9-6-2016

Pushing and Pulling Sara: A Case Study of the Contrasting Influences of High School and University Experiences on Engineering Agency, Identity, and Participation

Allison Godwin
Purdue University, godwina@purdue.edu

Geoff Potvin
Florida International University

Pushing and Pulling Sara: A Case Study of the Contrasting Influences of High School and University Experiences on Engineering Agency, Identity, and Participation

ALLISON GODWIN

School of Engineering Education, Purdue University, West Lafayette, Indiana, 47907, USA, godwina@purdue.edu

GEOFF POTVIN

Department of Physics and STEM Transformation Institute, Florida International University, Miami, Florida, 33199, USA, gpotvin@fiu.edu

Abstract: This manuscript reports on a longitudinal case study of how one woman, Sara, who had previously considered dropping out of high school authored strong mathematics and science identities and purposefully exhibited agency through her experiences in high school science. These experiences empowered her to choose an engineering major in college; however, her introductory university engineering experiences ultimately pushed her out of engineering. Drawing on critical agency theory, we argue that by paying careful attention to how and why women author their identities and build agency through their experiences in high school, we may gain insight into why women may choose an engineering path in college. Additionally, we examine how Sara's perceptions of engineering structures and practices chipped away at the critical engineering agency she developed and caused her to leave engineering after her first year in college.

Keywords: critical engineering agency, engineering choice, college attrition

Identity development embedded in individualized science learning experiences and the development of critical agency are vitally important for students to engage deeply with science and engineering and ultimately pursue pathways into STEM careers. Other perspectives on how students begin their participation in narrowly defined communities of practice in science and engineering often fail to embrace concerns of equity and diversity (Basu & Calabrese Barton, 2008; Nasir & Hand, 2006). Individuals must learn not only STEM content but also must see these subjects as opportunities to make a positive change in the world and must deeply identify with the subject area in order to legitimize their burgeoning participation within STEM communities of practice.

Prior to college, many students do not have direct experiences with engineering content or practices. However, strong physics and mathematics identities have been shown to be vitally important in students' choice of engineering career paths in college (Godwin et al., 2016). In this work we use "math person" to refer to student's identities in mathematics because it is consistent with their own words and our prior work. Additionally, with the recent advent of the Next Generation Science Standards (NGSS), students may have more opportunities to experience engineering-related contexts within their K-12 science classrooms in the future. Thus, the science classroom is an important space in understanding how students develop identities in engineering-related subjects like science and mathematics and begin to see engineering as a potential career pathway. Students' experiences within science classrooms have the potential to foster critical agency through legitimate participation in the cultures of science and engineering and the valuing of the knowledge, identities, and contributions of students that may otherwise be overlooked. Often, education research is focused either on the K-12 STEM experiences of students or on the post-secondary aspects of content learning (as often found in various discipline-based education research communities). Our work spans secondary and post-secondary spaces to give a longitudinal description of how science experiences in high school and engineering experiences in college affected the critical agency of one woman, Sara[1].

This manuscript presents a case study of Sara, a student who had previously considered dropping out of high school but instead went to college and chose an engineering career path. Sara, a White, female student from a rural town in the Midwest region of the United States, developed critical agency in her high school science classroom through her involvement in a

1 A pseudonym.

clean water program (an extra-curricular activity heavily integrated into the science classroom) at her high school and the influence of her high school chemistry teacher, Mr. S. This work explores her trajectory as she progressed from a high school senior who intended to pursue engineering in college to a second-year college student who became disillusioned with engineering and discontinued her engineering pursuits. Sara told a story of how she became empowered to choose engineering and how her strong STEM identities pulled her towards a STEM major. She also articulated how her engineering experiences in college chipped away at her identity and agency in engineering which ultimately pushed her out of these pursuits entirely. At the end of these experiences, Sara believed, that "anyone can do engineering," but, "it's not right for everyone." This longitudinal work examines Sara's high school and university experiences (as perceived by her) to understand how the mixed messages around agency, participation, and inclusion found in science and engineering classrooms interact to pull and push students who are still at the periphery of engineering towards and away from the discipline. In this study we answer two research questions: 1) How does one student's (Sara's) critical engineering agency influence her participation in science and engineering? And 2) How does Sara's perceptions of the structures and practices in different communities of practice impact her critical engineering agency?

Overview of Research Context

We met Sara during our week-long observation of her high school in the spring of 2013 as a part of a larger study investigating how sustainability pedagogies impact engineering decisions for female students. The school was chosen based on the type of sustainability pedagogy being implemented in physics and chemistry classes within the school. At the time, Sara was in her senior year of high school and enrolled in AP Chemistry taught by one of the teachers being observed, Mr. S.

The high school is comprised of approximately 400 students and is housed in the same building as the small town's middle and elementary schools. Trade classes are offered in this high school with high enrollments of students who plan on finishing their education with high school or continuing on to a local community college. About two-thirds of Sara’s graduating senior class attended some form of college after graduating from high school. Forty-seven percent of the school population qualified for free or reduced lunch, which is on par with the national average for high schools (NCES, 2011). Sara was similar to many of her high school peers, coming from a lower-middle socioeconomic bracket consistent with the rural surroundings of her high school.

Mr. S

Mr. S began teaching at the high school four years prior to our observation to fill an urgent gap in the chemistry department. He had 23 years of industrial experience as a chemist prior to his teaching career. Mr. S practiced different teaching techniques within the classroom that encouraged individual learning to meet specific milestones without much traditional instruction. His informal classroom environment, markedly different than other science teachers at the school, and his industry experience and “real-world connections” made him a favorite with many students.

Mr. S knew Sara starting from the summer after her freshman year in high school through the clean water program and two subsequent summer trips as well as functioning as her chemistry teacher for her sophomore and senior year of high school. Sara came from a disrupted family (her parents had divorced), and her mother remarried during the time we were in contact with her. Mr. S became a proxy father figure in her life. Mr. S had a daughter close in age to Sara, and she began to spend time at their house on a regular basis. Through this relationship, Mr. S had a unique relationship with Sara and gave us a teacher's and mentor's insight into Sara's critical agency development during high school. He reported that Sara was a unique case in the way she enjoyed chemistry and how she "just gets it." In other ways, he told us, she was a typical high school student who enjoyed learning about things in which she was interested and did not enjoy or put time into learning things she did not care about.

Clean Water Program

A unique aspect of this school is an integrated service project that helps to provide clean water in a developing nation. This program was initiated by the students in response to an urgent need for clean water in the wake of a devastating natural disaster in that country. The science department head allowed two sections of his integrated chemistry and physics class to develop committees to research why the water in this country was polluted, how to raise money for this project, how to develop a system for creating clean water, and how to raise awareness for this project. Over three semesters, students researched and innovated upon an existing membrane technology from a start-up company to create a portable water purifying system that uses electrochemistry to filter and purify 55 gallons per minute with chlorine derived from salt, water, and solar energy. During the previous two summers before we met, Sara and other students from this school traveled to this country to distribute the water purification devices and train people how to use them. This water program had grown to pervade the entire curriculum and culture of the school and community.

University Environment

After completing high school, Sara attended a private, religious liberal arts university based on her desire to continue her competitive swimming in college. This school had recently started an engineering degree program. Her engineering classes focused heavily on programming skills and individual work on engineering projects. These courses were taught in a lecture and studio lab style focusing on coding, Computer Aided Design (CAD), and robotics. In this environment, Sara felt like she did not have as much experience as her peers and that her "engineering design courses [were] pushing me away." Her perception of what engineers do and how she identified with engineering was changed by her experiences and perceived lack of ability to fully participate in engineering.

Critical Engineering Agency

We use the framework of critical engineering agency to examine how Sara's experiences shaped her identity and agency and influenced her career pathway. Prior work in critical agency theory has examined how students can deeply engage with science learning within the classroom and has recognized that the identities, cultures, and discourses that students bring with them into the classroom are not always valued as legitimate mechanisms or resources to help them participate in science or engineering (Basu, Calabrese Barton, Clairmont, & Locke, 2008; Basu & Calabrese Barton, 2010; Godwin & Potvin, 2015). The development of this framework for examining issues of equity and social justice allows a deeper examination of the disciplinary communities that frame students' development and enactment of critical agency (Basu et al., 2008). This framework expands an examination of what it means to be a "type" of person who does science or engineering to include knowledge and experiences from outside of the classroom and the ways in which students, even those at the margins of their classroom cultures, can develop the agency needed to legitimately participate in their science communities. Critical agency was first developed in a physics context and asserts that students gain a deep understanding of the subject, identify as experts in the subject or related topics, and use the subject as a foundation for advocating change such that “their identity develops, their position in the world advances, and/or they alter the world towards what they envision as more just” (Basu & Calabrese Barton, 2009; p. 388). Our prior work has focused on translating a critical agency framework in an engineering context in both qualitative (Godwin & Potvin, 2015) and quantitative studies (Godwin, Potvin, Hazari & Lock, 2016).

We define agency as an individual’s ability to shape the world around them both in their everyday actions (e.g., using their knowledge of science/engineering to design solutions for their community) and in their broader goals (e.g., pursuing a career in a service-related engineering field). Thus, agency in a subject area, in this case, engineering, is directly related to feelings of empowerment in that subject area. This empowerment is intricately coupled with students’ identity development.

Recent research in science and engineering education confirms the impact that developing agency within classroom contexts has on identity development, performance, learning, and persistence within STEM fields (Basu & Barton, 2009; Basu et al., 2008; Basu, 2008; Brown, 2004; Buxton, 2005; Calabrese Barton, Tan, & Rivet, 2008; Hazari, Sonnert, Sadler, & Shanahan, 2010; Olitsky, 2007; Tan & Barton, 2008a). For these reasons, we have chosen to use critical engineering agency as a way to understand Sara’s trajectory from an uninterested STEM student to an engineering student in her first year of college and her process of leaving engineering in her second year of college. Chinn’s (1999) study of female students’ choice of engineering careers found that agency in choosing an engineering degree was influenced by powerful adults such as teachers and by curricular choices that did not segregate females or minorities but rather incorporated content and strategies personally meaningful to them. Other strategies identified as leading to females' development of agency included: encouraging students to express their voice through open-ended projects and presentations; allowing students to design activities for the class on specific topics and enacting those activities; establishing a classroom atmosphere that encourages students to voluntarily make comments and answer questions; promoting peer-to-peer learning; and, most important for this study, making connections with topics of relevance to the world and students' lives. Another study used critical agency theory to examine how sustainability pedagogies could create routes for female recruitment in engineering by connecting real-world topics with engineering design (Klotz et al., 2014). This study found that emphasizing the social aspects of engineering could draw more underrepresented students into engineering.

Critical engineering agency also encompasses the development of subject-related identities in one or more realms associated with engineering. The concept of identity used in this paper relates to an individual's self-beliefs at a particular moment in time and how these responses develop over time through the authoring of a self within a particular context (Johnson, Brown, Carlone, & Cuevas, 2011). By understanding this authoring, statements of how students see themselves within STEM roles and career pathways can be examined. The importance of understanding identity is highlighted by Brickhouse and colleagues (2000), who note students need to see themselves as the "kind of people who would want to understand the world scientifically" (p. 443) if they are to enter engineering and science careers. In this paper, we examine Sara's identities over time as she negotiated her decision to choose engineering in college and then leave engineering.

Identities are socially constructed, and viable identities rely on feeling recognized by others, seeing oneself as able to understand the subject (competence beliefs), seeing oneself as able to perform well in the subject (performance beliefs), and being interested in the subject (Carlone & Johnson, 2007; Cass, Hazari, Cribbs, Sadler, & Sonnert, 2011; Godwin & Potvin, 2015; Hazari et al., 2010; Potvin, Beattie, & Paige, 2011). These dimensions richly capture the formation of a student's role identity within STEM and have been used in both qualitative and quantitative studies (Cass et al., 2011; Godwin & Potvin, 2015; Hazari et al., 2010; Potvin et al., 2012). In this work, we focus on performance/competence, interest, and recognition self-beliefs as aspects in which students may identify as experts in one or more areas associated with engineering.

Performance and competence beliefs have been demonstrated to be indistinguishable from each other for students early on in their college careers (Potvin & Hazari, 2013). Students in grades 9-16 do not respond differently to measures of competence beliefs (i.e., ability to understand a subject) and performance beliefs (i.e., ability to get a good grade in a subject). Nevertheless, these constructs are important as precursors to interest and recognition for identity development (Godwin et al., 2016). Self-efficacy and social cognitive theory (Bandura, 1997) along with expectancy-value theory (Eccles & Wigfield, 2002) also demonstrate the importance of student perceptions of performance/competence on the activities in which they participate (Bandura, 1997; Bussey & Bandura, 1999). Additionally, high scoring students on self-report measures of academic competence are "more persistent, more likely to adopt mastery and/or performance approach goals, less anxious, process the learning material at a deeper level, and achieve better study results" (Ferla, Valcke, Schuyten, 2010, p. 519). The link between students' competency beliefs and their choices demonstrates that competence beliefs are a viable construct for understanding student persistence. Pajares and Graham (1999) also found that students' self-efficacy was the only motivation variable that predicted students' academic performance when compared to anxiety, self-concept, and self-regulation. For these reasons, it is important to understand how students' perceptions about their performance can influence their actual performance in a course. These student self-perceptions have an important and significant impact on how students see themselves and the kind of people they are authoring themselves to be.

Interest is a vital component of engineering identity development. Individuals' interests have a rich theoretical basis as a fundamental construct in models for human learning (Renninger, Hidi, & Krapp, 1992). An individual's interests defined as a "person's likes, preferences, favorites, affinity toward, or attraction to a subject, topic, or activity" (Dunst & Raab, 2012, p. 1621). Interest in a particular subject impacts how individuals function, produce particular ways of life, and engage with STEM (Carlone, 2012). Previous studies have shown that students who are interested in engineering show differential interest and skill in mathematics and science (Godwin, Potvin, Hazari, & Lock,013; Potvin, Tai, & Sadler, 2009) and that identities in mathematics, science, and physics are connected to students' choice of engineering as a career in college. For these reasons, interest in STEM has been an important part of behavioral research within engineering education (Geisinger & Raman, 2013; Godwin et al., 2016; Schreuders, Mannon, & Rutherford, 2009). Interest plays a key role in whether or not students want to take on the role identity of an engineer.

Recognition is also a significant factor in identity formation (Carlone & Johnson, 2007). In a recent paper using structural equation modeling to understand the impact of physics and mathematics identities on engineering choice, recognition was found to be the most important construct of identity on a choice of a career in engineering (Godwin et al., 2016). Recognition encompasses students' internalized beliefs of how others see them and accounts for the reflexive and social aspects of identity formation. Holland and Lave (2001) highlight this social component of identity formation, "because the self is the nexus of an ongoing flow of social activity and necessarily participates in this activity, it cannot be finalized or defined in itself, in its own terms" (p. 11). Authoring an identity is affected by how individuals interact with people in the communities and environments around them. Other work has underlined how students' beliefs of the ways in which authority figures view them can affect their perceptions of their own abilities (Bouchey & Harter, 2005; Eccles-Parsons, Adler, & Kaczala, 1982; Felson, 1989). Bouchey and Harter (2005) found middle school student perceptions of parents' and teachers' beliefs about their competence in math and science had a direct effect on students' perceived academic competence and their grades.

Many studies on engineering career pathways focus on academic preparation (Allen & Robbins, 2008), prior STEM experiences (Hazari et al., 2010; Maltese & Tai, 2011), self-efficacy and interest (Lent, Brown, & Hackett, 1994; Wang, 2013), awareness of engineering careers (Fouad, 1995; Karatas, Micklos, & Bodner, 2008), and the influence of others (Auger, Blackhurst, & Wahl, 2005; Fan & Chen, 2001). However, few studies focus on how students' perceptions of their ability to make a positive change in the world and their nascent STEM identities impact career pathways. Through Sara's story, critical agency theory provides an appropriate lens through which we can examine how Sara was empowered to develop an engineering identity and see engineering as a viable option for herself as well as understand her pathway out of engineering.

Communities of Practice and Critical Engineering Agency

In this work, Sara's perceived participation in engineering across her high school and university experiences was a significant factor in her career pathway. To understand this perceived participation, we use communities of practice to situate Sara's critical engineering agency. Authoring a new identity is situated in the dynamics of a community of practice or "figured worlds" (Holland et al., 2001). Figured worlds are ''socially produced, culturally constituted activities'' (Holland et al., 2001, pp. 40–41) where people come to conceptually and materially/procedurally produce new self-understandings (identities). Communities of practice are types of figured worlds because actors within this group define their membership by their culturally constructed and accepted practices of dialogue, actions, and values and legitimate participation results in identity formation. Lave and Wenger (1991) described a community of practice as:

> An aggregate of people who come together around mutual engagement in an endeavor. Ways of doing things, ways of talking, beliefs, values, power relations - in short, practices - emerge in the course of this mutual endeavor. As a social construct, a Community of Practice is different from the traditional community, primarily because it is defined simultaneously by its membership and by the practice in which that membership engages. (p. 464)

This approach to understanding identity development acknowledges the social context in which individuals shape and are shaped by participation in particular groups. Upon entry into a figured world, novices occupy peripheral social positions that are made available to them by more central members of the community. Novices can choose to exercise their agency to embrace, resist, or ignore the shaping forces within these communities. However, identities are formed through legitimate participation within the normative structures and practices of these communities. Newcomers to a community, like engineering, initially learn at the periphery. The things they are involved in, the tasks they do, and the actions they undertake are not key aspects of the community. However, as individuals develop more competence, they take on more central roles (e.g., an engineering student designing for a company during a senior design project). This type of participation “refers not just to local events of engagement in certain activities with certain people, but to a more encompassing process of being active participants in the practices of social communities and constructing identities in relation to these communities” (Wenger, 1998, p. 4). Becoming a central member in a community of practice involves developing identities – learning to speak, act, and create in ways that make sense to the community and fit with the cultural norms. If individuals are unable to move from the periphery to the core of a community of practice, they often do not form identities within a community and are not a full participant in the socio-cultural practices of the community.

Previous work in science education has focused on identities-in-practice within the context of an individual’s role and participation within a community of practice (Tan and Calabrese Barton, 2008b). Our work examines how Sara developed critical engineering agency in high school and the first two years of college. We believe that using both critical engineering agency and communities of practice frameworks allows us to examine her affective beliefs on her agency and identity in the context of her perceptions of her participation in science and engineering communities of practice.

Research Questions

In this work, we focus on two central questions:

1. How does one student's (Sara's) critical engineering agency influence her participation in science and engineering?

2. How does Sara's perceptions of the structures and practices in different communities of practice impact her critical engineering agency?

We focus on Sara's perceptions of her largely positive high school experiences and her mostly negative university experiences. The observation of what happened in these settings is important; however, *how* Sara internalized her experiences is the most important factor in determining her career pathway. Albert Bandura (1997) comments that "People's level of motivation, affective states, and actions are based more on *what they believe* than on what is objectively the case" (emphasis ours, p. 2). Understanding Sara's identity and the agency developed in high school and the decline of those beliefs in her university classroom is essential to understanding her trajectory.

Methods

Sara was chosen for this study based on reputational case sampling (Cohen, Manion, & Morrison, 2011). During a set of week-long observations of science classroom practices, her high school chemistry teacher identified her as an interesting case based on her history and engineering career interest. Additionally, her responses on an abridged version of the Sustainability and Gender in Engineering survey ("SaGE Survey," 2011) administered in her high school science course during the spring of 2013 indicated she held a high identity in mathematics and strong agency beliefs. Based on this, she was considered by the researchers to be an exemplar of a female student who developed critical engineering agency in high school and had changed her career decisions based on her high school experiences within and outside of the science classroom.

A case study is defined as "an empirical inquiry about a contemporary phenomenon (e.g., a "case"), set within its real-world context—especially when the boundaries between phenomenon and context are not clearly evident (Yin, 2009, p. 18)”. This approach is particularly appropriate for understanding how Sara, our case, developed critical engineering agency and experienced disconnect between her developed identity and empowerment and engineering experiences (i.e., the phenomena) over time. A case study uses multiple sources of data to provide insight into a particular issue (Miles & Huberman, 1994) — Sara’s choice of engineering — and builds upon the theory of critical engineering agency by exploring how her critical engineering agency was alternately fostered and hindered by her perceptions of her classroom experiences.

Data Sources

Data were collected longitudinally during five consecutive semesters (Spring 2013, Fall 2013, Spring 2014, Fall 2014, and Spring 2015) as “snapshots” of Sara’s journey from high school to college. During her senior year of high school (Spring 2013), an abridged version of the SaGE survey was collected and a face-to-face interview was conducted. Video of her AP Chemistry classroom and artifacts from her classes were also collected as part of the high school site visit. After she began college, another interview via telephone was conducted towards the end of Fall 2013 (Sara's first semester in college). A third interview was collected via phone at the end of her freshman year, in the spring of 2014. Syllabi from her engineering classes were also collected to understand the context and content of her engineering experiences in college. Additional interviews were collected in the same manner in her third and fourth semesters (Fall 2014 and Spring 2015, respectively) after she transferred to a new post-secondary institution. A pair of interviews with her high school chemistry teacher, Mr. S (in Spring 2013 and Spring 2014) also were collected (see Table 1). Semi-structured interview protocols were used with open-ended questions. After each prepared question, participants' responses were probed for more detail on the participant response.

Insert Table 1 here

The video, interviews with other students, and artifacts from her high school and university classrooms provide a rich context for understanding Sara's story which are included in the grounding of this study and claims made about the classroom environments in which Sara was situated. Our statements about what happens in her classes come not only from Sara's personal accounts but also from these additional data sources. While the focus of this study is on Sara's perceptions of her critical engineering agency and how she navigated through her high school and university experiences, we used these additional data streams to inform our interpretation. Consistent with our critical framework, we used crystallization to inform how our multiple sources of data, Sara's perspective and internalized beliefs about her experiences, and our own subjectivity influenced our findings (Ellingson, 2009). This approach is a poststructural approach to triangulation which stresses the socially constructed nature of reality and allows for a multifaceted, although partial and potentially different, perspectives within the same study (Richardson, 2000). In our work, we have prioritized Sara's voice and perceptions over imposing our interpretation of her context onto her descriptions. We use her context and other information as other facets of her narrative that provide alternative perspectives.

Analysis

We used a Directed Qualitative Content Analysis method to analyze our data (Mayring, 2000). A directed approach uses existing theory to define the initial coding categories. This technique has been traditionally used to analyze large amounts of text into a number of categories that represent meaning (Hsieh & Shannon, 2005). Qualitative content analysis has moved past its more “quantitative” origins to the interpretation of content through a systematic process of coding and meaning-making. The goal of a directed approach to content analysis is to validate or conceptually extend an existing theoretical framework or theory. Thus, this approach is particularly suitable for understanding critical agency in a new context, specifically engineering. The steps for this approach include creating definitions and examples of coding rules based on theory, deductive coding of interview transcripts, revision of categories based on data, and interpretation of the results (Mayring, 2000). We used deductive codes for Sara’s descriptions of her various STEM identities including the constructs of performance/competence, interest, and recognition as well as her agency (or perceived agency) and her descriptions of her participation in the classroom and what allowed that participation. Data were also inductively coded to examine new themes in the narrative.

In coding the data, a constant comparative method was used to move between the data collection and the data analysis to inform additional data collection. This method also involves finding similarities between statements and incidences in the same and different interviews and observations (Miles & Huberman, 1994). We employed this method as we collected each interview and other data sources. During this process, memo writing and diagramming were important reflective steps to elaborate categories and take a step back from the detailed coding scheme at the transcript level to organize the developing categories (Miles & Huberman, 1994). We also used incoming data to iteratively inform the conclusions we drew from the data. As Sara's story unfolded, we were careful to note any contradictions in themes and include them as counterpoints in this analysis.

In this paper, we tell Sara’s story in chronological order. First, we present her account of experiences in high school that pulled her toward an engineering career and led to her developing a strong critical engineering agency. Then, we describe her account of experiences in college that conflicted with her identity and pushed her out of engineering.

Pulling Sara

In our initial interview, Sara described how she went from being “totally uninterested” in science in middle school to being very interested in chemistry in her AP science class. Mr. S also described her initial trajectory, “she started out leaning towards, um, quitting school and going into some sort of charitable work…. she still wants to do that [charitable work], but if she goes into the engineering side, um, she thinks she can be much more effective.” Sara echoed this prior trajectory and noted the influence of Mr. S on her pathway, “I think that if I never would have gotten into chemistry I wouldn't have gotten as close with my chemistry teacher, Mr. S, and that wouldn't have happened I could have been on a totally different path. I was going to go for my GED or whatnot and so that was one of the key things that helped influence where I was going.” Sara illustrates how her performance/competence beliefs about science allowed her to form an interest in science and the connections she could make to mathematics. She spoke about how she spent more time engaging with science once she became interested in the subject:

> I used to get like B’s in math and science and I was like okay at it. And I felt like I was decent but I just, it never fully, like I never just liked it a lot. I was like I don’t care…And then whenever I got into high school it was just like oh, this is a different way to look at things. This is like you can use math to like figure out things, and you can see how things move and work and function and like whatnot. So I guess, I was just a lot more interested, and whenever I’m interested then I like put my time in like, like everyone does and so, I mean, I guess that’s what the difference is. I don’t know. In eighth grade our math teacher was really good so then like I started liking math like a lot better then. And

> then, like algebra came really easily to me and then after that I just started excelling both in the science and math department so. And then once I started excelling then I like liked it a lot better because I don't like to do things that I'm not good at so.

This cycle is consistent with previous quantitative work that showed performance/competence must be mediated by interest and/or recognition in order for strong subject-related identities to form (Godwin et al., 2016). Sara described that when she did "okay" she also just "didn't care," but when she started doing well in science classes she started liking the subject. A lack of interest in middle school in her science courses prevented Sara from engaging with science and forming a science person identity. However, her experiences in high school changed her perceptions about science as a discipline.

As the content of her courses changed and became more interesting, her desire to be an integral member of her science classroom grew. Sara began to more deeply identify with science and took on a leadership role within the classroom. She described how "everyone would come [to me] the day before the test" and ask how to do specific chemistry questions. She felt that she contributed to her chemistry study group in her AP class through her ability to do "all like the calculations and stuff because…I just get it and then they'll [be] looking at it and they [are all] like I do not get this at all. So then, then I help out a lot of times." When we first met Sara, she was deeply engaged in the content of her science classroom and she clearly felt that she was recognized by Mr. S and other students as a "science person."

Sara described Mr. S's influence on her desire to pursue a science career by saying, "I guess like for narrowing my, what I wanted to do, [Mr. S] was definitely like the biggest factor in it." She described how she "got to know" Mr. S through the clean water program and through being in his chemistry and later AP chemistry classes. As her attitude toward learning changed through her interactions with her science teacher and her involvement in the clean water program, Sara began to see herself as the type of person that could actually choose a STEM career. In her junior year, she came to Mr. S with the desire to pursue a degree in some “scientific thingy” and, through his influence, she explored the options available to her. By the time we met her as a senior, she had chosen to pursue chemical engineering and had already applied to several engineering colleges.

The clean water program had a significant influence on Sara's identity and career interests:

> It [experience with the clean water program] definitely led me to like want to do something and like especially with the water purification system, like we created, like we didn’t create the system but we definitely like renovated it and made it better and more efficient, like it purifies water a lot faster and better and lasts a lot longer. And we figured out ways to, um, make the battery work like solar panel stuff. So I mean, it kind of just showed me that I like doing that kind of things and figuring out, and then like I can still help people but then design things through my like potential career or science or whatever.

Sara repeatedly commented on how her experiences in the clean water program and seeing how science and engineering could positively impact the world increased her desire to choose an engineering career. Her desire to be an engineer derived from what she could do with that career (e.g., a means to an end) and not necessarily for the career as an end itself.

Sara was pulled towards engineering through the influence of multiple key people and experiences in high school. The combination of her participation in the clean water program, her relationship with Mr. S, and her interest and authoring of an identity in mathematics and chemistry empowered her to pursue a previously-unconsidered degree in chemical engineering at a large, engineering-focused school. Also factoring into her choices was her desire to continue competitive swimming, one of her other passions, in college.

Pushing Sara

Engineering Experiences

The second interview with Sara took place near the end of her first semester in college, several months after our initial data collection and after her transition from high school to college. Instead of enrolling in the engineering-focused school she had indicated in her first interview, she chose to attend a small, private, religious-based university. This school offered her a full swimming scholarship that facilitated her swimming activities swim while pursuing an engineering degree. Sara’s competing interests in her extra-curricular activity and interest in engineering combined to determine her choice of college. The idea of competing interests is discussed by Osborne, Simon, and Collins, who state that behavior “may be influenced by the fact that attitudes other than the ones under consideration may be more strongly held” (Osborne, Simon, & Collins, 2003, p. 1055).

Sara’s college choice significantly affected her experiences. Because of the nature of the institution, she had to follow certain practices such as attending chapel twice a week, following a dress code, adhering to a curfew, and requesting to leave campus on the weekend. Sara explained that she did not expect to have limited freedom in college but rather to have the opportunity to make her own choices. While she felt that she was getting a wonderful education and loved the opportunity to pursue competitive swimming, she did consciously make sacrifices to balance her competing interests. She acknowledged that the stricter environment was “probably good for me, just cause even though rules can get really annoying it does keep me on task, keeps me out of trouble, and stuff and whatnot." She struggled with following the rules early on but, over time, developed friendships and connections nonetheless.

Since this school did not offer chemical engineering as a major, Sara had to choose a different discipline. She chose geological engineering, which was a new major at this institution. She rationalized this: "I might as well try it out and see if I like it and I'm pretty much enjoying it." To Sara, geological engineering was the closest available option to chemical engineering. However, note that this choice of major may not be as spontaneous as may initially appear. Sara spoke often of her experiences in the clean water program at her high school and how it affected her, and she saw geological engineering as a way to bridge her college major and her interest in using her high school experiences while attending a school that allowed her to swim competitively.

In subsequent interviews over the next academic year, Sara described her difficulty in transitioning to the university environment. She described her engineering classes as "difficult" and "confusing." The classes focused primarily on individual assignments and coding in an electrical engineering context with one end-of-semester team project. Her engineering design course did not foster her interest in engineering or connect with her prior experiences. Instead, Sara viewed her engineering design course as a barrier to overcome in order to reach the more interesting and relevant engineering courses in her future:

> I've heard that once I get past these introductory level classes they [upper-level engineering courses] are a lot different and better. It's just kind of boring right now. 'Cause I think it's just the information and stuff. So, apparently it gets better (laughs).

When asked if she felt like an engineer, Sara said that she did not "know enough" to be an engineer. Her discussion of what it meant to be an engineer centered on passing a threshold of engineering content knowledge. She said that compared to other “kids” who had prior experience in programming or design, she was just a “newbie.” She defined being an engineer as having certain knowledge as measured by successful completion of particular coursework.

While Sara did not report feeling like an engineer at this stage, she talked about her contributions to engineering group design projects. While she appreciated her group members’ “different attributes coming together and things that are their strengths in different group projects,” she felt that she specifically contributed to being “better at the whole drawing parts and stuff and just like conceptual things like being able to see the bigger picture of it.” When asked to reflect on her future track for engineering, Sara did not have a clear picture of what she wanted to accomplish. She just pictured herself working in industry, creating and designing things with her requisite engineering knowledge. In her discussion, she kept coming back to the influence of her chemistry teacher, Mr. S, on her choices:

> I think that if I never would have gotten into chemistry, I wouldn’t have gotten as close with my chemistry teacher and that wouldn’t have happened. I could have been on a totally different path……I mean he helped me like chemistry a lot and then just talking to him and then like well that and the influences of the clean water program I knew I wanted to do something with geology or helping people. And that and [Mr. S] helped connect those ‘cause he like he has a degree in chemical engineering and I was going to go for that.

Despite the fact that she disliked her courses in her first year of engineering and thought that they were boring, Sara was still set on continuing in engineering during this round of data collection. She did admit thinking about switching out of engineering, but dismissed that idea by focusing on the promise of future engineering classes that “will get better, so I am kind of stressing that." The reasons that she cited for thinking about leaving were the difficulties that she had in learning the required design software as well as a lack of interest in her design courses. She described her lack of interest in the courses as the result of course content that did not tie to her experiences and her feeling of being an "outsider" in the classroom.

Leaving Engineering

Contacting Sara in her third semester of college for further interviews proved to be more difficult than in prior semesters. She did not respond to her previous university email address and was no longer listed in the directory of that institution. Contacting Sara by phone, we found out that Sara had changed institutions, moved to a new city, and enrolled in college as an "undeclared" major. The institution she chose to attend was quite different that her first university. Located in a much larger, urban city, this public state school was over ten times the size of her previous institution. It offered degrees in almost double the number of engineering disciplines, but she said that she "couldn't see herself doing it anymore."

She voiced her doubts by saying, "I, like, before I got into engineering I had like zero engineering experiences with anything, so like I had to teach myself on my own." This statement is striking because Sara did have real engineering experiences before college, but the context in which engineering content was taught prioritized technical skills, coding, and CAD ability over her hands-on experiences in design, piping and water flows, installation of design projects, and communication with stakeholders in those communities, all of which characterized her clean water program experiences. She described how other students had robotics or programming experiences before college and that these students had "actual" engineering experiences, but she did not. Additionally, her perceptions of what a day-to-day career in engineering entailed had changed as well. She went from describing how she was excited about an engineering career that focused on “figure[ing] out how things work and design things like that so that’s how the engineering part would come,” (Interview 1 - Spring 2013) and “I like doing that kind of things [experiences with the clean water program] and figuring stuff out, and then like I can still help people but then design things through my like potential career or science or whatever” (Interview 2 - Fall 2013) to stating,

> I didn’t just want to sit at a desk and like stay inside all day and not be very, like doing, like being, like most of, at least from what I’ve seen, it seems like most of engineering was kind of like indoors at a desk and that didn’t really appeal too much to me.

During the period when she saw engineering as a career in which she could actualize her agency to create practical, hands-on solutions, her intentions to persist in engineering were strong. However, the experiences in her university environment led her to disconnect her experiences from her perceptions of engineering.

Her experiences in her engineering program changed her perceptions of an engineer from being a person who serves others and makes the world a better place through technological innovations to a person who isolates him/herself and works on a computer. The disconnect between her real-world engineering experiences in high school and her engineering experiences precipitated her decision to leave engineering for another STEM field. The experiences that she had in high school left a lasting impact on her desire to obtain a college degree and interest in STEM. However, she did not feel like she fit in engineering any longer.

We spoke to Sara again during her fourth semester of college (the second at her new university). She chose to major in exercise science with a long-term goal of being a physical therapist. She connected this career pathway with her mathematics and science identities and described it as being hands-on and allowing her to make a difference. Her classes “weren’t all that challenging," but she enjoyed working with others and using her abilities in ways that she could not envision with a career in engineering. Her move from engineering to exercise science had less to do with losing her STEM identities or agency beliefs and more to do with finding a career that fit with how she saw herself.

Discussion

The study of Sara is compelling because it illustrates how fostering specific self-beliefs and classroom interactions attracted one woman into engineering, even as late as her senior year of high school. This study also illustrates how her identities and agency beliefs, neglected in the first few years of college, precipitated her leaving engineering. This case is not just an illustration of critical engineering agency; it augments our understanding of how critical engineering agency can be developed through high school experiences and the importance of connecting engineering in the classroom to authentic experiences that could have fostered Sara's empowerment and identity development. This story has implications for how science can foster STEM career intentions, how engineering is represented as a discipline, factors that could make engineering more attractive to women, and the struggles students may face in the first year of engineering in college. Sara's case illustrates one example of the power of identity, agency beliefs, and the role of change agents in students' lives. It also shows that while many students focus on a STEM career as early as middle school and many girls lose interest in mathematics and science early (National Science Board, 2003), high school may not be too late for particular students to develop a desire to pursue engineering career pathways. This case study is not generalizable to all students; however, we believe that there are transferable implications from Sara's story.

In this discussion section, we first examine the opportunities created in the high school science classroom for Sara to develop critical agency in support of greater participation and learning in and out of her science classroom. We also discuss how Sara's perceptions of the structures in her post-secondary engineering environment chipped away at her critical agency and ultimately made her feel that engineering was "not for her." We then discuss the relationship of authoring identities in STEM, agency, and career outcomes.

Creating Opportunities for Participation

How might a science, mathematics, or engineering class change to reflect Sara's experiences? How might we change the actors, the script, or the stage? Sara was successful in navigating a successful path that merged her experiences with the clean water program and her science learning. This negotiation was also facilitated by her unique and strong relationship with her high school science teacher, Mr. S. His role in Sara's college decisions gives a powerful example of how creating opportunities for legitimate participation in a community of practice fostered Sara's interest in a STEM career. The student-centered high school experiences that leveraged real-world engineering experiences made a significant and positive difference in empowering Sara to choose engineering. However, such experiences must also be supported in post-secondary education to support a continued, constructive development. As Sara noted, in reference to her coding experiences to make a positive impact on critical engineering agency as described by Sara, "I didn't feel whenever we had to follow a strict thing, it [engineering] wasn't as creative. But when like with [the clean water] program it was kind of because we had to think of different ideas and like improve it and whatnot."

Several different factors emerged as important for Sara's empowerment to move from potentially dropping out of high school to pursuing engineering in college. Her critical engineering agency played an important role in her major choice: her interest in engineering and her decision-making process were propelled by her interest in mathematics and science (specifically, in chemistry) as well as Mr. S's recognition of her as a science person and her desire to help people and make a difference in the world through her actions.

Role of Mr. S in Sara's Trajectory.

Sara's chemistry teacher crossed boundaries from just being a high school teacher in the classroom setting to being a mentor, clean water project leader, and father figure in Sara's life. His relationship is particular in Sara's pathway into and out of STEM. She credited him with connecting her newly fostered interest in chemistry with her desire to help people through a career in engineering. Not only did Mr. S give Sara guidance in her career choice, but he fostered her interests and recognized her as a student capable of achieving great things. Elsewhere in her life, Sara had not been recognized as a talented student in science, but Mr. S gave her that recognition, which went beyond simple acknowledgment of being able to get good grades. Sara described her in- and out-of-school experiences, "I had more time to get to know [Mr. S] better, and so I got to know more about him and engineering and he told me that he thought I would be good at it." Mr. S empowered Sara by connecting her identities and agency beliefs with her experiences in the clean water program and the science curriculum to give her an authentic voice in the classroom.

Mr. S's classroom prompted students to negotiate their own learning and relate their experiences outside of the classroom with the canonical knowledge taught in traditional high school classroom environments. Students were regularly asked to draw connections between what was taught in class and their personal experiences. The class was also structured around self-paced, active learning activities in class rather than direct instruction. Sara described how this environment fit her:

> Because most teachers are just like lecture for so long. I do notes, sit there forever, get bored, try not to fall asleep and whatnot. But he [Mr. S] just, I love it, like because I can come in here, I don't feel pressured to get my work done but I, like I'm this type of student that like I will get my stuff done, like I don't know why it matters when I get it done as long as I do. And that's what I've never understood and [Mr. S] gets that.

He also asked students to take their learning and apply it to "big picture" problems like bringing clean water to developing countries. Mr. S's unique role in Sara's life allowed him to guide her in her development in this hybrid space.

Lack of Interest and Participation in Engineering Courses.

We also note that Sara did not describe her first year engineering and mathematics courses as exciting or interesting. She saw them as stepping stones to more interesting courses to come later. Her lack of interest led her to put less effort into these activities and stifled her motivation to continue in engineering. She did not have an identity as an engineer or engineering person from these interactions with an engineering community of practice. She described a lack of seeing herself as an engineer because she "didn't know enough yet," that she felt like a "newbie," and that "this engineering thing really isn't for me." Her discussion of her engineering courses highlighted her lack of legitimate participation and frustration that engineering was an isolating discipline, "Whenever I have questions and whenever I am stuck, I can't just go over to the teacher [college] and ask for help because he might not be in his office, he might not be there, and so I've kind of had to also not only work on my own." Sara repeatedly discussed how difficult her engineering class was and that she just had to do it on her own. This classroom experience was vastly different than her high school environment in which she felt like a central member. We are not suggesting that engineering identity development *cannot* occur in first year engineering courses, but Sara's case illustrates the importance of feeling supported and having legitimate participation within a community of practice to facilitate an engineering identity, consistent with other work (Du, 2006; Pierrakos, Beam, Constanz, Johri & Anderson, 2009; Godwin & Potvin, 2015). Such lack of legitimate participation is connected to students' depressed feelings of belongingness and adds to many students' decisions to leave engineering (Geisinger & Raman, 2013; Seymour & Hewitt, 1997).

This case illustrates how Sara's isolating experiences of individualized, technical work with no community support may push out students at the margins out of engineering. Sara demonstrated that she did have the potential to be a successful engineer through her knowledge, passion, and desire to pursue an engineering career. Her high school classroom and clean water program experiences had significant, positive impacts on her development of STEM-related interest, identities, and agency beliefs which, in turn, played a role in her decision to enroll in engineering. However, these aspects of her critical engineering agency were not fostered in her university environment. Sara's experience highlights the vital need for educating our engineering instructors through professional development about why student-centered teaching, affinity groups, and creating authentic engineering experiences connected to real-world problems is so important to retaining talent in engineering which are often not widely used practices but evidenced-based ways to improve student engagement (Borrego, Froyd, & Hall, 2010; Catalano & Catalano, 1999; Dym, Agogino, Eris, Frey, & Leifer, 2005; Fleming, 2012; Chanderbhan-Forde, Heppner, & Borman, 2012). Sara discussed her lack of engagement in her engineering classes saying,

> I struggled with engineering design on the computer was ‘cause it was like very um, more independent than... I'm generally and independent learner, but like we weren't really taught how to like pretty much anything. And, I like before I got into engineering I had like zero engineering experiences with anything, so like I had to kind of teach myself on my own. And, I just didn't fully grasp it all because of that I don't think.

Sara had a unique perspective to offer in her university classroom, but she felt she never had the chance to use or share it and her clean water experiences in her first year. She hoped her experiences would be relevant in later engineering classes “whenever I get to like those classes involving more of the like geological aspects that I think that it will be more like relevant or whatever, but it’s not now.” The practices of educating engineering students emphasize professional training and acquiring the narrow content knowledge, forms of discourse, and expertise to be an engineer. Sara emphasized this point by saying that she did not feel like an engineer during her first year of coursework because she did not “know very much stuff yet” and was “not even close to as smart as I need to be.” Sara viewed competence in engineering to be about acquiring enough of the “right” knowledge to participate in an engineering community of practice. The narrow definition of what constitutes engineering knowledge within her environment functioned as a significant barrier to Sara’s participation and persistence in engineering.

Implications for Teaching Engineering.

Engineering as a field makes significant societal impact. However, course content is often tied to understanding complex equations, abstract theories, and “getting the right answer” rather than emphasizing the practical and societal importance of engineering knowledge (Cech, 2008; Stevens, O’Connor, Garrison, Jocuns, & Amos, 2008). The perceived lack of a connection to societal problems is a top barrier to women entering engineering (Widnall, 2000). Similarly, female undergraduates often see projects in the broader context of social and environmental impact while males focus on more technical details (Lord, 2010). Sara's case illustrates the importance of connecting engineering content to students' interests, prior experiences, and to society at large to foster critical engineering agency. She described the classroom environment saying, "most teachers are just like lecture for so long, do notes, sit there forever, get bored, try not to fall asleep and whatnot. But [Mr. S] just, I love it, like because I can come in here and get my work done and go to [Mr. S] and he tells me like oh, okay, so, yeah…and he connects stuff to things that are more like relevant or whatever." Sara went on to describe how the clean water program and Mr. S helped her decide on an engineering career path. When Sara described her engineering class experiences, she used words like "boring" and "pushing me away." Recent movements in science education have emphasized the importance of socioscientific inquiry (Aikenhead, 2006; Sadler, Barab, Scott, 2007; Osborne, Williams, Tytler, & Cripps Clark, 2008) and connections between science and students' personal experiences for agency and identity development (Hazari et al., 2010; Mallya, Mensah, Contento, Koch, & Calabrese Barton, 2012; Tan, Calabrese Barton, Kang, & O'Neill, 2013). While some engineering programs do implement these practices, many do not. Sara's story highlights the need not only to teach engineering content but also to connect that content to students' experiences in meaningful ways. Sara discussed how her chemistry classroom was. Common calls for engineering education reform include

> strengthening the mathematical basis of engineering; increasing the focus on design and laboratory work; emphasizing communications and social skills; integrating the liberal arts, particularly social sciences, into the curriculum; incorporating good teaching and

> continued curricular development; and instilling in students an appreciation for lifelong learning (National Research Council, 1995 as cited in Riley, 2003, p. 139).

This mainstream approach to engineering education may ignore how content can impact students' identities and agency and may differentially affect women and students of color. Sara's case is one illustration of how engineering environments can negatively impact a student's intentions to persist in engineering and has implications for "traditional" engineering education.

Adding Depth to Critical Engineering Agency

The positions that students are afforded in particular communities of practice can significantly impact their abilities to author identities, engage with learning, and develop and leverage their agency. The environments Sara experienced juxtaposed two very different positions. In her high school classroom, Sara's opinions and prior knowledge were valued. Mr. S connected her experiences with the clean water program to the science curriculum which created opportunities for her to see herself as a central and legitimate participant in science. He also created opportunities to learn about the clean water program through technical content as well as sociocultural issues in developing countries. She melded another salient identity as someone who could effectively use science in another country to improve the resident's quality of life, solve problems, and make a difference in the world. However, her position within engineering in college did not afford the same opportunities to use her background knowledge and experiences to author an identity and defined a space in which she did not feel like she had agency.

Influence of Context on Identity Saliency

Students have multiple identities that interact within a particular context (Stryker & Burke, 2000). Depending on one's positionality, each identity has differing authority and salience in the process termed by Bakhtin as "dialogism" (Bakhtin, 1981). Each identity has a different value and position as associated with a particular social group or individual that wields different power within a community of practice. In authoring identities, a person is negotiating how they align their roles with people within their community of practice and fit their own identities at any point in time within the group. In this process, identities develop and are stable only as long as the relational authority they claim and the space of authoring is available.

In our prior work, we examined the paths between the constructs of identity, agency beliefs, and engineering choice (Godwin et al., 2016) and the ways in which women spoke about their identities in physics, mathematics, science, and engineering that impacted how they saw themselves as members of the engineering community (Godwin & Potvin, 2015). However, these studies did not give a thick description of how a student's positionality and the affordances of their environment can create spaces conducive to authoring identities and agency. In her high school science experiences, Sara authored identities counter to the "normative" culture and perception of engineering as a technocratic, male-dominated field strengthening her agency and empowerment to choose engineering as a major in college.

However, once the boundaries of her space of authoring changed, her ability to develop her critical engineering agency was hindered. Her engineering instructors and the classroom norms valued technical knowledge and only the "right" engineering experiences prior to college. This change in what knowledge and participation were valued in the classroom caused Sara to feel like she was not an engineer because she did not have the same experiences as other students in robotics and coding. Sara did not see herself as an engineer because, within her community of practice in engineering, she did not fit within the cultural norms that shaped what it meant to be an engineer. She shared with us that she left engineering not because she did not see herself as a math or science person but because she did not think that "it [engineering] really fit [her] personality." Sara could not articulate why she did not feel like she fit within engineering specifically, but that it just "wasn't for me," and she "just [didn't] see myself doing it for the long-term." Sara's perceptions of engineering coming into college fit with the desire of many engineering educators to "change the conversation" about what engineering does and how it impacts others (Committee on Public Understanding of Engineering Messages, 2008). Unfortunately, the unreformed curriculum, atomized work, and lack of connections to society did not support Sara's identity and agency development.

Implications for Using Critical Engineering Agency

This case study adds to our understanding of how critical engineering agency can function as a lens to understand how students can be given space to author their identities and the subsequent impacts on outcomes like career choice. Sara described specific examples of both positive and negative experiences that impacted her agency and identity development. Other frameworks to understand student career choices, especially engineering, have focused on the individual's beliefs of self-efficacy, outcome expectations, predispositions (Lent, Brown, & Hackett, 1994); lack of belonging (Marra, 2009); structures that impact students like inadequate teaching (Barinard & Carlin, 1998; Christopher Strenta, Elliott, Adair, Matier, & Scott, 1994; Geisinger & Raman, 2013; Johnson, 2007; Seymour & Hewitt, 1997); the competitive environment fostered in science and engineering classrooms (Strenta et al., 1994); or overt discrimination (Good, Halpin, & Halpin, 2002; McDade, 1988; Tonso, 1999). These studies highlight interventions at the individual level or at the institutional level that could be implemented to improve recruitment and retention. Critical engineering agency, by contrast, allows us to examine the mid-level of developing identities within the communities of practice in the subculture of a classroom as well as with a discipline as a whole. Investigations at this middle scale can allow us to understand how students learn what it means to be a scientist or engineer, how they develop (or not) identities within their classroom communities of practice, and how they connect these identities with their career goals and learning.

Critical Engineering Agency in the Science Classroom

Our study suggests a new and potentially powerful direction for understanding how students begin to form subject-related identities within their secondary and postsecondary environments and how these self-beliefs impact career outcomes. Examining critical engineering agency in the context of communities of practice allows us to see the connections between science classrooms, students' positions, outside learning opportunities, and career choices. In the case of Sara, a student who had considered dropping out of high school, we see how learning to meaningfully participate within a science community was in part due to Mr. S's ability to connect Sara's interests in the clean water program with science learning in the classroom, her identification with science, and her empowerment to see a STEM career as a positive way to make a change in her community and world. Acknowledging and supporting this type of identity development and valuing Sara's knowledge that she brought into the classroom as a legitimate form of participation within that community allowed her to become a central player and leader within her science sphere of influence and opened pathways into STEM fields. We can learn from this case ways to redefine what it means to be a science person within the science classroom.

Critical Engineering Agency in the Engineering Classroom

As a direct counterpoint, Sara's experiences within her engineering classes were isolating and did not empower her to take on a participatory role. The knowledge that was valued within Sara's courses was the knowledge of engineering design processes, computer programing, and having the right answer to a problem. Arguably, Sara would have made excellent contributions to engineering with her strong desire to “help people out” and her real-world engineering experiences. Sara did not truly participate within the college engineering community of practice because this environment did not offer her the space to author an engineering identity or see engineering as a career path to make a difference in the world. She could not leverage her existing agency and outside knowledge as sanctioned ways of knowing within engineering. Educators must attune themselves to learning as a multifaceted endeavor that has identity authoring and agency development at its core.

Limitations and Future Work

We acknowledge the limitations of no direct observations of Sara’s college classrooms on framing this work. While Sara’s perceptions of her experiences are the most important part of understanding her critical engineering agency (Bandura, 1997), external information about the class structure, peer-to-peer interactions, and other students’ perceptions about the course could have provided additional insight into the structures of the classroom and Sara's position in it. Without this additional information, we can only provide Sara’s story from her perspective and from the static artifacts collected. There is a deep and rich context for this work over a two-and-a-half-year period. We have worked to present the most salient details for understanding the “push” and “pull” effects on Sara’s identity and agency within her science classroom and engineering experiences. Future work could include examining other facets of Sara’s story including the particular influence of Mr. S and the impact of classroom environments on Sara’s perceptions.

Additionally, we acknowledge that the findings of this work are limited to a single case. Sara’s experiences do align well with other research on women in engineering; however, each student's story is unique in some aspects. The course structures that were supportive and detrimental to Sara’s critical engineering agency may be different for other students. Some students were currently excelling in the engineering learning environment and were participating as legitimate members of the engineering community. However, Sara reported that most of these students were white and male. Sara stated that she was one of four female students out of almost 150 students in the first-year engineering program at her school. Seeking ways to change engineering instruction that not only favors the existing classroom majority but also underrepresented students is a vital part of creating an engineering community of practice that is more broadly inclusive of the population.

Sara’s story is the beginning of an exploration of how critical engineering agency can positively impact the transition from high school to college environments for diverse learners. Our future work includes exploring how other underrepresented students in engineering develop and leverage their identity and agency in engineering. We would also like to examine how the integration of out-of-school experiences with in-school instruction provides ways for learners to support their science and engineering learning.

Conclusion

Sara’s trajectory has shown us that the development of critical engineering agency can positively impact career outcomes, like engineering choice. This work also illustrated the importance of the authoring space available for students within their experiences in the secondary and postsecondary spaces. Direct participation in course content and feeling like her knowledge and experiences were valued was vitally important for Sara’s development. The structures in her engineering classes distanced her relationship with her professors, the content, and her ability to connect her out-of-school experiences with her course learning. The emphasis on technical prowess and individual work isolated Sara. This environment pushed Sara out of engineering in spite of her initial interest and talents. By the end of this study, Sara saw engineering as individual desk work that did not have real-world impact so she chose another career path that better fit with her STEM identities and agency. Creating classroom environments that support students in the authoring of their identities and create opportunities to see science and engineering as a way to make a positive change in the world can allow students to be active participants in their own learning and can foster and support STEM-related career choices.

Acknowledgements

This work was supported in part by the U.S. National Science Foundation through grant 1036617 and a Graduate Research Fellowship. The opinions expressed are those of the authors and do not necessarily represent those of the NSF. The authors wish to thank the participants of this study and the editors and anonymous reviewers whose constructive comments improved the quality of this article.

References Cited

Aikenhead, G. S. (2006). Science education for everyday life: Evidence-based practice. Teachers College Press.

Allen, J., & Robbins, S. B. (2008). Prediction of college major persistence based on vocational interests, academic preparation, and first-year academic performance. Research in Higher Education, 49(1), 62-79.

Auger, R., Blackhurst, A., & Wahl, K. (2005). The development of elementary-aged children's career aspirations and expectations. Professional School Counseling, 8(4), 322-329.

Bandura, A. (1997). Self-efficacy: The exercise of control. Worth Publishers.

Bakhtin, M. M. (1981). The dialogic imagination: Four essays. (M. Holoquist, Ed., Trans. & C. Emerson, Trans.). Austin, TX: University of Texas Press.

Basu, S. J. (2008). Powerful learners and critical agents: The goals of five urban Caribbean youth in a conceptual physics classroom. Science Education, 92(2), 252–277. doi: 10.1002/sce.20241

Basu, S. J., & Calabrese Barton, A. (2009). Critical physics agency: Furthur unraveling the intersections of subject matter knowledge. Cultural Studies of Science Education, 4(2), 345–371. doi: 10.1007/s11422-008-9155-4

Basu, S. J., Calabrese Barton, A., Clairmont, N., & Locke, D. (2008). Developing a framework for critical science agency through a case study in a conceptual physics context. Cultural Studies of Science Education, 4(2), 373–378. doi: 10.1007/s11422-008-9135-8

Borrego, M., Froyd, J. E., & Hall, T. S. (2010). Diffusion of engineering education innovations: A survey of awareness and adoption rates in US engineering departments. Journal of Engineering Education, 99(3), 185-207: 10.1002/j.2168-9830.2010.tb01056.

Bouchey, H.A., Harter, S. (2005). Reflected appraisals, academic self-perceptions, and math/science performance during early adolescence. Journal of Educational Psychology. 673–686. doi: 10.1037/0022-0663.97.4.673

Brainard, S. G., & Carlin, L. (1998). A six-year longitudinal study of undergraduate women in engineering and science. Journal of Engineering Education, 87(4), 369–375. doi:10.1002/j.2168-9830.1998.tb00367.x

Brickhouse, N. W., Lowery, P., & Schultz, K. (2000). What kind of a girl does science? The construction of school science identities. Journal of Research in Science Teaching, 37(5), 441–458. doi: 10.1002/(SICI)1098-2736(200005)37:5<441::AID-TEA4>3.0.CO;2-3

Brown, B. A. (2004). Discursive identity: Assimilation into the culture of science and its implications for minority students. Journal of Research in Science Teaching, 41(8), 810–834. doi: 10.1002/tea.20228

Bussey, K., & Bandura, A. (1999). Social cognitive theory of gender development and differentiation. Psychological Review, 106(4), 676-713. doi: 10.1037/0033-295x.106.4.676

Buxton, C. A. (2005). Creating a culture of academic success in an urban science and math magnet high school. Science Education, 89(3), 392–417. doi: 10.1002/sce.20057

Calabrese Barton, A. C., & Tan, E. (2009). Funds of knowledge and discourses and hybrid space. Journal of Research in Science Teaching, 46(1), 50–73. doi:10.1002/tea.20269

Calabrese Barton, A., & Tan, E. (2010). We be burnin'! Agency, identity, and science learning. Journal of the Learning Sciences, 19(2), 187–229. doi: 10.1080/10508400903530044

Calabrese Barton, A., Tan, E., & Rivet, A. (2008). Creating hybrid spaces for engaging school science among urban middle school girls. American Educational Research Journal, 45(1), 68–103. doi: 10.3102/0002831207308641

Calabrese Barton, A. & Yang, K. (2000). The culture of power and science education: Learning from Miguel. Journal of Research in Science Teaching, 37(8), 871–889. doi: 10.1002/1098-2736(200010)37:8<871::AID-TEA7>3.0.CO;2-9

Carlone, H. B. (2012). Methodological considerations for studying identities in school science: An anthropological approach. In M. Varelas (Ed.), M. Identity Construction and Science Education Research: Learning, Teaching, and Being in Multiple Contexts. (pp. 9-25). Rotterdam: Sense Publishers.

Cass, C. A., Hazari, Z., Cribbs, J., Sadler, P. M., & Sonnert, G. (2011). Examining the impact of mathematics identity on the choice of engineering careers for male and female students. In Proceedings from Frontiers in Education Conference (FIE). Rapid City, SD.

Catalano, G. D., & Catalano, K. (1999). Transformation: From Teacher-Centered to Student-Centered Engineering Education. Journal of Engineering Education, 88(1), 59-64. doi: 10.1002/j.2168-9830.1999.tb00412.x

Cech, E. A. (2014). Culture of disengagement in engineering education?. Science, Technology & Human Values, 39(1), 42-72. doi: 10.1177/0162243913504305

Chanderbhan-Forde, S., Heppner, R. S., & Borman, K. M. (2012). “The doors are open” but they don’t come in: Cultural capital and the pathway to engineering degrees for women. Journal of Women and Minorities in Science and Engineering, 18(2), 179-198.

Chinn, P. W. (1999). Multiple worlds/mismatched meanings: Barriers to minority women engineers. Journal of Research in Science Teaching, 36(6), 621–636. doi: 10.1002/(SICI)1098-2736(199908)36:6<621::AID-TEA3>3.0.CO;2-V

Christopher Strenta, A., Elliott, R., Adair, R., Matier, M., & Scott, J. (1994). Choosing and leaving science in highly selective institutions. Research in Higher Education, 35(5), 513–547. doi:10.1007/bf02497086

Cohen, L., Manion, L., & Morrison, K. (2011). Research Methods in Education [7th ed]. Taylor & Francis, p. 784.

Committee on Public Understanding of Engineering Messages. (2008) National Academy of Engineering. Changing the conversation: Messages for improving public understanding of engineering. Washington DC: National Academies Press. Retrieved from http://www.nap.edu/catalog/12187/changing-the-conversation-messages-for-improving-public-understanding-of-engineering

Dewey, J. (1980). The school and society (Vol. 151): SIU Press.

Donmoyer, R. (1990). Generalizability and the single-case study. In E. W. Eisner & A. Peshkin (Eds.), Qualitative inquiry in education: The continuing debate (pp. 175–200). New York: Teachers College Press.

Du, X. Y. (2006). Gendered practices of constructing an engineering identity in a problem-based learning environment. European Journal of Engineering Education, 31(01), 35-42.

Dunst, C. J., & Raab, M. (2012). Interest-based child participation in everyday learning activities. Encyclopedia of the Sciences of Learning, 1621–1623.

Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J. (2005). Engineering design thinking, teaching, and learning. Journal of Engineering Education, 94(1), 103-120. doi: 10.1002/j.2168-9830.2005.tb00832.x

Ellingson, L. L. (2009). Engaging crystallization in qualitative research: An introduction. Sage.

Fan, X., & Chen, M. (2001). Parental involvement and students' academic achievement: A meta-analysis. Educational psychology review, 13(1), 1-22.

Felson, R. B. (1989). Parents and the reflected appraisal process: A longitudinal analysis. Journal of Personality and Social Psychology, 56, 965–971. doi: 10.1037/0022-3514.56.6.965

Fleming, J. (2012). Enhancing minority student retention and academic performance: What we can learn from program evaluations. John Wiley & Sons.

Foor, C. E., Walden, S. E., & Trytten, D. A. (2007). “I wish that I belonged more in this whole engineering group:” Achieving individual diversity. Journal of Engineering Education, 96(2), 103–115. doi: 10.1002/j.2168-9830.2007.tb00921.x

Fouad, N. A. (1995). Career linking: An intervention to promote math and science career awareness. Journal of Counseling and Development, 73(5), 527.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. Proceedings of the National Academy of Sciences, 111(23), 8410-8415. doi: 10.1073/pnas.1319030111

Geisinger, B. N., & Raman, D. R. (2013). Why they leave: Understanding student attrition from engineering majors. International Journal of Engineering Education, 29(4), 914–925.

Godwin, A., & Potvin, G. (2015). Fostering female belongingness in engineering through the lens of critical engineering agency. International Journal of Engineering Education, 31(4), 938–952.

Godwin, A., Potvin, G., & Hazari, Z. (2013). The development of critical engineering agency, identity, and the impact on engineering career choices. In American Society for Engineering Education Annual Conference & Exposition (pp. 1–14). Atlanta, GA. Retrieved from: https://peer.asee.org/22569

Godwin, A., Potvin, G., Hazari, Z., & Lock, R. (2016). Identity, critical agency, and engineering: An affective model for predicting engineering as a career choice. Journal of Engineering Education, 105(2), 312–340. doi:10.1002/jee.20118

Good, J., Halpin, G., & Halpin, G. (2002). Retaining Black students in engineering: Do minority programs have a longitudinal impact? Journal of College Student Retention: Research, Theory and Practice, 3(4), 351–364. doi:10.2190/a0eu-tf7u-ruyn-584x

Hazari, Z., Sonnert, G., Sadler, P. M., & Shanahan, M.-C. C. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. Journal of Research in Science Teaching, 47(8), 978–1003. doi:10.1002/tea.20363

Holland, D., & Lave, J. (2001). History in person: An introduction. History in person: Enduring struggles, contentious practice, intimate identities, Santa Fe, NM: School of American Research Press; Oxford, UK: James Currey. p. 3-33.

Hsieh, H.-F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. Qualitative Health Research, 15(9), 1277–1288. doi: 10.1177/1049732305276687

Johnson, A. (2007). Unintended consequences: How science professors discourage women of color. Science Education, 91(5), 805–821. doi:10.1002/sce.20208

Johnson, A., Brown, J., Carlone, H., & Cuevas, A. (2011). Authoring identity amid the treacherous terrain of science: A multiracial feminist examination of the journeys of three women of color in science. Journal of Research in Science Teaching, 48(4), 339–366. doi: 10.1002/tea.20411

Karatas, F., Micklos, A., & Bodner, G. (2008). Sixth grade students' images of engineering: what do engineers do? In Proceedings of the 2008 ASEE Annual Conference, Pittsburg, PA.

Klotz, L., Potvin, G., Godwin, A., Cribbs, J., Hazari, Z., & Barclay, N. (2014). Sustainability as a Route to Broadening Participation in Engineering. Journal of Engineering Education, 103(1), 137–153. doi:10.1002/jee.20034

Lave, J., & Wenger, E. (1991). Situated learning: Legitimate peripheral participation. Cambridge University Press.

Lent, R. W., Brown, S. D., & Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice, and performance. Journal of Vocational Behavior, 45(1), 79–122. doi: 10.1006/jvbe.1994.1027

Lord, M. (2010). Not what students need. ASEE Prism, 19(5), 44–46. Retrieved from http://search.proquest.com/docview/236233931?accountid=13360

Mallya, A., Mensah, F. M., Contento, I. R., Koch, P. A., & Calabrese Barton, A. (2012). Extending science beyond the classroom door: Learning from students' experiences with the Choice, Control and Change (C3) curriculum. Journal of Research in Science Teaching, 49(2), 244-269. doi: 10.1002/tea.21006

Maltese, A. V., & Tai, R. H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among US students. Science Education, 95(5), 877-907.

Marra, R.M., Shen, D., Roders, K.A., Bogue,B. (2009) Leaving engineering: A multi-year single institution study, Paper presented at the Annual Meeting of the American Educational Researcher's Association, San Diego, CA.

Mayring, P. (2000). Qualitative content analysis. Forum: Qualitative Social Research [Online], 1(2). Retrieved from www.qualitative-research.net/fqs-texte/2-00/2-00mayring-e.htm

McDade, L. A. (1988). Knowing the "right stuff": Attrition, gender, and scientific literacy. Anthropology & Education Quarterly, 19(2), 93–114. doi:10.1525/aeq.1988.19.2.05x1802h

Miles, M. B., & Huberman, A. M. (1994). Qualitative data analysis (2nd ed., p. 338). Thousand Oaks, CA: SAGE Publications, Inc.

Moje, E. B., Ciechanowski, K. M., Kramer, K., Ellis, L., Carrillo, R., & Collazo, T. (2004). Working toward third space in content area literacy: An examination of everyday funds of knowledge and discourse. Reading Research Quarterly, 39(1), 38–70. doi: 10.1598/rrq.39.1.4

Nasir, N. S., & Hand, V. M. (2006). Exploring sociocultural perspectives on race, culture, and learning. Review of Educational Research, 76(4), 449–475. doi:10.3102/00346543076004449.

National Science Board (2003). The Science and Engineering Workforce: Realizing America's Potential. National Science Foundation (NSB 03-69). Retrived from https://www.nsf.gov/nsb/documents/2003/nsb0369/start.htm

(NCES) National Center for Education Statistics. (2011). Digest of Education Statistics. Retrieved from http://nces.ed.gov/Programs/digest/

Olitsky, S. (2007). Facilitating identity formation, group membership, and learning in science classrooms: What can be learned from out-of-field teaching in an urban school? Science Education, 91(2), 201-221. doi: 10.1002/sce.20182

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. International Journal of Science Education, 25(9), 1049–1079. doi: 10.1080/0950069032000032199

Osborne, J., Williams, G., Tytler, K., & Cripps Clark, J. (2008). Opening up pathways: Engagement in STEM across the Primary-Secondary school transition. Department of Education, Employment and Workplace Relations. Retrieved from http://www.industry.gov.au/skills/Resources/Documents/OpenPathinSciTechMathEnginPrimSecSchTrans.pdf

Pajares, F., & Graham, L. (1999). Self-efficacy, motivation constructs, and mathematics performance of entering middle school students. Contemporary Educational Psychology, 24(2), 124-139. doi: 10.1006/ceps.1998.0991

Pierrakos, O., Beam, T. K., Constantz, J., Johri, A., & Anderson, R. (2009, October). On the development of a professional identity: Engineering persisters vs engineering switchers. In *Frontiers in Education Conference, 2009. FIE'09. 39th IEEE* (pp. 1-6).

Potvin, G., Beattie, C., & Paige, K. (2011). Towards the measurement of undergraduate students' physics identity. Presented at the American Association of Physics Teachers Summer Conference, Omaha, NB.

Potvin, G., & Hazari, Z. (2013). The development and measurement of identity across the physical sciences. In 2013 Physics Education Research Conference Proceedings (pp. 281-284). Portland, OR.

Prince, M. (2004). Does active learning work? A review of the research. Journal of engineering education, 93(3), 223-231. doi: 10.1002/j.2168-9830.2004.tb00809.x

Renninger, A., Hidi, S., & Krapp, A. (Eds.). (2014). The role of interest in learning and development. NY: Psychology Press.

Richarson, L. (2000). Writing: A method of inquiry. In N. K. Denzin & Y. S. Lincoln (Eds.), Handbook of Qualitative Research (2nd ed., pp. 923-943). Thousand Oaks, CA: Sage.

Riley, D. (2003). Employing liberative pedgagogies in engineering education. Journal of Women and Minorities in Science and Engineering, 9(2), 137–158. doi:10.1615/jwomenminorscieneng.v9.i2.20

Sadler, T. D., Barab, S. A., & Scott, B. (2007). What do students gain by engaging in socioscientific inquiry? Research in Science Education, 37(4), 371–391. doi:10.1007/s11165-006-9030-9

SaGE Survey. (2011). SaGE: Sustainability and Gender in Engineering (Survey). Clemson University. https://engineering.purdue.edu/ENE/Research/SaGE_survey_Godwin_2014

Schreuders, P. D., Mannon, S. E., & Rutherford, B. (2009). Pipeline or personal preference: Women in engineering. European Journal of Engineering Education, 34(1), 97–112. doi:10.1080/03043790902721488

Seymour, E., & Hewitt, N. (1997). Talking about leaving: Why undergraduates leave the sciences (p. 429). Boulder, CO: Westview Press.

Stevens, R., O'Connor, K., Garrison, L., Jocuns, A., & Amos, D. M. (2008). Becoming an engineer: Toward a three dimensional view of engineering learning. Journal of Engineering Education, 97(3), 355–368. doi: 10.1002/j.2168-9830.2008.tb00984.x

Stryker, S., & Burke, P. J. (2000). The past, present, and future of an identity theory. Social Psychology Quarterly, 63(4), 284. doi:10.2307/2695840

Stump, G. S., Hilpert, J. C., 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: 10.1002/j.2168-9830.2011.tb00023.x

Tan, E., & Calabrese Barton, A. (2008a). From peripheral to central, the story of Melanie's metamorphosis in an urban middle school science class. Science Education, 92(24), 567-590. doi: 10.1002/sce.20253

Tan, E., & Calabrese Barton, A. (2008b). Unpacking science for all through the lens of identities-in-practice: The stories of Amelia and Ginny. Cultural Studies of Science Education,3(1), 43-71. doi: 10.1007/s11422-007-9076-7

Tonso, K. L. (1999). Engineering gender – gendering engineering: A cultural model for belonging. Journal of Women and Minorities in Science and Engineering, 5(4), 365-405. doi: 10.1615/jwomenminorscieneng.v5.i4.60

Turner, E., & Font, B. (2003). Fostering critical mathematical agency: Urban middle school students engage in mathematics to understand, critique and act upon their world. In American Education Studies Association Conference. Mexico City.

Varelas, M. (Ed.). (2012). Identity construction and science education research: Learning, teaching, and being in multiple contexts. Rotterdam, NY: Sense Publishers.

Vygotsky, L. S. (2012). Thought and language. E. Hanfmann, G. Vakar, & A. Kozulin (Eds.).

Wang, X. (2013). Why students choose STEM majors motivation, high school learning, and postsecondary context of support. American Educational Research Journal, 50(5), 1081-1121. doi: 10.3102/0002831213488622

Wang, J., Dyehouse, M., Weber, N. R., & Strobel, J. (2012). Conceptualizing authenticity in engineering education: A systematic literature review. In American Society for Engineering Education Annual Conference and Exposition. Retrieved from https://peer.asee.org/21098

Wenger, E. (1999). Communities of practice: Learning, meaning, and identity. New York: Cambridge University Press.

Widnall, S. (2000). Digits of Pi: Barriers and enablers for women in engineering. In SE Regional National Academy of Engineering Meeting, Georgia Institute of Technology, Atlanta, GA.

Yin, R. K. (2009). Case study research: Design and methods (5th ed.). SAGE Publications, Inc.