagement) aligned with the tenants of IPA and was appropriate to be studied with interviews. Interviews, like all data sources, have limitations. In the context of this study, data may have been limited by participants' lack of familiarity with cognitive engagement. We sought to mitigate this concern by sensitizing participants to the concept of cognitive engagement, thought of as mental effort, and broadening our interview discussion to engagement more generally before extracting cognitive engagement in data analysis.

Participants were asked to interview approximately two weeks after the completion of the winter academic term (10-week term from January to March). This timing 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 protocol 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 protocol; this provided participants *stake* in what was covered in the interview. The focus of the study remained cognitive engagement: the interviewer led students to broadly discuss all facets of their engagement, and probed more deeply when mental effort was discussed. It was during data analysis that cognitive engagement was extracted from other forms of engagement. This aligns with IPA methodology, which suggests "We aim to set up the interview as an event which facilitates discussion of relevant topics, and will allow the research question to be answered subsequently, via analysis (J. A. Smith et al., 2009, p. 57). Furthermore, this added to theoretical validation: "the research process needs to be able to capture the full extent of the social reality that is of interest" (Walther, Sochacka, & Kellam, 2013, p. 641). We did not impose bounds on cognitive engagement; rather, we provided participants with a starting point from which they could discuss the full extent of their cognitive 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."

The interview schedule was designed in alignment with the principles of IPA inquiry as well as literature on cognitive engagement. Specifically, the research team's prior work quantitatively measuring cognitive engagement using overt behaviors defined by Chi and Wylie's ICAP framework (2014) informed how cognitive engagement could be explored from multiple angles. Prompts therefore were designed to allow participants to discuss their classroom behaviors and how that led to the mental effort participants were putting forth towards their learning.

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 1**). This framed cognitive engagement in both context and time; Part 1 also drew in components of behavioral and emotional engagement such as learning patterns and interest. 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 to a course, specifically their engineering courses from the previous term (Part 2, as seen in **Table 1**). 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. We guided the conversation specifically towards deep versus shallow cognitive engagement in Part 2. 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 deeper student engagement (Part 3, as seen in **Table 1**). 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.

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. This worked to ensure communicative validation, defined in part by the need for researchers' interpretations to be based in the accounts of the participants (Walther et al., 2013). By staying immersed in a single participant and hearing the transcript in the participant's own voice throughout analysis, we made conscious effort to focus all interpretation on the data.

Cases were analyzed sequentially, with the researchers immersing themselves in the data of a single participant and undergoing analysis before moving on to the next case. Per the IPA methodology (J. A. Smith et al., 2009), each transcript was first annotated with descriptive, linguistic, and conceptual comments. A different annotation style was used for each comment type to be able to differentiate amongst them. Developing an explicit procedure for handling and differentiating these comments worked towards process reliability, which is the establishment of dependable procedures in working with the data (Walther et al., 2013). Descriptive comments corresponded to a highlighted portion of text and were located on the right of the page; descriptive comments were observations grounded in the participants' own positionality. Linguistic comments corresponded to boxed text and were written directly above the noted word. These comments focused on the words participants' used and how word choice informed meaning. Conceptual comments corresponded to underlined text and were located on the left of the page. The focus of conceptual comments was interpretation. At this point, the researchers made meaning from the participant's experience and formed the potential themes of the transcript. Annotations formed the basis for participant-based emergent themes.

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 to speak for themselves. We attempted to remain entirely grounded in the experience of each participant. To do this, reflective journaling

Table 1: 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?

occurred after each data collection interview, again after concluding data analysis on each participant, and anytime a prior participant came to mind in subsequent data analysis. Reflective journaling served to allow us to keep a record of our thoughts, ideas, interpretations, and experiences of each participant story. As part of dynamic bracketing, we intentionally moved away from preconceived notions and immersed ourselves in the next participant and their story (i.e., attempted to set aside prior interpretations when they re-entered the mind).

After completing comments on the transcript, comments, keywords, and locations in the transcript were transferred to color-coded notecards. Colored notecards corresponded to the descriptive, linguistic, and conceptual comments established during the analysis of a transcript. This allowed for comments to be organized into emergent themes based in a single participant's data. Themes were based in the researchers' interpretation of the meaning of a participant's experience of engagement. We organized and reorganized the underlying constructs discussed in each interview to tell the participant's story of engagement, emphasizing the influential contextual factors they discussed. After developing themes for a participant and bracketing off interpretations, analysis of the next transcript commenced. After analyzing all participants, we looked at the participant-based emergent themes (groups of notecards) for each participant. These themes formed the basis for the super-ordinate themes that explained experiences across participants. Super-ordinate themes were established as we moved and removed notecards into meaningful groupings; not all notecards were included, indicating that not all themes were meaningful to the group of participants. Participants did not all have to have a similar experience within a super-ordinate theme, rather their divergent experiences within a theme might deepen our understanding of the phenomenon. We focused our attention on super-ordinate themes that best explained our participants' experience of the phenomenon of interest—cognitive engagement. Super-ordinate themes were given titles and contextual definitions upon completion of analysis. A visual depiction of the analysis process is presented in **Figure 1**.

To focus results around cognitive engagement, we considered each participant's experience first in the light of the meta-construct of engagement for contextualization. Then, we honed in on the themes that related to the shaping of their cognitive engagement specifically; we focused on evidence of mental effort or exertion towards learning (e.g., language of working or thinking hard to understand a concept). Super-ordinate themes were therefore related to engagement broadly, and cognitive engagement of participants is used as supporting evidence of the theme's relevance to participants. 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. Three super-ordinate themes were developed and are discussed in the Results below.

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 three super-ordinate themes, with occurrences within participants used as supporting evidence of how the broad theme applies on an individual level (i.e., to the particular). We present a summary of themes in **Table 2** 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.

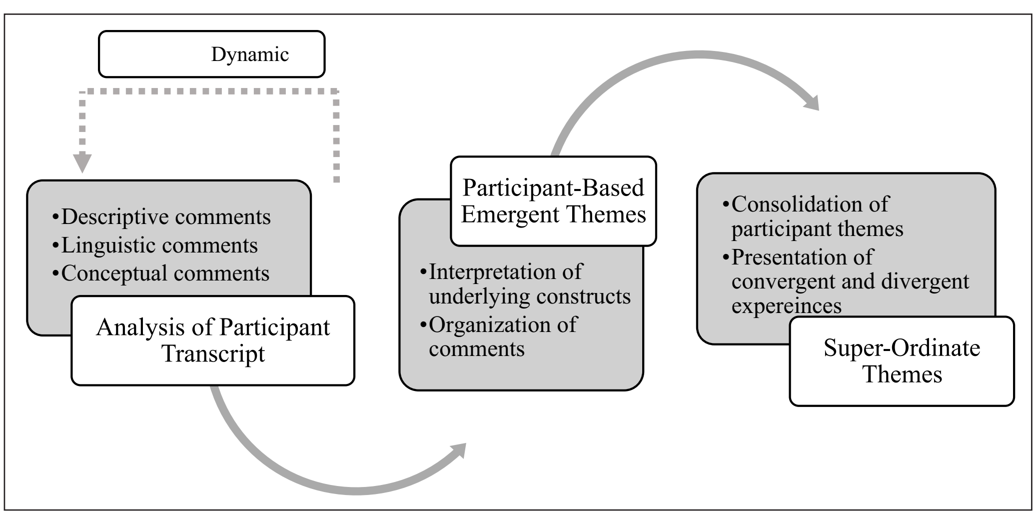

Figure 1: A visual depiction of the IPA process of this study.

Theme 1: Behaviors for Engagement Opportunity

When discussing cognitive engagement in the classroom (mental effort or exertion towards learning), participants pointed to an established pattern of behaviors that either opened the door for deep cognitive engagement or left little opportunity for it. These behaviors presented as values: always attending class, completing homework assignments, and/or passing courses. These values were personal, like for Bruce, who repeatedly mentioned that he had "never not turned in an assignment." His repetition was an attempt to convince the researcher of the value he placed on the behavior of completing his assignments, even if he admitted to occasionally "not maybe having the best academic integrity." Bruce's behavior meant that each assignment was a potential place of deep engagement; course features (Theme 3) were determining factors if opportunity for deep cognitive engagement was realized, or if Bruce would decrease his mental effort with poor academic integrity.

These results align with experiences educators might have with students in the classroom; there are students who never show up to class, and students like Alisa: "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." Alisa's consistency inherently created more cognitive engagement opportunities than the approach of Kara, who made case-by-case determinations on whether she should show up to class:

> 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.

For Kara, the behavioral value was "get past the class." Both Alisa and Kara's words point to a potential, not a guarantee of engagement: "whether I pay attention or not, so yeah" or "but mentally I was putting it on the back burner." Participants used first-person language when discussing their consistent behavioral values in classroom contexts. As they transitioned to discussing the ways in which behaviors did not result in deep cognitive engagement, participants were increasingly defensive and abstract (e.g., "it wasn't engaging, it wasn't a super exciting subject to me"). This pointed to the crucial role of contextual factors in fulfilling engagement opportunities.

Data did not support that participants learned more than their peers, rather participants had a set of behaviors that resulted in consistent opportunities for academic success. We found that participants were committed to their academic behaviors, particularly those that resulted in a memorable failure or success. For Alisa, this was attending office hours: "'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." Yet, when prompted, Alisa indicated that she went to office hours even when the professor was not helpful in increasing her understanding. Alisa provided an example of the ways in which participants continued with behaviors they believed had reasonable likelihood of success—be that success deepened cognitive engagement or simply fulfilling a value (e.g., passing a course).

Table 2: Summary of themes addressing what shaped the cognitive engagement within participants.

Theme	***Description***	***Example Quotes***
Behaviors for Engagement Opportunity	Participants placed value on behaviors that resulted in them creating or failing to create an environment for themselves to cognitively engage	*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*
Engagement for the Future Self	The future self participants created guided their engagement potential; looking to their future self, participants determined meaningful and applicable curriculum	*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.*
Engagement in Course Context	Both engagement potential and the future self was 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*

These results point towards an acknowledgement that the behaviors of students in a classroom will impact the opportunities they have for deep cognitive engagement with learning material. In fact, participants' engagement opportunities emerged from a complex internal set of values displayed as their day-to-day behaviors. While we also exposed the influential role instructors played on determining cognitive engagement (see Theme 3), we posit students' behaviors hold some influential power over the potential depth of their engagement.

Theme 2: Engagement for the Future Self

While participant behavior undoubtedly played an important role in determining their engagement potential, it was also meaningfully informed by the future self they envisioned. Educators may hold limited influence over the behavioral choices and values of their students but do hold potential to help co-create future selves of students. An expansive view of their future selves was not only a factor in influencing participants' behaviors, but also the degree to which they deepened their cognitive engagement in courses.

When participants had an unwavering vision of their future self, their resulting behaviors limited engagement opportunities in other courses. 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 values of attending a course to ensure exposure to material, but minimized her deep cognitive engagement based on a perceived lack of usefulness to her future self.

In contrast, Cole held an expansive vision of his future—become a successful engineering who owns his own company: "I know, I want to probably own my own company, or take over someone else's company, I don't know." The language Cole used was indicative of his contrasting created future self: Cole starts by saying I know and concludes with saying I don't know. Cole's perception of his future self was not cemented in reality. A lack of true knowing about the future while having reasonable possibilities as motivators resulted in participants deepening their cognitive engagement.

Even though Cole had no assurance of his future as a business owner, when he 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 deep cognitive engagement associated with material he found interesting and relevant to his created future self. Participants' cognitive engagement deepened across courses and subjects they deemed relevant to achieving their future goals; the more expansive the future self participants created, the greater the breadth of courses they deemed relevant and applicable.

However, participants' perceived future selves were not simply something they brought to their courses, like behaviors. Instead, they were negotiated at the intersection of internal beliefs and external curricular factors, with instructors and course contexts also playing a key role. As conflict arose between course curriculum and external internship experiences, the perceived needs of the future self-guided participants' cognitive engagement:

> 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 self, as he started off saying "it's more helpful to know what you're learning in class applies to the real world." Cole was surprised by how little of his coursework knowledge applied to his work. His surprise was indicative of the depth to which he was influenced by his views of his future self. Instead of renegotiating his conception of his future self, 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. In his insistence on maintaining an expansive view of his future self, Cole continues in his deep cognitive engagement with course material for learning.

Theme 3: Engagement in Course Context

Behavior for engagement opportunities (Theme 1) was personal to participants and future selves (Theme 2) were negotiated as participants brought their behaviors into contact with their academic and professional contexts; for all participants, their cognitive engagement hinged strongly on the contextual features present in their courses. Particularly, there was a clear correlation between how much they cared and how much the instructor cared—participants mirrored the depth of cognitive engagement they perceived in their instructors. This mirroring would go as far as to conflict with the future selves students created; for example, high quality instruction could result in creating a new interest with a subject whereas poor instruction in 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.

Participants were aligned with their instructors to such a degree that they felt discomfort in assigning a motivation or a true lack of care. Zach negotiated with himself that his structures instructor must care because Zach himself cares about the course. Important in this negotiation was the perception participants held of their instructors. The perception of care, whether it came through or "an aloof perception that maybe like, 'well if you don't care about this, why the hell should I care about this?'" was deeply influential in the depth to which a student cognitively engaged in a particular course. 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.

Time in college developed a deeply held set of beliefs in participants through which they perceived the level of care of their instructors. Bruce, 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; Bruce uses the engagement of his instructors to justify his own cognitive 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. While Bruce's behaviors created a potential for deep engagement as he completed each homework assignment, his perceived lack of care by his instructor resulted in him completing his assignments without really learning, or deeply cognitively engaging.

The power participants gave to their instructors was primarily over the depth of their cognitive engagement; these academically successful participants would continue to engage in behaviors that resulted in their success, but not all of these behaviors resulted in knowledge-building associated with cognitive engagement. Cole discussed how his notetaking behavior intertwined 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 mirrored the instructional practices of "actually solv[ing] out problems" or "actually just writ[ing] out on the board." Cole felt dissonance with instructors who did not clearly communicate information that was important on crowded slides. Cole, like other participants, viewed it as the role of the instructor to do the cognitive work of determining what information was important in a course or simply on the slide. When the perception was that the instructor did not put forth the cognitive effort to make meaning of blocks of information, Cole mirrored this engagement. His behavior of notetaking did not reach its full cognitive engagement potential.

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 could 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.

The notable exception to mirroring instructors' engagement was when participants believed that meaningful understanding of the material was critical to their future self. Participants were 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 to align participants with their future selves. Participants did not give instructors the power to limit their engagement potential, rather the power to fulfill it.

Discussion

In our results, we presented the ways in which participant behavioral values informed engagement opportunities, how an expansive view of their future selves deepened participant cognitive engagement in an array of contexts, and the role perceived instructor cognitive engagement was reflected in participants across their course contexts. Our aim is that these results inform the community's broader understanding of the student experience, particularly of those students who are already poised for deep cognitive engagement. 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 three 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 values on behaviors that informed their learning opportunities. This aligns with the documented evidence that personalized values and beliefs impact student cognition. Behaviors discussed with our participants can be seen as part of their self-regulated learning strategies. Literature has pointed to effective self-regulated learning strategies: previewing before class, engaging in class, reviewing after class, holding study sessions, and seeking help as a supplement (Chasmar, Melloy, & Benson, 2015). These strategies were some of the same behavior values discussed with participants: attending class regularly, completing all assignments, and attending office hours. Research has also suggested that a need for competence had an effect on student's motivation (Ciani, Sheldon, Hilpert, & Easter, 2011). Ties between cognitive engagement and motivation indicate that the behaviors driven by our participants' need for competence in the course (i.e., passing) preceded motivation for deep cognitive engagement. Furthermore, the behaviors of participants were driven in large part by their epistemic beliefs (beliefs related to knowledge and knowing); some participants were meaningfully motivated by expanding their own knowledge (e.g., Zach) while others were more focused on completion and minimizing effort (e.g., Kara). Literature would suggest Zach had epistemic aims (desire to gain knowledge) while Kara held non-epistemic ones (goals not directed at seeking knowledge). Epistemic aims have be known to impact aspects of cognition; students with non-epistemic aims may be more sensitive to the contextual pressures of their instructors (Faber & Benson, 2017). We used the behaviors that formed engagement opportunities 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 the future selves created by participants played a determining role on the extent to which they actualized the engagement opportunities created by their behaviors. This aligns with the previously established relationship between future goal orientation and cognitive engagement in courses (Appleton et al., 2006; Greene & Miller, 1996). Other IPA work has suggested that future goals play a role in determining how students will accomplish present tasks (Kirn & Benson, 2018). Kirn and Benson suggest that a lack of clear future goals resulted in a lack of measurable accomplishments in the present, while too tightly defined goals may result in students finding a lack of relevance in extraneous engineering tasks. We also observed the latter to be true in this study; when participants could not connect a future self to the learning context, they deferred to shallow cognitive engagement strategies that did not maximize their learning opportunities. External factors such as family and internships and internal factors such as instructors and curriculum have the potential to help facilitate expansive future selves in students. As students relate coursework to their future goals, they may be more likely to adopt learning goals associated with deep cognitive engagement (Ciani et al., 2011), pointing towards an importance of instructors aiding in student development of future selves. Others who work in the space of Future Time Perspective (FTP) have indicated goal orientation varies among engineering students (McGough & Benson, 2017) and acknowledge instruction can impact FTP in meaningful ways (Husman & Lens, 1999).

Theme 3 indicates that classroom context, particularly perceived instructor cognitive engagement indeed played 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, 2018). 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). Others have indicated that the expectations of the instructor has meaningfully informed cognition, particularly in how students approach problems and set goals (Faber & Benson, 2017). In this way, instructors are the critical piece in tying behaviors with engagement opportunity and future selves into the classroom context: as instructors increase the depth with which they cognitively engage with course material, students will reflect this in their own learning.

Conclusions

As instructors are pushed towards more active learning environments, this research suggests that they must take into account the interplay of student values and future selves, as well as their own positionality. It should be noted that while increasing cognitive engagement should still be emphasized, participants do bring their own values to the classroom. These values inform their behaviors, thereby establishing their opportunities for engagement. Future selves may initially be generated from background, but we suggest that ongoing collegiate experience can shift and shape these future selves. This expansion of future selves was seen as critical to participants deeply cognitively engaging with a wide range of course material. Finally, we emphasize the role of the instructor in deepening student cognitive engagement, echoing 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 (2010). Not only can instructors help shape the future selves students create, they can themselves engage with material in a way they hope their students will mirror.

Implications for Practice

This work is situated in a discussion of cognitive engagement in engineering classrooms. Research pushes evidence-based instructional strategies, instructors are resistant, and much is still to be learned about the ways students are responsive to strategies targeted at increasing engagement. 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. 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 apparent disengagement by the instructor 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 deeply cognitively engage at all.

Beyond the instructor, it was participants' future selves that largely shaped their deep cognitive engagement with particular course material; when participants saw a connection between what they were learning in class and the realization of a future self, their cognitive engagement increased. Our results suggest that students may require a broader view of their future goals in order to generate deeper 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 deep 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 to reflectively consider 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.

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 instructors 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 deeply cognitively engage?

Competing Interests

The authors have no competing interests to declare.

References

Appleton, J. J., Christenson, S. L., Kim, D., & Reschly, A. L. (2006). Measuring cognitive and psychological engagement: validation of the student engagement instrument. *Journal of School Psychology*, *44*, 427–445. DOI: https://doi.org/10.1016/j.jsp.2006.04.002

Barlow, A., Brown, S., Lutz, B., Pitterson, N., Hunsu, N., & Adesope, O. (2020). Development of the Student Course Cognitive Engagement Instrument (SCCEI) for college engineering courses. *International Journal of STEM Education*, *7*(1). DOI: https://doi.org/10.1186/s40594-020-00220-9

Bédard, D., Lison, C., Dalle, D., & Boutin, N. (2010). Predictors of student's engagement and persistence in an innovative PBL curriculum: Applications for engineering education. *International Journal of Engineering Education*, *26*(3), 1–12. DOI: https://doi.org/10.7771/1541-5015.1355

Berg, B. L., & Lune, H. (2014). *Qualitative research methods for the social sciences* (8th ed.). Boston: Pearson.

Chasmar, J. M., Melloy, B. J., & Benson, L. (2015). Use of self-regulated learning strategies by second-year industrial engineering students. *ASEE Annual Conference and Exposition, Conference Proceedings, 22nd ASEE Annual Conference and Exposition: Making Value for Society*. DOI: https://doi.org/10.18260/p.24979

Chen, J. C., Whittinghill, D. C., & Kadlowec, J. A. (2010). Classes that click: Fast rich feedback to enhance student learning and satisfaction. *Journal of Engineering Education*, *99*(2), 159–168. DOI: https://doi.org/10.1002/j.2168-9830.2010.tb01052.x

Chi, M. T. H. (2009). Active-constructive-interactive: A conceptual framework for differentiating learning activities. *Topics in Cognitive Science*, *1*(1), 73–105. DOI: https://doi.org/10.1111/j.1756-8765.2008.01005.x

Chi, M. T. H., Adams, J., Bogusch, E. B., Bruchok, C., Kang, S., Lancaster, M., … Yaghmourian, D. L. (2018). Translating the ICAP theory of cognitive engagement into practice. *Cognitive Science*, *42*, 1777–1832. DOI: https://doi.org/10.1111/cogs.12626

Chi, M. T. H., & Wylie, R. (2014). The ICAP framework: linking cognitive engagement to active learning outcomes. *Educational Psychologist*, *49*(4), 219–243. DOI: https://doi.org/10.1080/00461520.2014.965823

Ciani, K. D., Sheldon, K. M., Hilpert, J. C., & Easter, M. A. (2011). Antecedents and trajectories of achievement goals: A self-determination theory perspective. *British Journal of Educational Psychology*, *81*(2), 223–243. DOI: https://doi.org/10.1348/000709910X517399

Craik, F. I. M., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior*, *11*(6), 671–684. DOI: https://doi.org/10.1016/S0022-5371(72)80001-X

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). SAGE Publications.

DeMonbrun, M., Finelli, C. J., Prince, M., Borrego, M., Shekhar, P., Henderson, C., & Waters, C. (2017). Creating an instrument to measure student response to instructional practices. *Journal of Engineering Education*, *106*(2), 273–298. DOI: https://doi.org/10.1002/jee.20162

Faber, C., & Benson, L. C. (2017). Engineering students' epistemic cognition in the context of problem solving. *Journal of Engineering Education*, *106*(4), 677–709. DOI: https://doi.org/10.1002/jee.20183

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement: Potential of the concept, state of the evidence. *Review of Educational Research*, *74*(1), 59–109. DOI: https://doi.org/10.3102/00346543074001059

Greene, B. A. (2015). Measuring cognitive engagement with self-report scales: Reflections from over 20 years of research. *Educational Psychologist*, *50*(1), 14–30. DOI: https://doi.org/10.1080/00461520.2014.989230

Greene, B. A., & Miller, R. B. (1996). Influences on achievement: Goals, perceived ability, and cognitive engagement. *Contemporary Educational Psychology*, *21*, 181–192. DOI: https://doi.org/10.1006/ceps.1996.0015

Guba, E., & Lincoln, Y. (1989). Fourth generation evaluation foreword. In *Fourth Generation Evaluation*.

Heller, R. S., Beil, C., Dam, K., & Haerum, B. (2010). Student and faculty perceptions of engagement in engineering. *Journal of Engineering Education*, *99*(3), 253–261. DOI: https://doi.org/10.1002/j.2168-9830.2010.tb01060.x

Henderson, C., & Dancy, M. H. (2011). Increasing the impact and diffusion of STEM education innovations. *Invited Paper for the National Academy of Engineering, Center for the Advancement of Engineering Education Forum*. http://www. nae.edu/File. aspx

Huff, J., & Clements, H. (2018). The hidden person within the frustrated student: An interpretative phenomenological analysis of a student's experience in a programming course. *American Society for Engineering Education Annual Conference & Exposition*. DOI: https://doi.org/10.18260/1-2--28971

Huff, J. L., Smith, J. A., Jesiek, B. K., Zoltowski, C. B., Graziano, W. G., & Oakes, W. C. (2015). From methods to methodology: Reflection on keeping the philosophical commitments of interpretative phenomenological analysis. *Proceedings—Frontiers in Education Conference, FIE*, (February). DOI: https://doi.org/10.1109/FIE.2014.7044253

Husman, J., & Lens, W. (1999). Toward a model of the value aspect of motivation in education developing appreciation for particular learning domains and activities. *Educational Psychologist*, *34*(2), 113–125. DOI: https://doi.org/10.1207/s15326985ep3402_4

Hutchinson, J. R., & Huberman, M. (1994). Knowledge and dissemination and use in science and mathematics education: A literature review. *Journal of Science Education and Technology*, *3*(1). DOI: https://doi.org/10.1007/BF01575814

Kirn, A., & Benson, L. (2018). Engineering students' perceptions of problem solving and their future. *Journal of Engineering Education*, *107*(1), 87–112. DOI: https://doi.org/10.1002/jee.20190

Kirn, A., Godwin, A., Cass, C., Ross, M., & Huff, J. (2017). Mindful methodology: A transparent dialogue on adapting interpretative phenomenological analysis for engineering education research. *American Society for Engineering Education Annual Conference & Exposition*. DOI: https://doi.org/10.18260/1-2--28669

Kirn, A., Huff, J. L., Godwin, A., Ross, M., & Cass, C. (2019). Exploring tensions of using interpretative phenomenological analysis in a domain with conflicting cultural practices. *Qualitative Research in Psychology*, *16*(2), 305–324. DOI: https://doi.org/10.1080/14780887.2018.1563270

McGough, C., & Benson, L. (2017). Distribution of characteristic ways that students think about the future in large enrollment engineering classes. *ASEE Annual Conference and Exposition, Conference Proceedings*, *2017-June*. DOI: https://doi.org/10.18260/1-2--28187

National Academies of Sciences Engineering and Medicine. (2018). Implications for learning in school. In *How People Learn II: Learners, Contexts, and Cultures*, (pp. 135–162). DOI: https://doi.org/10.17226/24783

Nokes-Malach, T. J., Richey, E., & Gadgil, S. (2015). When is it better to learn together? Insights from research on collaborative learning. *Education Psychology Review*, *27*. DOI: https://doi.org/10.1007/s10648-015-9312-8

Pawley, A. L. (2017). Shifting the "default": The case for making diversity the expected condition for engineering education and making whiteness and maleness visible. *Journal of Engineering Education*, *106*(4), 531–533. DOI: https://doi.org/10.1002/jee.20181

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education*, *93*(3), 223–231. DOI: https://doi.org/10.1002/j.2168-9830.2004.tb00809.x

Reschly, A. L., & Christenson, S. L. (2012). Jingle jangle and conceptual haziness: Evolution and future directions of the engagement construct. In *Handbook of Research on Student Engagement* (pp. 3–20). DOI: https://doi.org/10.1007/978-1-4614-2018-7

Sinatra, G. M., & Chinn, C. A. (2011). Thinking and reasoning in science: Promoting epistemic conceptual change. In *Critical theories and models of learning and development relevant to learning and teaching* (Vol. 1, pp. 257–282). DOI: https://doi.org/10.1037/13275-011

Sinatra, G. M., Heddy, B. C., & Lombardi, D. (2015). The challenges of defining and measuring student engagement in science. *Educational Psychologist*, *50*(1), 1–13. DOI: https://doi.org/10.1080/00461520.2014.1002924

Smith, J. A., Flowers, P., & Larkin, M. (2009). *Interpretive phenonenologial analysis: Theory, method and research*. London: SAGE Publications.

Smith, J. A., & Osborn, M. (2007). Interpretative phenomenological analysis. In *Qualitative Psychology* (pp. 53–80). DOI: https://doi.org/10.1002/9781119975144.ch9

Smith, K. A., Sheppard, S. D., Johnson, D. W., & Johnson, R. T. (2005). Pedagogies of engagement: classroom-based practices. *Journal of Engineering Education*, *94*(1), 87–101. DOI: https://doi.org/10.1002/j.2168-9830.2005.tb00831.x

Stump, G., Hilpert, J., Husman, J., Chung, W.-T., & Kim, W. (2011). Collaborative learning in engineering students: gender and achievement. *Journal of Engineering Education*, *100*(3), 475–497. DOI: https://doi.org/10.1002/j.2168-9830.2011.tb00023.x

Walther, J., Sochacka, N. W., & Kellam, N. N. (2013). Quality in interpretive engineering education research: Reflections on an example study. *Journal of Engineering Education*, *102*(4), 626–659. DOI: https://doi.org/10.1002/jee.20029

Zhao, C.-M., & Kuh, G. D. (2004). Adding value: learning communities and student engagement. *Research in Higher Education*, *45*(2), 115–138. DOI: https://doi.org/10.1023/B:RIHE.0000015692.88534.de

How to cite this article: Barlow, A., & Brown, S. (2020). Discovering Upper-Division Students' Cognitive Engagement Across Engineering Courses—An Interpretive Phenomenological Analysis Approach. *Studies in Engineering Education*, 1(1), pp. 58–73.

Submitted: 14 August 2019 **Accepted:** 01 October 2020 **Published:** 20 November 2020

VIRGINIA TECH. | VT Publishing

Studies in Engineering Education is a peer-reviewed open access journal published by VT Publishing.

OPEN ACCESS