ABSTRACT

Title of Dissertation: BEYOND DIVERSITY AS USUAL: EXPANDING CRITICAL CULTURAL APPROACHES TO MARGINALIZATION IN ENGINEERING EDUCATION

Stephen Secules, Doctor of Philosophy, 2017

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In general, what we think of as "diversity work" in undergraduate engineering education focuses in the following ways: more on the overlooked assets of minority groups than on the acts of overlooking, more on the experiences of marginalized groups than on the mechanisms of marginalization by dominant groups, more on supporting and increasing minority student retention than on critiquing and remediating the systems which lead minority students to leave engineering. This dissertation presents a series of arguments which push beyond a status quo understanding of diversity in engineering education.

The first approach the dissertation takes up is to problematize educational facts around failure by interrogating their roots in interactions and cultural norms in an engineering classroom. In another argument, the dissertation places the engineering classroom cultural norms of competition, whiteness, and masculinity in a critical historical context of the discipline at large. Finally, I demonstrate how engaging students in a critique of marginalizing educational culture can be an important source of agency.

In addition to applying and demonstrating the value of specific novel approaches in engineering education, the dissertation contributes to the research community by discussing the respective affordances between these and other possible scholarly approaches to culture and marginalization in education. I also suggest how a consideration of the taken-for-granted culture of engineering education can be an important tool for instructors seeking to gain insight into persistent educational problems. In addition, this dissertation makes implications for diversity support practice, envisioning new forms of support programming rooted in intersectionality and critical praxis.

BEYOND DIVERSITY AS USUAL: EXPANDING CRITICAL CULTURAL APPROACHES TO MARGINALIZATION IN ENGINEERING EDUCATION

by

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Dissertation submitted to the Faculty of the Graduate School of the University of Maryland, College Park, in partial fulfillment of the requirements for the degree of Doctor of Philosophy
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# Acknowledgements

Although our traditional images of the lone-wolf ethnographer and the hermetical scholar may frame this dissertation as a massive individual effort, a good deal of credit is due to the people who provided opportunities, support, inspiration, and challenging thoughts along the way. First and foremost, my advisors Dr. Ayush Gupta and Dr. Andy Elby have been invaluable guides to help my work flourish and find my voice inside the dissertation. Their presence was felt as my weekly co-thinkers and collaborators, as patient responders to many over-zealous late night emails, and as a first line of support to handle the many challenges this work has thrown at me. With Andy as my head cheerleader and Ayush as my warmest critic and nearest confidant, I have grown as a scholar and a person. I think the thing that impresses me most about their advising support (contrary to some of the counter stories you hear about cutthroat academic hazing) was how consistently they prioritized and looked out for what was best for me: in publication, in assistantship roles, in professional development, and in future career prospects.

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# Statement of Co-Authorship

Chapter 3 of this dissertation is based on previously co-authored publications in the following venues:

1) Secules, S., Gupta, A., & Elby, A. (2016). “Turning away” from the Struggling Individual Student: An Account of the Cultural Construction of Engineering Ability in an Undergraduate Programming Class. In American Society for Engineering Education Annual Conference. New Orleans, LA.
2) Secules, S., Gupta, A., Elby, A., & Turpen, C. (2016). “Turning Away” from the Struggling Student: Revealing Culture in the Construction of Engineering Ability. In American Educational Research Association. Washington DC.
3) Secules, S., Gupta, A., Elby, A., & Turpen, C. (under review). “Turning away” from the Struggling Individual Student: An Account of the Cultural Construction of Engineering Ability in an Undergraduate Programming Class. Journal of Engineering Education submission.

Chapter 5 of this dissertation is based on previously co-authored publications in the following venues:

1) Secules, S., Gupta, A., & Elby, A. (2015). Theorizing can contribute to marginalized students’ agency in engineering persistence. American Society for Engineering Education Annual Conference. http://doi.org/10.18260/p.24403

2) Secules, S., Gupta, A., & Elby, A., Tanu, E. (under review). Supporting the Narrative Agency of a Marginalized Engineering Student. Journal of Engineering Education submission.

In each case, the format of the work included has been altered to conform with standard dissertation format, and minor changes have been made, for instance inserting a section which clarifies subsequent usage of the language of “paper” and “we” within the chapter.

The dissertation examining committee has determined that Stephen Secules has made substantial contributions to the jointly authored work warranting it's inclusion in the dissertation.

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# Chapter 1: Beyond Diversity as Usual

## An Introductory Analogy

This dissertation represents a contribution to scholarship on diversity in undergraduate engineering education. A central claim of this dissertation will be that the standard practices of diversity work in engineering are an important starting point but limited in their insight and power to change the persistent educational problems on which they focus. The dissertation comprises several different approaches to forging new ground in diversity work, but the uniting theme of the approaches is drawing on new theories to critically examine the culture of the discipline to resist and subvert its marginalizing norms.

Engineering educators (being originally engineers) seem partial to pragmatic action over theory, and to generalizable best practices over contextual understandings. My approach in this dissertation is to use comparably small and contextual studies to demonstrate new ways of thinking about diversity. I am aware that it may be an inherent challenge to convince the eventual audience of engineering education to value this approach, and my work could be at risk of being misunderstood or ignored. On the other hand, it is in some ways because engineering education practitioners and researchers do not as readily attend to cultural nuance and challenging theoretical perspectives that I think it is so important for me to do work in this way. My orientation towards my audience is political: it is in part because I know these ideas are challenging and not what engineers are used to reading that I want to keep writing in this vein until it brings about a change in perspective.

Still, I can sense some skepticism of the eventual audience about the whole project of a dissertation with as many cultural theories and as small a research subject "N" as this dissertation will present. I want to preempt that skepticism with a brief story about how influential context and nuance can be in understanding the social world:

*I am attending a business meeting and am right on time. Four out of five of the attendees are present as well, so the meeting begins without the 5$^{th}$ member. Still, 20 minutes into the meeting the 5$^{th}$ member has not arrived and I begin to wonder about the punctuality and commitment of the missing individual. Everyone else was able to make it on time, after all.*

*After half an hour we receive a phone call on the conference room phone. It is the 5$^{th}$ member, he was never given keycard access to this building the meeting is in and has been locked out. He has been trying furiously this whole time to find someone to let him inside.*

In the above story, the absence of the 5$^{th}$ member is the central concern through the first paragraph and remains the relevant fact through the second, but the context of the locked building shifts the perceived meaning of the absence entirely. This says something about the possibility of new information to change the meaning of previously considered objective truths. And although both inferences were true based on the available information at the time, it is clear that the greater context has enhanced the accuracy of the conclusion. A few other key features:

- The narration focused on the missing member and his deficit personal qualities, whereas in retrospect it would have been more appropriate to investigate the building infrastructure. This suggests a shift in focus from the individuals with problems to systems and people connected to those problems.
- The narrator had experienced the "history" of the meeting up until the point of the phone call, but an incomplete one which led the narrator to draw incorrect inferences. This suggests historical context can have significant impact on present day meanings.
- The narration took certain aspects of the meeting for granted: that every member had equal access to attend the meeting, and that a meeting with one missing member should start on time rather than search for the missing member. Once questioned, some norms (i.e., culture) of a situation can appear dubious and worth reshaping.
- At first the narrator has a passive concern for the missing member. After uncovering more information, the narrator likely feels chastened for having started the meeting early and a greater imperative to resolve the problem.

At times, engineering education research can tend towards narrow empiricism in this way, to carefully document the data about a social issue without as carefully uncovering or presenting the relevant context behind the data. With improper context, many dominant groups in the discipline can take a passive approach to diversity issues, seeing these issues as disconnected from their own identities and the fundamental work of the discipline. This dissertation will make a case for expanding our critical awareness of engineering culture towards a new view enabled by new tools for analysis and a greater sense of urgency regarding diversity in engineering.

In the next sections I lay out what I see as the standard “diversity work” engineering education engages in, address the value and limitations of this work, and make a specific case for the importance of expanding on critical cultural approaches to diversity in engineering.

### *The Diversity Work Status Quo*

If you live in the diversity in engineering education world for long enough you experience patterns, you notice a certain status quo. You can see features of the status quo in institutional resources and responses, in collections of individual efforts, in conversations about diversity in scholarly publications and presentations. In labeling features of a diversity work status quo I wish to emphasize their prevalence, partially in order to motivate the value that new paradigms could bring. I also emphasize the status quo features’ relevance and importance to diversity issues, while noting limitations which could be addressed with new ways of working and thinking. Here I emphasize key status quo activities in diversity work and what it adds to our awareness of the issues.

Perhaps the quintessential diversity work begins with a comparison of numerical representation (D. Riley, Slaton, & Pawley, 2014, p. 336), say between the engineering profession and the US working-age population. Though women are over half of the population in the US, they are only 30% of professional engineers (National Science Foundation, 2013). Underrepresented racial minorities (African American, Asian-American, Latino, etc,), make up only 13% of professional engineers, compared to 30% of the population. Drawing on overall numbers from the national reporting bodies can paint a picture of the size of the diversity problem. The nature of the problem can then be framed in multiple ways: engineering as a position of relative social and economic privilege which is not equally accessible, or engineering as needing a diversity of perspective to reach the best product (Slaton, 2015).

In education-focused work, the diversity work status quo moves to the underrepresentation issues as embedded within the engineering education pipeline (Lichtenstein, Chen, Smith, & Maldonado, 2014, p. 313). Factors related to the retention or attrition of underrepresented groups include cultural mismatch, microaggressions, mismatched vocational purpose, and a lack of role models (Marra, Rodgers, Shen, & Bogue, 2009; Seymour & Hewitt, 2000; Wilson, Bates, Scott, & Marie, 2015; Zeldin, Britner, & Pajares, 2008). Quantitative research helps position the educational context as a high leverage player for better or worse in responding to the diversity problem of the profession.

Another important component of the diversity work status quo seeks to understand underrepresentation issues on a human scale and to note the sorts of marginalizing experiences documented by qualitative researchers listening to students from underrepresented groups (D. Riley et al., 2014, p. 348). These qualitative research accounts become touchstones which draw our empathy and orient our thinking (e.g., Danielak, Gupta, & Elby, 2014; Foor, Walden, & Trytten, 2007). Similarly, we might draw an anecdotal experience of our own, as a member of an underrepresented group who came up through engineering, or as a person with friends or students or children who have similar experiences. With the insight of personal experience we see the pie charts and p-values play out on the human level, and we can see how day-to-day experiences connect to broader trajectories. We also sense the great emotional toll of the process of an averted educational trajectory. Qualitative and experiential accounts help us think about elements of dignity and humanity, elements which are impossible to quantify but are undergirding many of our motivations and orientations to the issues.

Finally, included in the diversity work status quo are standard institutional responses to diversity. The institutional response to diversity issues is often concentrated in recruitment efforts, scholarship provisions, and in extra-curricular and co-curricular efforts which provide support for minority populations (W. C. Lee & Matusovich, 2016). These programming efforts often take the form of mentoring (e.g., Schwartz, 2012), tutoring and student support centers (e.g., W. C. Lee, Kajfez, & Matusovich, 2013), living-and-learning communities (e.g., Inkelas & Soldner, 2011; Soldner, Rowan-Kenyon, Inkelas, Garvey, & Robbins, 2012). The goal of this programming is typically the recruitment and retention of minority students, accomplished by providing safe space and resources to enhance their participation in engineering. These efforts are a key element of the diversity work status quo, taking action instead of merely documenting the problem.

These activities are notably prominent and consistent in engineering education, and they represent a key set of activities alluded to in discussing and introducing diversity work in literature and presentations on diversity (e.g., Camacho & Lord, 2011; Ko, Kachchaf, Hodari, & Ong, 2014; W. C. Lee & Matusovich, 2016; Lichtenstein et al., 2014; Ong, Wright, Espinosa, & Orfield, 2011). Perhaps given this consistency, these elements make up a collective status quo and normative context for understanding diversity in engineering (Figure 1).

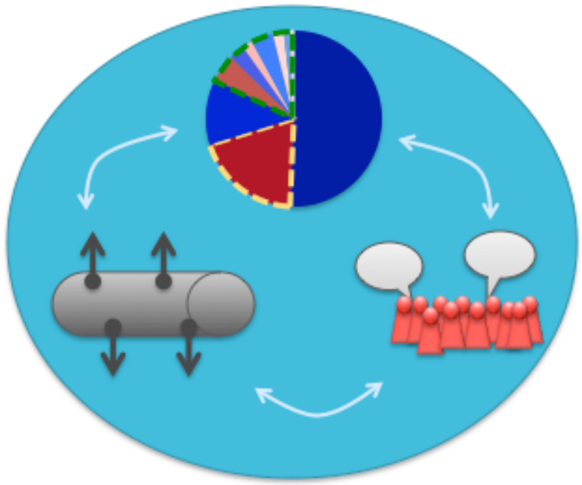

*Figure 1: A status quo for diversity work.*

*(Including a pie chart representing representation numbers, a pipeline representing retention factors, and quote bubbles representing the voices of marginalized students from qualitative research or personal experience.)*

***Limitations of the Diversity Work Status Quo***

In the prior section I presented the contours of what I have termed a diversity work status quo. In naming these activities a status quo I mean that I consider them a normal baseline, a starting point for our work on diversity issues. That is, I do not want to imply an a priori pejorative stance to the features of the status quo, but instead think that all human activities that attain some level of consistency would accrue towards an identifiable status quo, and that we can notice and mark the status quo in order to take stock of it and to consider what additional activities and approaches outside of those named would be valuable to explore.

In addition to the importance of having *a* status quo, as the prior section pointed out, there are good reasons for the current diversity status quo being perhaps *the* best starting place for diversity efforts. Each feature I named has an important role: If we never asked about underrepresentation numbers we wouldn't know the reality we are dealing with. If we never asked about retention we wouldn't know how education can affect representation outcomes. Without hearing about experiences of marginalization we wouldn't see the human impact and emotional toll of these issues. And diversity support programs represent a critical response on the front lines of addressing the diversity issue. The status quo proves to be valuable in orienting day-to-day work as a social justice struggle which is far-reaching, interpersonally embedded, and susceptible to change.

Nevertheless, there are some limitations of the ordinary diversity context as I have presented it. Figure 2 presents aspects of diversity which I suggest are typically not as prominently at the forefront of status quo diversity research, practice, or publication, but which this dissertation will argue are highly influential:

- Although the experiences and issues of marginalized populations are affected by and perhaps primarily shaped by the *Actions of Dominant Groups*[1], we usually background them in the diversity conversation.
- The aspects inside Figure 1 offer a fairly "present day" snapshot, or chart a few years' worth of progress on representation statistics. The *History* which has

[1] As I use them, marginalized and dominant groups are not static categories but describe contextual and relational situations. They connect to, but are not precisely the same as, categories of underrepresentation and overrepresentation statistics with respect to race and gender. There may be several axes of oppression and privilege contained in a qualification of dominance or marginality, and this dissertation takes up certain elements of marginalization (e.g., in Chapter 3, meritocratic hierarchy, gender) and backgrounds others (e.g., sexuality, religion, a non-URM racial/ethnic identity such as Asian). Likewise, considering marginality and dominance as a spectrum of positionality and experience, there are inevitably populations who sit at a nuanced position within this spectrum, experiencing some forms and degrees of marginalization and participating (perhaps passively) in some forms of dominance. I will attempt to clarify what is meant by these and other labels in the context of specific arguments in the forthcoming chapters.

shaped the present day context, particularly the history before the days of diversity statistics, are comparably less prominent in the diversity conversation (see Chapter 4).

- In an ordinary diversity context, the fundamental *Nature of Engineering* is seen as relatively static and unimplicated, and is seen as apolitical and predating the representation issues, rather than contested and enacted in everyday practices of engineering.
- Although some qualitative research on marginalization does implicate a chilly climate or competitive educational *culture*, comparably little is done to critically analyze engineering culture or engineering educational culture to understand how it may be reproducing and shaping experiences. (See Chapter 3)
- Diversity research (concerning terms like marginalization, identity, equity, and culture) is typically seen as disconnected from research on *classrooms* (concerning pedagogy, curriculum, learning, epistemology, and interactions).
- Programmatic work shows a similar separation to the scholarship division of classroom and diversity, where diversity work aims to support marginalized students outside of classrooms, rather than engaging a *critique* or *resistance* of marginalizing circumstances in the department (see Chapter 5).

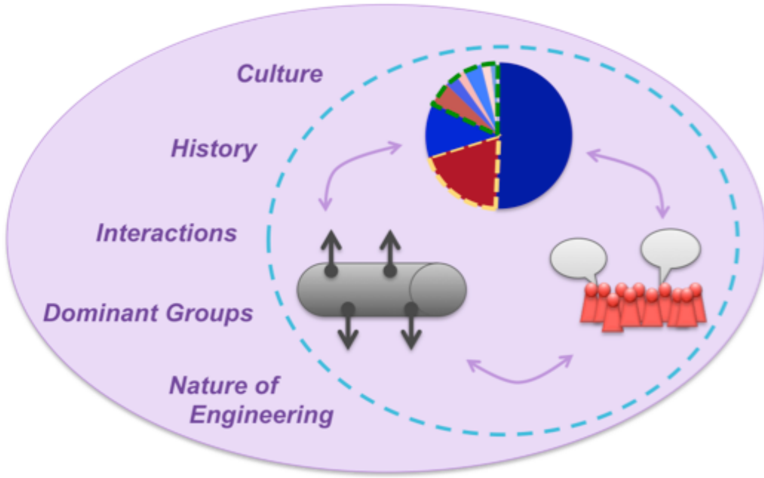


*Figure 2: The diversity status quo including additional factors.*

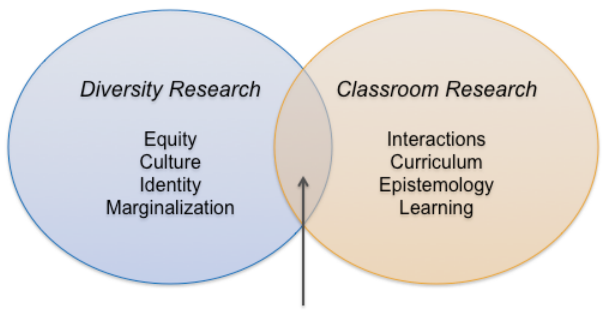


*Figure 3: Status quo diversity research and classroom research rarely overlap.*

### *Dissertation Focus*

This dissertation positions theoretical, methodological, and social justice approaches which are not yet used in engineering as presenting potential new paradigms for research and practice on diversity in engineering education. My work intersects diversity with classroom practices, pedagogy, interactions, and learning (i.e., the area of overlap in Figure 3). It critically examines the culture of engineering education, focusing on the actions of dominant groups in present day educational settings as well as across the discipline's history. It examines and questions the Nature of Engineering as enacted in engineering settings, and engages in a critique of marginalizing engineering cultural norms in an attempt to wrest them away from the fundamental content of engineering. This disciplinary cultural critique is presented both theoretically, as my own scholarly analysis, as well as embedded in a student's narrative which the dissertation research supported in constructing.

In general, this dissertation offers a critical cultural analysis of inequity and marginalization in engineering education in order to explore new ways of recognizing, explaining, and addressing the well-documented problems of underrepresentation in engineering. In service of this broader aim, I will ask: How do students come to be interactionally constructed as a local case of a problem associated with underrepresentation and attrition? What role does disciplinary culture play in constructing the problem? What tools and strategies can students and practitioners employ to resist marginalizing disciplinary culture? What role should scholars, ethnographers, activists, and practitioners embodying relative privilege play in responding to marginalization with scholarship and action?

Having presented an overview of the purpose of the dissertation in responding to a diversity work status quo, I now turn to my own researcher experiences and positionality in preparing for the dissertation work, including introducing the institutional context and logistics of the studies which make up the dissertation.

**Researcher Positionality and Institutional Context**

This dissertation is more than a timely intellectual application of new theory on culture to dissect engineering educational problems. Given that the interpretive and ethnographic methodologies I draw on treat the researcher as the primary instrument, this work is also deeply personal. What I am able to "know" about an educational setting, my access to and methods to learning about it, and how I am heard when I communicate about it, are all shaped by my unique researcher perspective and social positionalities. Acknowledging that researcher positionality statements are inevitably incomplete and can tend towards navel-gazing (Pillow, 2003; Salzman, 2014), I think one important way I can situate this research is to make an attempt at explicating for others those pieces of self that I think have made the largest contribution.

In short, I see my primary researcher positionality as communicating with those in power in engineering new insights and perspectives on the issues of those at the margins, with an aim to critique and shift views and practices. In practice, the fodder for this insight felt like it came from several specific personal resources and circumstances. I have some unique intuitions about the engineering classroom from my perspective as a peripheral insider (or a familiar outsider) to engineering. Through various experiences I gained and continue gaining a double consciousness about the discipline, embodying simultaneous understanding and questioning of engineering-as-normal. I have an ease for communicating with and empathy with students from marginalized groups, allowing for insight gained from the student perspective to fuel my research. And, I have enough of a shared perspective with those in power in engineering that I have the potential to communicate with them as an insider. The following life narrative will situate where these resources came from.

***Researcher Narrative: Shaping the Ethnographic Perspective***

I grew up a few miles away from the research subject university and attended majority racial minority public schools from the time I was six. But I had never really appreciated that this was an atypical childhood experience for a White boy until I chose as different an experience as I could imagine for college—Dartmouth College in New Hampshire. I had a strong initial reaction against the White, old-money, old-boys-club[2] which was Dartmouth in the early 2000s. I felt simultaneously tied up with and disconnected from the majority students. I looked and talked like many of them, but I felt like I didn't fit in the fraternity system, I wasn't from the part of Maryland anyone had heard of or liked, and I didn't get to take research trips to France or unpaid internships in NYC. Instead I simply tried to get good grades and I worked at home all summer to avoid more student debt. I grappled for the first time with how the racial and socioeconomic power corresponded to a university's institutional elitism, and I grappled with how uncomfortable I felt and what this meant for my identity. Along the same time period I generally woke me up to various injustices in the world, and my early budding sense of activism drove me to seek out strange places to try to save the world: a series of service trips to Guatemala and Ecuador, a not-meant-to-be Peace Corps application.

I became an engineering major and eventually a professional engineer. But I always felt a distance between my primary intellectual interest of acoustics, from the more pressing social justice issues that motivated me. In part, I see the choice of the engineering career path as mapping onto being a closeted gay man, looking to match my expectations for a normative straight male life—achievement in technical subjects, stability and security in a career, providing for a future family. More of my friends were always musicians, musical theatre enthusiasts, liberal arts majors, and even to this day most of my friends are women. Again I had a strange sense of a lack of fit: of mostly

[2] Dartmouth did not become co-educational until 1978, and the prominent position of fraternity life and alumni networks of rich White guys kept a lot of the feeling of an old-boys-club alive.

identifying with and feeling similar to my closest female friends in engineering classes, rather than the nerdy or frat brother types of White guys I probably looked like. To paint with a broad brush, I, like my closest female engineering friends, was more interested in doing well on my engineering coursework than in joining clubs for junkyard wars and building racecars; I was more enthusiastic about engineering's power to solve real world problems, than enthusiastic about technology and gadgets. But, I came to a growing awareness that the experience of a White male in engineering was different, regardless of his non-normative background or nature. I might have felt out of my depth when expected to handle power tools without prior instruction, and there were several internal pep talks about how to project confidence and mimic what the others seemed to already know how to do. But again, I looked the part; my capability wasn't second-guessed as my female friends were, even when perhaps it should have been.

After several years in an acoustical engineering career, still grappling with this tension between social justice issues and the limited expectations of my day-to-day work, I experienced a jarring breakthrough in the form of coming out to myself about my sexuality. This triggered an awakening to and a realignment towards marginalization as now a central concern of mine. Elements of privilege as a passable and self-identifying straight man that had disappeared with a more honest identification, were a shock to my system. Several institutions I once deemed so fundamental I hadn't thought much about them now seemed built to exclude me—not just state-ordained marriage prior to 2013, but so many other mundane occurrences of presumed heterosexuality and gender normativity—bridal parties, bachelor/bachelorette parties, baby showers, not to mention fraternities/sororities, man caves, and girls' nights out. I started to notice, if the world got divided up into men and women, I usually fell on the wrong side of things, in my own category, or outside of social institutions entirely. If many gender norms that I took for granted now looked clearly to be disenfranchising me, how much more so for the cultural norms I had still never had to question? What were the times when gender and racial norms and stereotypes had played in my favor-- pushed me forward, covered for me, then hidden themselves from view? Even simply recognizing a new position not at the top of a social food chain—was frankly devastating; the loss of the dream up until that point in which I had earned my success and social standing largely as an individual rather than via a world which holds others back by design—was equally so.

That may be a long way of saying, I think my coming out and awakening to marginalization and the shaping of my research interests. Having effectively walked a precarious walk up to engineering professionalization via channels of White privilege, economic and academic privilege, patriarchy, gender normativity, and particularly structured engineering and educational institutions, I now wanted to do something to restructure the system, or at least help those who hadn't gotten as lucky as I had in the demographic lottery. In other words, I could start to see this material, invisible to many insiders as it was to me, as the process of the cultural construction of my own professional engineering status.

We all experience the world in multiple ways, not in absolute categories like privileged or oppressed. In particular, I feel that several aspects of these pre-PhD experiences placed me at a boundary between insider/outsider and privilege/oppression and provided me with this double-consciousness about the engineering classroom. My experiences as a White man in racial minority schools and with many female friends may have meant I have a comparative ease with communicating across race and gender lines, which provides a tool to expand initial intuitions around raced and gendered experiential critiques. But I also have experiences in conversation with, interacting with, and studying and working with White male engineers, and in my writing I embody a level of in-group self-critique of White male engineers. Although I know I am not unique in having experiences across identity categories, I do feel that my particular experiences have been influential in the work I choose and how I take it up.

***Embedding in an Institutional Context***

Coming to the subject university from a broad orientation towards social justice and equity, an early teaching experience sensitized me to some particular issues of marginalization in classrooms. During my first two years I worked as a teaching assistant and then as a full instructor for an introductory course on engineering design. There appeared to be patterns of gendered roles and positioning on design teams, often on the basis of little more than stereotypes, and seemingly made worse by a competitive and pressured pedagogical environment. Initially as part of a graduate course research assignment, I investigated the experiences of women in the course. In the process I gained further insight into marginalized student perspectives and began the longitudinal interview study presented in Chapter 3.

As I gained experience with qualitative interviewing, it seemed empathy and communicating with marginalized students came relatively naturally to me (though I've never surpassed embarrassment over how many "ums" and "ahs" my interviews have). Interviewing women and students of color seemed similar to talking to my friends from college and back home, only now I was trying to unpack their experiences in a more formal way than I had ever tried before. I also gained theoretical and methodological tools in several formative classes—field-noting (Emerson, Fretz, & Linda L. Shaw, 2011) in Qualitative Methodology in Anthropology, bell hooks' (1992) critical theorizing in Identity Experience and Culture in Education, Spivak's (1988) post-structuralism in Critical Methodologies in Education—which helped me refine my qualitative and ethnographic tool set and gave me insights into theory and research design.

This theoretical and methodological toolset shaped my graduate assistantship work in an alternative computer programming course, which I began in my second term of my first PhD year. My advisors and I looked at it as a justifiable match in terms of my qualifications, a way for me to stay funded, and a way for them to get their funded grant work done out of the grad students available. In that first term, I approached my first field-noting work as an ill-defined job, I tried to keep paying attention while nothing much seemed to be happening, I tried to write down at least enough observation to justify having come way across campus to be here.

I gave end-of-semester interviews to the five students in the small pilot course of the programming course. For transfer and registration reasons two students in the course had already had significant programming content, and were able to work very quickly in lab and ask advanced questions during lecture. One student had no prior programming experience and worked more slowly than his peers on lab assignments. In his post interview, he told me "I just don't think I have the brain for programming." I thought about how unfortunate that was, that his first introduction to programming class made him think that he couldn't do programming, rather than thinking he had only just gotten started learning about a useful new tool for an engineer, and I thought about the moments of classroom activities that probably contributed, elements of programming speed and public knowledge displays that were much more important in this lab setting than I knew would be in the real engineering world. In a subsequent term, I tried to find the cultural and interactional roots of this process. Drawing on Ray McDermott's cultural construction of ability (Varenne & Mcdermott, 1999a), a theory I had been exposed to in an early Education PhD course but had struggled with at the time, eventually resulted in the study I present in Chapter 3.

Although I had originally intended to expand the cultural construction lens to a larger dissertation-length empirical study, certain logistical difficulties and newfound inspiration lent themselves to pursuing and assembling additional journal length projects instead. I found myself inspired by critical racial histories of the US and engineering (Alexander, 2010; Slaton, 2010b), and I was also critiqued by a former professor for ignoring a body of gender and Science, Technology, and Society (STS) scholarship[3] as I positioned the work from Chapter 3. This led me to a post hoc literature review project, to situate my prior ethnographic work in terms of the historical context of these authors, which I present in Chapter 4.

Likewise, during my dissertation proposal, I was asked by a committee member why I had chosen cultural construction as the framework for Chapter 3, what the affordances of choosing it were and what were some of its most challenging intellectual critiques. This also aligned with an interest of mine in unpacking the work of peer scholars (who I found myself presenting alongside in an AERA session on cultural

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[3] Some in the STS community refer to it as Science, Technology, and Society (Zeidler, Sadler, Simmons, & Howes, 2005, p. 358), while others refer to it as Science and Technology Studies (Faulkner, 2000, p. 88). I will tend to refer to it in the former way, or as STS scholarship.

approaches in engineering education), so in Chapter 2 I take up a thorough comparison of three prominent research traditions and modern-day approaches to culture and marginalization in education.

**Organization of the Dissertation**

This dissertation makes a contribution to scholarship and practice on diversity in engineering education by presenting a series of arguments which push beyond a status quo understanding of diversity in engineering education by engaging a critical analysis of engineering educational culture, including dominant group actions, disciplinary norms, and historical context.

The first chapter of the dissertation has laid out the features and limitations of the diversity work status quo and positioned my work as a contribution in exploring new paradigms for scholarship and practice. It also laid out the progression of life experience and institutional circumstances which led to the studies contained herein.

The second chapter is a comparison of cultural frameworks to approaching marginalization in education. After situating three historical scholarly lineages, I compare and contrast the assumptions, affordances, and limitations of three modern approaches, two of which (Cultural Construction and Liberatory Pedagogy) are connected to the studies presented in forthcoming chapters.

The third chapter presents a critical ethnography of an introductory programming course for undergraduate electrical engineers. Having identified a persistent educational problem of a student being “not cut out for” engineering, I push back against interpretations which look for the sources of this problem in the individual traits or socialization of the individual. Instead, I argue that many actors, classroom interactions, institutional structures, and disciplinary culture are ultimately constructing the category of “not cut out for” engineering.

The fourth chapter expands on three cultural norms which emerged as consequential in the programming course ethnography, and which seem endemic in engineering settings more broadly: competition, Whiteness, and masculinity. Focusing on understanding the roots of engineering culture, I draw on critical historical and Science, Technology, and Society studies to position these cultural norms in broader historical patterns and consider the ways in which they are mutually reinforcing and connected to power.

The fifth chapter presents a narrative inquiry study which emerged out of a series of longitudinal interviews with a female undergraduate engineering student. I use a lens of critical theorizing to suggest that the way the student engages in a cultural critique of marginalizing experiences and messages is a powerful and under-considered form of agency for the work of supporting marginalized students in engineering.

The sixth chapter concludes the dissertation by assessing the contribution of the dissertation to the scholarly literature and current practice on diversity in engineering education. In suggesting implications and further work, I lay out several further ethnographic and design research studies which can build on the work of this dissertation.

# Chapter 2: Comparing Scholarly Approaches to Culture and Marginalization in Education

## Introduction

As I mentioned in Chapter 1, much of the insight and inspiration for the empirical work in this dissertation comes from theoretical and methodological approaches beyond the engineering education community. These prominent approaches to studying culture and marginalization in education contrast with the norms in engineering education research. This chapter presents a review of these outside scholarly traditions and positions them with respect to each other to consider the relative affordances of each approach. In order to provide clarity about the multiple purposes and audiences for the chapter, I will begin by positioning it with respect to the development of this dissertation and to the broader scholarly community. Then I will preview the structure of the chapter and discuss how I made choices about which research approaches to discuss.

### *Origin with Respect to the Dissertation*

As it turns out, I was embedded early on into the research settings which turned out to be the context for my dissertation. Although I had some intuitions and interests regarding marginalization and equity, I was collecting data (student interviews, classroom observation) without yet knowing what it all meant or what to do with it. I was rarely inspired by the approaches common in the engineering education community; instead I found inspiration through a few key Education and Anthropology scholars. I read Ray

McDermott and Herve Varenne's[4] work early in my graduate studies, and this had a major influence on the way I saw and collected my classroom data for the work in the programming course (Chapter 3). I also encountered bell hooks, and she helped shape my view of the power of an interview study I was already pursuing (Chapter 5). Thus, encountering theory and methodological approaches on culture and marginalization in education was pivotal in the shaping of this dissertation.

During the dissertation proposal defense (which was framed more completely around McDermott's cultural construction framework), I was challenged by a committee member to explain what were the affordances of taking up cultural construction, versus say other ways of thinking about culture and marginalization. Furthermore, there was curiosity about the intellectual conversation McDermott was embedded in, what the primary intellectual critiques of his work amounted to. These were challenging questions I did not have immediate answers to, which spurred me towards a great deal of further reading and synthesis around respective approaches to marginalization and culture in education. Thus the chapter could be seen as emerging from the following key research questions:

- Aside from McDermott, what are major approaches to scholarship on culture and marginalization in education? What are the guiding assumptions, well-trusted tools, and respective affordances of each of these approaches?

[4] Many times in this dissertation I will reference McDermott as a shorthand for both Ray McDermott and Herve Varenne. Although they co-authored most of their seminal work, I also primarily drew on the original source material from McDermott's studies (Appendix A), so that McDermott is more definitively the scholar who inspired my work, and Varenne is an influential collaborator.

- What are the primary intellectual critiques levied on McDermott and between respective approaches?

These questions came to organize a good portion of my reading, reflecting, writing, and conversation throughout the dissertation process. Energized by this challenge, I took opportunities (e.g., rereading journal articles on culture and marginalization in STEM education, an AERA session on applying cultural construction and cultural production in engineering education) to look for the answers to these questions.

Even before I began the process of searching for these answers, I had an intuition that the answers about McDermott's peers and critics might not be clearly and unanimously laid out. In my literature reviews, I had found that McDermott was typically cited for a pithy quote or for a key sub-finding (e.g., the interactional aspects of Learning Disability, McDermott, 1993) rather than in papers grappling with, arguing for, or critiquing the substance of his work. In seeking answers to the committee's questions, the confirmation of my intuitions about the lack of definitive answers led me to think even harder about the topic, and led me to additional research questions for this comparison:

- If the intellectual critiques (of McDermott) are not stated outright, what are the critiques implied when respective scholars justify and position the value of their work.
- If these conversations are not taking place, if McDermott's work is not so much critiqued as ignored, why is this the case?

These questions point towards a positioning I developed during my search for answers: I began to see prompting further conversation on the respective affordances between theoretical and methodological approaches as a relevant topic for the broader scholarly community.

### *Orienting Towards an Audience in the Scholarly Community*

An overarching theme of this dissertation will be how educational stakeholders with similar orientations towards social justice in education can make vastly different choices about how to approach a given situation, or even hold different views of the basic facts of the situation. This chapter continues that theme with regards to education scholars working on marginalization and culture. It prompts a needed conversation about the respective affordances, differences in values and purpose, differences in theoretical lens, and differences in identity and voice between researchers taking disparate approaches to a similar set of problems.

This chapter presents scholars as in conversation with certain predecessors and nearby scholarly peers, but less often in conversation with other peers, who may come from disparate traditions and arrive at similar but different approaches. It sees the lack of critical conversation as a symptom of some level of intellectual insularity, perhaps a reluctance to levy critique at peers, or a difficulty with achieving a substantial level of familiarity with multiple intellectual traditions to discuss them. Rare but valuable pieces of writing attempt to lay out the respective affordances of disparate cultural approaches (Carlone & Johnson, 2012; Carlone, Johnson, & Eisenhart, n.d.) and to position the work within historical scholarly traditions (B. Levinson & Holland, 1996; McDermott & Raley, 2016; Varenne & Koyama, 2016). Even in these prominent historical and scholarly reviews, a certain lack of intellectual overlap remains. For example, the disparate cultural approaches laid out in Carlone, Johnson, and Eisenhart's review did not discuss

McDermott's Cultural Construction, and Varenne suggests an interactional version of Cultural Production (Varenne & Koyama, 2016) without acknowledging what for many others is the seminal work in this domain: The Cultural Production of the Educated Person (B. Levinson & Holland, 1996).

I see my contribution with this literature review as incremental rather than comprehensive: as any synthesis comparing across scholarly approaches will incorporate some things and ignore others, I hope to contribute to the scholarly community by placing certain approaches, which seem to have remained intellectually insular up to now, in contrast and conversation with one another.

### *Structure of the Chapter*

In the next section, the chapter will lay out three parallel historical scholarly lineages, in order to show how the three modern day frameworks I discuss came to be, and in order to note the overlaps and lack of overlaps between the scholarly traditions. Although these lineages come from secondhand accounts of the lineage, and may not represent all conversations, influences, and impacts between scholars, I suggest the lack of textual acknowledgement of the intersections between research communities is indicative of the way in which the communities position themselves as separate.

In a subsequent section, I will discuss how three modern day approaches to culture and marginalization in STEM education compare with one another. I will make this comparison by contrasting what I see as the guiding theoretical lens and driving purposes assumed by the scholars. Then I will play out a methodological thought experiment of each approach within the research site of Chapter 3. I will use this theoretical and methodological characterization to point out the affordances and implied critiques of each of the respective scholarly approaches.

In a final section, I will point towards a possibly significant dimension of the researcher demographic identity, discuss how identity may impact voice in the scholarly community, and consider which approaches are available and productive for respective groups of scholars. I will conclude by reflecting on and challenging my own chosen theoretical and methodological approaches and my identity, purpose, and voice in the scholarly community.

**Scholarship on Marginalization and Culture in Education**

Before I begin, I want to clarify the boundaries of the scholarship I am referring to as "scholarship on marginalization and culture in education."

First, although my eventual primary target for *education* scholarship is in shifting formal undergraduate institutions, I do necessarily mean to imply a focus on theories of formal institutions over informal education, but I do not prioritize informal settings over formal education either. It seems often that scholars choose their specific research setting with a purpose to contribute to a specific institution or to society overall; often informal learning settings are used to reflect back critiques or new possibilities to formal learning settings (e.g., Rogoff, Paradise, Arauz, Correa-Chávez, & Angelillo, 2003). By scholarship on education then, I mean work on understanding and improving the educative process, including those who approach this improvement through improving formal institutions and those who challenge formal settings through the design of their own less formal settings.

By *marginalization*, I am referring both to issues of historical oppression and power which intersect education, and to the small moments in the classroom which connect to those broader forces. I would group many scholars trying to respond to marginalization in oppression into this lens in order to consider the affordances of their approaches (Foor et al., 2007; D. B. Martin, 2007; O'Connor, Peck, & Cafarella, 2015; Seymour & Hewitt, 2000; J. M. Smith & Lucena, 2016; Tonso, 2006a). On the contrary, I see some other prominent work in qualitative and anthropological education research which does not centrally take up this cause, and which I will therefore not directly consider in this review. For instance, seminal anthropological work in Engineering Education looked at students navigating the engineering major in acquiring disciplinary knowledge and forming disciplinary identities (Stevens, O'Connor, Garrison, Jocuns, & Amo, 2008). Another prominent anthropological study looked at the ways design is a process of situated cognition where student peer contributions and the idiosyncracies of an artifact become consequential in the shaping of the design cognition and product (Roth, 2013). These two pieces of scholarship provide valuable anthropological insight into students' experiences in engineering, but they are not centrally concerned with understanding or responding to marginalization and oppression.

Next, in a focus on *culture* I am targeting approaches in the anthropology of education broadly speaking. The relative affordances between quantitative approaches and qualitative research has been laid out substantially by others (Eisenhart, 2009), and Chapter 3 compares additional qualitative approaches (e.g., interviews highlighting cultural difference), and will not be repeated here. By reviewing work focusing on culture I mean engaging with cultural practices, situated interactions, and social organizations, and often employing methods of embedded participant observation and interviews. Chapter 1 began and Chapter 3 elaborates a case for why a cultural lens is valuable in education research. Here I will compare traditions which incorporate a cultural lens but yet have distinct approaches to studying or responding to culture.

An open question for this review is what role the scholar / anthropologist / activist takes in order to pursue their social justice mission. The Anthropological community is often debating the appropriate role of anthropologists regarding social justice: whether social justice should be at the forefront of all Anthropology (President's address at the 2016 Council on Education of the American Anthropological Association annual meeting) or backgrounded, whether the history of examining exotic culture as an intellectual pursuit necessitates a positionality of solidarity with research participants (Bourgois, 2014), and whether Anthropology needs to strive to retain some of its original intellectual identity prior to taking up the activist cause (Wolcott, 2016). These remain the open questions and debates of this chapter and dissertation, so the review includes various roles for the scholar-activist regarding marginalization in education.

Finally, although my final context of interest is undergraduate engineering education, for the sake of this chapter I broaden what I consider my context in order to assemble more examples than what has been specifically explored in the engineering education literature. Thus I align engineering education with scholarship in STEM education more generally, which grapples with similar forms of marginalization (e.g., gender-based marginalization and a social/technical divide) and which shows promising applications of the theoretical approaches discussed. There is a pattern in the forthcoming scholarly lineages of a theory or approach which has been developed in broader social studies, then being applied and redeveloped by seminal education theorists, then being applied in STEM education. So in many cases a wider array of scholarship is used to show the influences and traditions of key approaches to culture and marginalization in STEM education. This chapter can be seen particularly as in conversation with those in STEM education who work on culture and marginalization in education, in order to spur further exploration and conversation in engineering education scholarship.

***Scholarly Lineage***

A key to understanding social justice oriented education is to examine the lineage of scholars: scholars presenting who they draw upon and which features of earlier work they adapt and expand on to address new challenges. Although one expects that scholars are also familiar with a large body of scholarship and in some way may be (even unconsciously) building on any of the scholarship which came beforehand, a scholar still formally draws upon certain prior work and for a particular reason. The scholarly lineage is an important clue for why the work has been taken up in particular ways and has particular features. These lineages tend to be surprisingly distinct, rather than overlapping, even in our globally- and technologically-connected modern scholarly community.

I will discuss three primary scholarly traditions and their respective modern day inheritors:

- a Sociology of Schooling tradition, which has tended to build on theories of social reproduction to assess the reproduction and resistance of the status quo in education, and which has as a modern day inheritor the framework of Cultural Production (B. Levinson & Holland, 1996),

- an Anthropology of the Classroom tradition, which has tended to adapt traditional ethnographic methods to understand classroom interactions, and which has as a modern day inheritor the framework of Cultural Construction (McDermott & Varenne, 2006a),
- and a Pedagogical Activism tradition, which has used education to respond to marginalization and undo oppression, and which has as a modern day inheritor the work of Liberatory Pedagogy.

First, I will outline these lineages briefly, noting the historical progression towards some of the prominent present day approaches, then I will compare and contrast some of the present day instantiations for an understanding of how these choices affect the work. In general, I present the lineages as the seminal scholars have laid out in key publications which I identify. In places, I have added personal commentary (usually as footnotes) where an apparent tradition has resonance but was not included in the original lineage (e.g., "funds of knowledge" as a traditional Anthropology conducted *outside* the classroom). Therefore, these scholarly lineages should not be read as a comprehensive and conclusive account of all scholarship on marginalization and culture in education, but on the specific influences identified by seminal accounts of the development of Cultural Production, Cultural Construction, and Liberatory Pedagogy.

Figure 4 provides a graphical overview which the next sections elaborate in text.

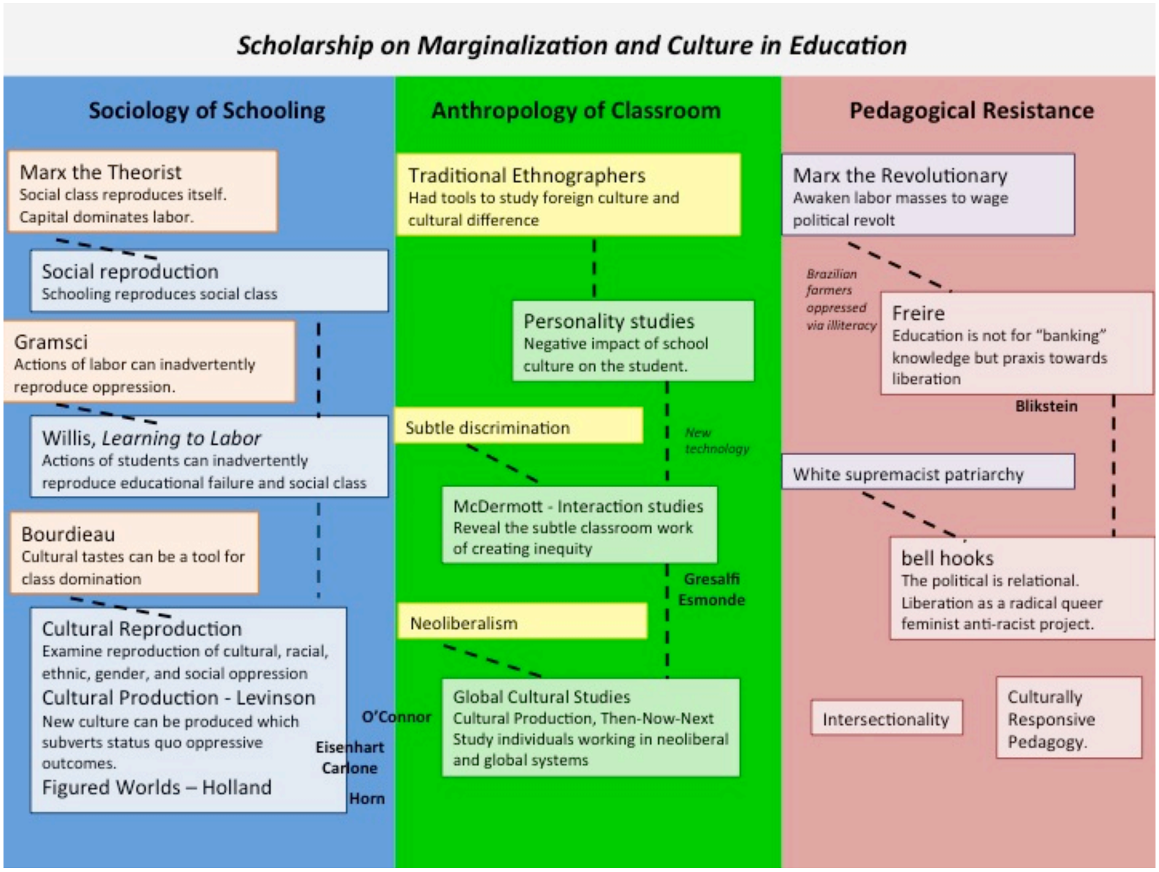


*Figure 4: A graphical figurative overview of the scholarly lineages.*

### *Sociology of Schooling*

The lineage presented in this section draws heavily on the Introduction to The Cultural Production of the Educated Person (1996) and a chapter of the Companion Guide to Anthropology of Education (Shumar & Mir, 2016).

A guiding tenet of sociology which draws on a Marxist tradition is that social class tends to reproduce itself, with divides between capital and labor remaining even when masked by a façade of economic opportunity or political change. This simple observation becomes a starting point and a working hypothesis for an investigation of the structures and actions of society which reproduce the outcome. This work on *social reproduction* was developed primarily in European and British traditions, where social class is arguably the prominent guiding framework for understanding power and oppression (Morrow & Torres, 1995). An early adaptation of social reproduction to education theory in the 1960s produced a similarly simple and radical starting point for educational sociology: that education reproduces social class (e.g., Bowles & Gintis, 1976; Entwistle, 1978). Although social reproduction had primarily been developed in Europe, that polemic adapted to education emerged as an important counterweight to narratives about education as the great equalizer of access to the American Dream.

Criticisms of the initial social reproduction in education theory accused it of being a tautological "black box," proving little and offering little insight to mechanisms of either reproduction or resistance of this central phenomenon. Inspired by a movement within broader sociology led by Gramsci (1971), a next generation of educational sociologists took the initial phenomenon of social reproduction as a starting point and a working hypothesis for an investigation of the educational structures and actions which reproduce social class. Paul Willis (1975) emerged as a leader in this work, providing insight into the actions which reproduced social class among the "lads" of working class England. This work tended to identify mechanisms for social reproduction, including somewhat surprising mechanisms like the lads' views that their male teachers were emasculated by their education and that acting out behaviorally was an important resistance of that emasculation. Importantly, the inclusion of actions and perspectives of the lads themselves invigorated the theory with agency and interaction, Willis and his contemporaries (e.g., Apple, 1982) provided critical movement towards a more thorough understanding in social reproduction.

Additional criticisms of social reproduction in education, including of Willis, came from the United States, where the realities of social class seem to stand prominently in parallel with several other forms of oppression. In the period when the British theories were being developed (1960s – 1970s) the consciousness of US racial oppression uniquely shaping social oppression in a way that the social reproduction of class did not address. The French scholar Bourdieu (1984) provided a partial answer. In his theory of *cultural capital*, the elite maintained separation from working class in part by defining the ineffable aspects of elite "culture"—the tastes for literature, art, music, cuisine, dress, and other aspects of life. These aspects of culture were noted to be arbitrary but functioned as a tool to justify and reify a social hierarchy. In the context of education, arbitrary cultural values could function as a tool to serve the ruling class, and become a justification for educational success/failure and reproduced social class. Perhaps because race and gender norms are significantly arbitrary and must be recreated and justified in order to retain their power (whereas social class is intrinsically tied to economic resources and power), Bourdieu's theory of cultural capital became a useful tool for American educational sociology looking to theorize systems of oppression other than social class.

Although scholarship which looks to cultural difference as a root of oppression continues to flourish in social and educational analysis, it has also been criticized for being static and essentializing as an explanation, and tautological in much the way that initial social reproduction theory was (i.e., where social differences are entirely explained by the social differences themselves). In response, American anthropologists in this sociological tradition drew on Bordieau's cultural capital and Willis's nuanced social reproduction to formalize a theory of *cultural reproduction* (B. Levinson & Holland, 1996). Cultural reproduction invigorates structure and culture (with an acknowledgement of purposeful or inadvertent human actions) into the work of reproducing oppressive systems around race and gender. Cultural reproduction theory was seen as attending to nuance contained in each theory it drew on, and thus could draw on each of their strengths. It also inherited a weakness that each of the theories in the sociology of education had effectively maintained until this point—it was seen as pessimistic and only accounting for an oppressive status quo. Although nuanced in terms of causes, reproduction provided no space to understand divergent effects or cultural change. In the late 1980s, American anthropologists in the sociological tradition developed a further theory which addressed the process of cultural change: *cultural production*. This new framework made theoretical space for both cultural reproduction and cultural production, which (as the name suggests) placed greater weight on novel productions away from the status quo. Cultural production has remained one of the prominent approaches in the sociological anthropology of education (Carlone et al., n.d.).

Finally, in the 1990s it seems that the end goals of looking at the production of culture were limiting the scope of theory, so scholars developed frameworks which incorporated more central constructs which could be used flexibly in many different ways. The general framework of Structure-Culture-Agency is a simple way scholars keep each of these three aspects in mind, and it has been formalized as an interpretive framework in many modern educational works (e.g., T. M. Brown & Rodriguez, 2009). In addition, *figured worlds* comes out of the tradition of cultural production and emphasizes on the one hand identity and agency, and on the other hand the fluidity of the "cultural worlds" that individuals move through (D. Holland, Lachicotte, Skinner, & Cain, 1998). Although this framework is potentially so nuanced that it can accomplish the objectives of any prior framework cited, it is also potentially so full that it can be used in many different ways which are technically consistent with the theory, but which bear little resemblance to each other or insight into how the theory infused the analysis.

I have traced the progression of scholarship in this Sociology of Schooling strand. While some of these frameworks have been critiqued and revised or replaced (e.g., initial social reproduction theory) others continue to be used in education research today. Thus although a framework may have been in some ways superseded or refined (e.g., cultural production by figured worlds), there are still many adherents who find more explanatory power in a prior iteration. Several modern day STEM education scholars pursue work which draws on or echoes Bourdieu's cultural capital theory (e.g., Chanderbhan-Forde, Heppner, & Borman, 2012; Samuelson & Litzler, 2016; Zevenbergen, 2000). Cultural Production has found a particularly strong presence in work which looks at the reproduction or resistance of gender underrepresentation and marginalization in STEM education (e.g., Carlone, 2004; Carlone, Haun-Frank, & Webb, 2011; Eisenhart & Finkel, 1998; Hegedus, Carlone, & Carter, 2014; Tonso, 1996, 2006b). Figured worlds, the youngest of the frameworks, is also prominent as a framework in the modern STEM education scholarship (Horn, 2008; Jurow, 2005; Tonso, 2006a).

### *Anthropology of Classroom Interactions*

The lineage presented in his section draws heavily on two chapters of the Companion Guide to Anthropology of Education (McDermott & Raley, 2016; Varenne & Koyama, 2016).

An American Anthropological tradition is often traced back to early 20th century ethnographers traveling to exotic locations to understand the local culture. This tradition can be contrasted with the Marxist sociological tradition in a few key ways. American Anthropology was developed (obviously) in the United States primarily as a set of tools for understanding foreign and exotic culture. Perhaps in part the culture and narratives of the US and Europe contributed to a divergence: in Europe a feeling of reproduced social class drove Marxist theorists, in the US the feeling that the American Dream can surmount social class is at least highly salient if not always highly accurate. In White American culture which dominated / dominates intellectual circles, a feeling of a vast homogenous culture-less culture could drive one to seek out the culture beyond one's shores, whereas in Europe a sense of new culture can be felt each time one crosses one of the relatively smaller European borders. Whereas Sociology may be defined by a guiding theory, American Anthropology has predominantly been defined by a set of methods (e.g., participant observation, ethnography) to investigate "culture," local practices, and meanings, etc.

In the early 20th century, the impact of two world wars alongside ever increasing immigration and globalization led anthropologists to try to understand the fundamental character of individuals from different cultures[5]. The resulting "personality studies" sought the cultural roots for disagreements and difficulties among diverse and mixing groups (Benedict, 1946). This has some parallels with Bordieau's cultural capital—in its attention to cultural difference and its risk of essentializing that difference. But

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[5] The Anthropology of Classroom Interactions lineage accounts I drew on often move back and forth between history and scholarship, to reveal the historical context as a primary trigger for the lineage of successive scholarly movements (McDermott & Raley, 2016; Varenne & Koyama, 2016).

personality studies aimed at solving a different problem, a problem among people in interaction, rather than a problem of the tools of societal level domination. It also brought more critical attention to one's own cultural "personality," in comparison to other groups, thus these studies led to new critical comments about American culture. When brought into education research, personality studies looked critically at the affective position of the American student inside American school (Henry, 1963). This work brought an important critical focus to the psychological position of the American student, and it focused less on inequity and material differences between groups.

The civil rights and parallel social movements of the 1960s brought new social and educational realities. Discrimination in public services was no longer sanctioned or codified in law; inequity perpetuated via educational segregation was specifically outlawed by the Brown vs. Board of Education decision of 1954. Increasingly, discriminatory and White supremacist intent could no longer be overtly expressed. In many spheres, this led White supremacist effects to become more covert, masked behind culture, taste, IQ, academic performance, and other social markers not overtly about race. In criminal justice, the war on drugs would be waged to have unequal effects on respective racial groups, barely masking the effect of perpetuating racial social control (Alexander, 2010). In social theory, Oscar Lewis presented his prominent cultural psychology of socioeconomic inequity, his *culture of poverty* theory (O. Lewis, 1971). This has parallels to the social reproduction tradition, in that looking at the after-effects and documenting aspects of a group which consistently does not escape poverty, one can find insight into an original Marxist tenet. Although he could also be seen as in this Anthropological tradition regarding his ethnographic methods (participant observation of a town in Mexico) and attention to culture, he is mentioned (McDermott & Raley, 2016, p. 41) only in passing as an intellectual movement which required resisting, since this intellectual tradition functioned quite effectively as victim blaming. Lewis saw socialized cultural deficits as both the source and the effect of poverty, thus the system is bound to reproduce itself and most other means of influence and amelioration are absolved and ignored[6].

In education, researchers concerned with inequity came to identify that linguistic differences were being employed against minority groups as a tool to recreate and justify inequity. This led to a period of educational anthropologists conducting careful microgenetic interaction analysis, where linguistic idiosyncracies were deconstructed and invalidated as markers of underlying student intelligence and performance. This was a period of developing "tools for the defense" (McDermott & Raley, 2016, p. 42) of marginalized students, and exposing the mechanisms of marginalization. During this period, attention to racial inequities overlapped with and existed alongside a focus on other forms of marginalization, such as the construction of learning disability as a psychometric and classroom reality[7]. Educational anthropologists conducting interaction studies (e.g., Hood, McDermott, & Cole, 1980; McDermott & Roth, 1978; H. Mehan, 1979) were characterized by their focus on everyday classroom settings, their

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[6] In education research, a related approach found a *pedagogy of poverty* prevalent in low income schools which was seen as a source and a cause of continuing poor achievement of students. While this work progressed in its increased intention on social inequities and marginalization, its focus on the culture tended to blame the marginalized communities for purported cultural deficits which trap them in poverty (Haberman, 1991).

[7] In purpose, these efforts coincided with ethnographic efforts to examine learning and cognition in natural settings, to criticize the ecological validity of pscychometric studies, and to question schooling for wielding them as sorting mechanisms (Cole et al., 1997; Jean Lave, 1988).

methodological advance of using modern audiotape and videotape not available to traditional ethnographers, and a post-structural attention to the interactional production of categories and accepted realities rather than traditional ethnographic documentation of these received categories. These technological and analytical features seem critical to the intent of the research to resist subtle discrimination in everyday educational settings; since no participants would admit to or acknowledge such discrimination, it was only by carefully parsing educational interactions (which had been caught on camera) that they could be critiqued.

The 1980s[8] began the rise of neoliberalism as a defining force in American and international politics. Neoliberalism was marked by a new type of sleight of hand, where social progress and a liberal agenda was appealed to largely in the service of capitalist and militarist interests. An anti-union strain in UK politics was appealed to as economic freedom, and the class and race war of the war on drugs took up appeals to personal health and safety. Although the movement has been conceived of as political it has also

[8] Although not discussed in this lineage, the 1980s also brought a new sense of globalization and awareness of diversity. American culture was viewed as too often defined by a (White) majority and should attend more to its many multi-cultural components. This period saw a resurgence of attention to cultural difference, as opposed to the interactional accounting of cultural inequities. In education an attention to the productive resources of diverse cultures was intended to push back against a majority defined dominant culture. Frameworks such as funds of knowledge sought to investigate these diverse and non-dominant cultures to show their resources, and to prove that they could be but are not typically used as the pedagogical basis for American schooling (Moll, Amanti, Neff, & Gonzalez, 2009). These traditions would use traditional ethnographic methods and interpretivist frameworks but would find their primary settings *outside* of classrooms. These cultural resource traditions largely carry forth to the present day, often finding expression as assets, community cultural wealth, and funds of knowledge research.

been seen as continuous in 1980s to 2000s political rhetoric and policy regardless of specific American or international political party.[9]

In education, neoliberalism was marked by a strong appeal to the betterment of the individual self, via continuing and accelerating programs to fix schools and students (No Child Left Behind) in ways which often proved either ineffective or ultimately damaging. The swiftness and all-encompassing power of these institutional changes brought a new attention to the responses of educational stakeholders dealing in the wake of neoliberal policies. This has been referred to by some (Varenne & Koyama, 2016) as Cultural Production (though seemingly separate from B. Levinson & Holland, 1996) or as Then-Now-Next. Where educational stakeholders have a collective understanding of "then," this is conceptually a cultural history of sorts, and given the speed with which the policies and conditions are shifting it may be helpful to conceptualize culture in a way less stable and more made up of component pieces of experience. The "now" is parallel to interaction analysis, with a concern for the unfolding of day-to-day reality. The attention however to stakeholders deciding "what happens next" shows a new attention to the tangible impact of agency to shape educational realities for other stakeholders. This period of educational anthropology has been marked by a new focus on the interactions of those shaped by and shaping educational policy and practice, and a multi-modal attention to the interactions and artifacts which expose that process in context. It seems

[9] In the 2016 election Hillary Clinton was thought to embody the neoliberal agenda of giving lip service to progress for all while maintaining and advancing a capitalist status quo. Thus it remains to be seen whether the election of Donald Trump (and Brexit, etc.) marks the end of neoliberalism in the US or generally, whether a new period is being formed and what its contours may be, or whether a blip of recalcitrant anti-establishment politics will be subsumed by a broader liberal agenda in the long run. Nonetheless the period of neoliberalism and Trumpism mark a defining and tumultuous period for social analysis around the turn of the 21st century.

there was a feeling among the adherents of interaction studies that 1) the implications of interaction studies for K-12 contexts had been largely discovered, 2) cultural context was changing quickly in the neoliberal context and needed a corresponding shift in the framework, and 3) more attention needed to be paid to the interactions of those in power in order to understand the classroom context. In a neoliberal classroom, teachers were seen as more highly constrained by the many and swiftly changing top down policies of neoliberal institutions (Varenne, 2008). Thus these scholars argue new attention should be paid to what individuals accomplished and what they created for themselves and for each other in the context of their heavy constraints.

The lineage of the Anthropology of the Classroom shows how educational anthropologists approached their study of the classroom in response to cultural and political realities of their time. Similar to the frameworks in Sociology of Schooling lineage, some have been largely superseded (e.g., personality studies) while others remain influential and prominent approaches in modern day STEM education. Although a less clearly defined group, several scholars continue to conduct interaction studies research on interactional equity (Esmonde, 2009) and the construction of ability (Gresalfi et al., 2009). The relatively recent movement to incorporate the impact of neoliberalism and globalization in education has found recent attention in STEM education (Carlone et al., 2017; Rahm & Brandt, 2016; Weinstein, 2016).

### *Pedagogical Activism*

The lineage presented in this section draws on the influences which bell hooks and Freire cite in their seminal works.

A third and final traditional approach is what I term Pedagogical Activism, a tradition which is less overtly analytical and more political in its orientation. Like the Sociology of Schooling tradition, Pedagogical Activism has its roots in the work of Marx. Unlike the Sociology of Schooling lineage which drew on Marx's theory of social reproduction, Pedagogical Activism draws on Marx's political purpose in inciting class rebellion amongst the proletariat. Although Marx was both a scholar and a political subversive, the divergent purposes of his successors has shaped the way his work is taken up.

Paulo Freire was the most prominent of Marx's disciples to connect the imperative of the class struggle to education. Freire's context was in the agrarian and extremely divided economy of Brazil, where an elite owner class had access to education and literacy and a large worker class did not. Freire's seminal work, Pedagogy of the Oppressed (1968), positioned education as the key force for liberation of the oppressed masses. Liberatory education, or *praxis*, was contrasted with a more conventional capitalist model of education, the "banking" model. In the banking model, knowledge is seen as a commodity to fill up the brains of individuals, where the task of schools is to provide the knowledge deemed valuable by society. In praxis on the other hand, oppressed people's learning directly contributes to their liberation, the knowledge is only as valuable as it is in enabling the pupil to liberate themselves from oppression. In Freire's educative model, the oppressed is empowered to liberate themselves, and in turn liberates their oppressors, since the role of oppressing others is in itself a form of oppression. This contrasts with a patronizing and omniscient version of education that the banking model and conventional schooling presupposes.

Freire in turn inspired a critical feminist scholar who takes the pen-name bell hooks. In her writings (particularly, Teaching to Transgress, 1994), hooks takes Freire's call for a liberatory educative process and extends beyond Freire's contexts (Brazilian economic oppression) to discuss intersectional systems of oppression in the United States including White supremacy, patriarchy, and heteronormativity. hooks, a self-identified Black lesbian, draws distinctions with Freire around these intersections of oppression. Although she sees Friere's theories as powerful and applicable to these forms of oppression, she sees his narrow focus on economic oppression as a symptom of masculine privilege. In addition, hooks extends Freire's view of education (literacy as a key skill for liberation) to include a relational and self-actualizing aspect of educational liberation. For hooks, the role of the teacher includes engaging the student on the learning they need for liberation in every personal and political aspect of their self. Freire also inspired a related trend in humanistic psychology, where Carl Rogers (1969) saw education as connected to the self-actualization of the individual. Although less overtly political than hooks, Rogers' work shares a view of the teacher-student relationship as an un-hierarchical and reflexive relationship which ultimately works towards growth and freedom of the student.

From hooks, the work of Pedagogical Activism moves in a less clear lineage but towards many prominent directions. hooks is a contemporary of the theory of intersectionality, which comes from the work of Kimberle Crenshaw. Intersectionality originally developed in the area of critical legal studies rather than a theory of education, and focused on the way that the law saw women as a particular class of person with respect to sexual assault, but did not address the fact that Black women, subject to both gender and racial oppression, experienced the law distinct from the majority group of women (Anders & DeVita, 2014). This original theory of structural intersectionality (which examined the distinct experiences of a group experiencing multiple axes of oppression) was also extended to include representational intersectionality (concerning which images of an identity group are presented, such as White women used to represent all women) and political intersectionality (concerning how multiple disparate identity groups can band together around common political purposes). Although it grew out of critical legal studies rather than the tradition of education scholars outlined, it merged with conversations started by hooks. In that intersectionality was originally conceived of as political and structural, rather than purely psychological and individual, it fundamentally coheres with the mission of liberatory pedagogy put forth by Freire and hooks.

hooks also inspired or predated a movement of cultural responsive pedagogy (CRP), a theory which looked to outline an ambitious, theoretically grounded, and specific set of pedagogies which disrupt conventional schooling practices and reach towards racial liberation (e.g., C. D. Lee, 2001). CRP, pioneered by scholars like Gloria Ladson Billings (2015) and Lisa Delpit (2003), transformed a conversation around instruction of minority majority and high poverty K-12 settings which had been dominated by deficit and majority-defined practices. Similar to funds of knowledge, CRP emphasized a responsiveness to the home culture of the students (primarily conceived in settings where that home culture is effectively unitary and “shared” among students), and it subverted the dominant knowledge bases and pedagogical practices which aligned with the culture of dominant students and teachers. At times, it also disrupts expertise (and "banking") aspects of typical K-12 classrooms which continuously create hierarchies of achievement and knowledge acquisition in the classroom (C. D. Lee, 2001, p. 124), an orientation towards meritocratic systems which aligns with Cultural Construction.

This more ad hoc assembled lineage has revealed a group of scholars who take up the educative process primarily as a form of activism. Several of these approaches are used in STEM education, including work which directly draws on Freire (Blikstein, 1990; D. Riley, 2003) and hooks (D. Riley, 2003). Intersectionality has come to have a prominent place in higher education (Mitchell, Simmons, & Greyerbiehl, 2014) and STEM education (Armstrong & Jovanovic, 2015; Bruning, Bystydzienski, & Eisenhart, 2015). Culturally responsive pedagogy has also found a strong presence in K-12 STEM education (e.g., Wilson-Lopez, Mejia, Hasbun, & Kasun, 2016), although it has had more limited application in higher education, perhaps because most university settings typically have many more student cultures represented in a classroom.

***Noting Tentative Patterns in the Scholarly Lineage***

Reviewing the scholarly lineage can help us note certain patterns. As previously noted, these lineages appear to be largely distinct and independent of one other. This may contribute to a lack of comparison between disciples of respective camps, as scholars within a tradition only need to have in depth knowledge of and justify choices within their scholarly community.

Even so, there is a danger in overstating these as mutually exclusive and not-overlapping sequences of traditions, although they are presented in the literature that way. What these lineages tell us is that one scholarly community envisions themselves as coming forth from a certain predecessor (Cultural Production from Marx as theorist and

Willis, Cultural Construction from traditional American Anthropologists, Pedagogical Activism from Marx as a revolutionary). We probably shouldn't presuppose that those doing Cultural Construction never read and weren't influenced by Marx (and as counter evidence, see Jean Lave & McDermott, 2004); and clearly traditional American Anthropological methods had a strong influence on Cultural Production scholars (D. C. Holland & Eisenhart, 1990, p. 68). In the present day, some scholars incorporate multiple of these traditions and form hybrids (e.g., O'Connor et al., 2015), while many others may be familiar with or subconsciously influenced by multiple traditions.

With a dose of skepticism about the true nature of the discontinuities I found in these scholarly lineages, I next discuss modern day research approaches which emerge from these roots, in order to consider the consequences of this potential insularity and the incommensurability of respective traditions.

**Disciples of the Scholarly Lineages in Current STEM Education Research**

This section discusses and contrasts modern day approaches to marginalization and culture. I have chosen to contrast three approaches in particular: out of the Sociology of Schooling I look at Cultural Production scholarship (B. Levinson & Holland, 1996), out of the Anthropology of the Classroom I look at Cultural Construction (McDermott & Varenne, 2006a), and out of the Pedagogical Activism I look at Liberatory Pedagogy (Freire, 1968; hooks, 1992).

The reasons for this choice are as follows:

1. Each of these frameworks has prominent examples which make significant contributions to the STEM education literature. This grounds my comparison in a relevant scholarly conversation between divergent yet productive

approaches, and means I can find examples of modern day work in STEM education to draw on.

2. Cultural Construction and Liberatory Pedagogy are also both represented as theoretical inspiration for portions of this dissertation (Chapter 3 and Chapter 5, respectively). The effort to place these frameworks in conversation with one another and with near peers and critics parallels my own synthesizing of and understanding about my own work.
3. Cultural Construction and Cultural Production seem deceptively similar to one another in nomenclature, and therefore are equated with each other by some reviews. I can find little discussion of their divergences or commonalities in the literature, and yet, I have found several noteworthy distinctions between the frameworks. This seemed strange, and like a gap in the research literature, perhaps exacerbated by a mutually exclusive, necessary and complete set of assumptions and predecessors which each scholarly community lives within.
4. The debate between Cultural Production and Cultural Construction seems, even to me at times, esoteric and intellectual; so the urgency of Liberatory Pedagogy seemed to provide a useful counterbalance to these two ethnographic traditions from a sense of activist purpose. At the same time, while Liberatory Pedagogy's strengths lie in taking quick and decisive action, it may at times fall short in first gaining a fundamental understanding of the problems. Although in some ways incommensurate, these three traditions seemed like a theoretically distinct and literature-embedded set with which to ground this comparison of scholarly traditions.

First, this section will proceed to compare the three approaches based on a blended sense of their guiding theoretical orientations and the purpose of their research. Next, it will play out a methodological thought experiment using the research context of Chapter 3 (an introductory programming course for electrical engineers). Finally, it will discuss implicit critiques and affordances between the respective approaches.

***Touchstone Examples of the Modern Day Approaches***

In order to help the theoretical and methodological comparisons be grounded for the reader, I will provide a summary of one or two touchstone examples for each approach.

Heidi Carlone and collaborators draw on Cultural Production (and at times, the related frameworks of Figured Worlds and practice theory), to look at the production of available identities in a classroom culture (in 2004, high school Physics; in Carlone et al., 2011, 4th grade science). Her 2011 study is a comparison of two 4$^{th}$ grade classrooms with different norms and emphases. She grounded the study in a card sort procedure to uncover the student-understood meanings of “science” and “science person.” In order to make an equity case, she noted discrepancies regarding who was considered a “science person” based on gender, race, or other localized classroom performances and identities. She then examined classroom practices in order to identify, code, compare, and relate them back to the production of science identity. She found that although the classrooms looked similar in terms of being “hands on” and some standard metrics, they were subtly different in terms of cultural practices which contributed to science identity. Although she notes a goal of providing a nuanced rather than dichotomous understanding between these classrooms, she finds that in one classroom science identity was largely reproducing the status quo raced and gendered meanings of science person and in another it was producing new definitions with greater access for more demographic groups to be a "science person."

Ray McDermott and Herve Varenne were the originators of Cultural Construction (which has overlaps with and similarities to interaction studies, cognitive ethnographies, and global cultural studies). Their seminal work looked at the interactional construction of Learning Disability (1993), literacy (1995), genius (2004), and several other phenomena they position as "educational facts." In their seminal 1990s work on Learning Disability, they revisited interaction data of a student (Adam) they had observed in a 1970s multi-site ethnographic study. Although in some settings (a psychometric test and a classroom) Adam was constructed to be a prime example of having a Learning Disability, they showed other settings (at home, on a fieldtrip) in which this label did not hold up. Detailing the prototypical interactions of a class which creates the educational fact, they argue that instead of a permanent feature of Adam's brain, in fact the classroom interactions and an American school culture looking to create failure in students is responsible for its creation. (For a full account of the historical development of McDermott's Cultural Construction framework, see Appendix A: Constructing McDermott's Cultural Analytic Framework.)

Two prominent disciples of Liberatory Pedagogy in engineering education today are Paulo Blikstein and Donna Riley. In Blikstein's (1990) work, he pursues an electrical engineering informal learning project in a low-income area of Brazil. Wanting the project to be personally and politically relevant to the students, he has to adjust his intended curriculum (based on energy conservation) to a curriculum embedded in the class and political struggles of the community (investigating and documenting electrical safety of makeshift electrical grid hacks). In Riley's (2003), she describes a curriculum for chemical engineering which resituates chemical engineering as a body of knowledge linked to issues of social injustice, and creates opportunities for the repurposed student-directed learning to respond to injustice. Both of these examples take a predominantly Freirean approach, however in Teaching to Transgress (1994) hooks also emphasized a relational form of liberatory teaching practice, which in part sees teaching as supporting an individual in the process of developing healing theory.

***Ontology, Epistemology, and Purpose***

Cultural Construction, Cultural Production, and Liberatory Pedagogy differ in several dimensions. Underlying some surface feature differences in context and methods, there also seem to be some deeper underlying differences related to the theoretical views of culture, positioning of knowledge claims, and purpose of the research. I see these as often intertwined, where a particular ontology of culture aligns with a particular purpose for research. It may be that the ontological view is guiding the researcher to conduct certain research, or it may be that the researcher has a particular goal in mind and therefore looks at culture in a certain way in service of that goal. Rather than a logical choice among hierarchized priorities, quite likely it is a messier reflexive relationship—it seems scholars have aligned themselves in pursuing a particular set of these commitments out of a combination of personal purposes and intellectual alignments.

In this section I will lay out what appear to be the broader orientations and commitments of the three traditions. For now, I will attempt to apply the viewpoint of the research tradition, and not present a critique of any of the traditions or between the respective traditions.

*Documenting Novel Cultural Productions in Education*

As noted in the section on scholarly lineage, Cultural Production work grows out of a view of society wherein oppressive systems tend to reproduce their oppression. This view of macro culture, as oppressive, conservative, and reproducing itself, is taken as the backdrop for much cultural production research. Macro culture of society writ large, conceived in this way, becomes something of a framework rather than a site of analysis; it is a stable substrate against which local (e.g., classroom-level) meso cultural productions can be compared and conceived. The goal, then, is to find and document the sites of cultural resistance, where a broader oppressive culture is not being reproduced.

This goal necessitates or emerges from an ontology of culture which delineates the meso from the macro in the first place. Perhaps as with ontologies in other complex intellectual domains (e.g., schema in cognitive science), the question is less whether meso culture exists and more whether one chooses to look for it. By looking for the contours and features of meso culture as distinct from macro culture, one inevitably finds confirmation of that choice in the form of distinct local features which can be compared to broader norms. Another component of the ontology of culture in society in this paradigm seems to be an emphasis on a production (anti-oppressive) / reproduction (oppressive) binary. Since the broader task of cultural production is grounded in helping new productions flourish, it inevitably maps many of the findings into a framework where features are either reproducing oppression or creating new cultural productions.

The purpose of the research is to find and describe the spaces which create new possibilities, in order to understand and encourage them to spread further.

The task of documenting the meso cultural production seems to be bolstered by interpretivist epistemology and knowledge claims. The ethnographer of cultural production relies on participant accounts of the culture, employing the tools of fairly traditional ethnographic research, participant observations and interviews to uncover local meanings. The insights of participants are often taken at face value, and bolstered as knowledge claims by the consistency between participant accounts and shared impressions of the local culture. By suggesting Cultural Production employs interpretivism, I mean to contrast this reliance on participant insights to local settings with an objectivist / positivist view (with a reliance on more “indisputable” forms of data), a subjective / post-modern view (with a rejection of received categories), and a critical theory view (with a suspicion of knowledge productions embedded in power).

*Uncovering the Cultural Construction of Educational Problems*

Cultural Construction work (with parallels to interaction studies and cultural studies) emerges instead from certain work extending the tools of traditional Anthropology to the Anthropology of Education in the United States. McDermott positions Cultural Construction as an extension of interaction studies, which had come “to the defense” of students experiencing marginalization at the hands of education, namely students experiencing “educational problems.” Thus, Cultural Construction was always primarily focused on revealing insight about classroom level interactions more than on documenting broader patterns of social/cultural reproduction/production.

Ontologically, culture is seen as pervasive and all-encompassing, while it is shaping local interactions. Thus there is no need for distinction of a meso and macro level of culture, all culture is seen as the global being expressed in the local. Culture is the water we ourselves don't know we're swimming in (Chapter 3). For participants, outside actors, and the researchers themselves-- everything can be influenced by culture. Therefore, McDermott discusses culture with a constant reflexivity, even stopping his own narration to implicate himself and his view as part of the system he is looking at. The purpose is to critique educational culture and reveal the interactions which perpetuate it. The work of the scholar is to identify and to puncture a view of shared educational culture which the reader is themselves embedded in—a highly reflexive project which necessitates and grows out of a view of culture as both global and local, equally relevant to the reader as to the participants in the study.

Epistemologically, Cultural Construction works somewhat closer to traditions of subjectivist, post-structuralist, post-modernist, and critical research, where even the facts participants and researchers receive in a setting can be called into question as embedded within and colored by the culture of analysis. Culture is so deep and encompassing that it is influencing even the perception and interpretation of events. This means that although Cultural Construction grew out of traditional ethnographic research it rarely employs the traditional tool of the participant interview, and it inevitably introduces culture to uphold or question perceived realities of participant observation. A local participant or reader who firmly believes in the reality of Learning Disability in a classroom will still have their views challenged by evidence to the contrary, if that is the culturally shared reality under scrutiny.

*Liberating Students through Pedagogy*

Finally, Liberatory Pedagogy comes from a tradition of political resistance to oppression, connecting that project to the liberatory potential present in educative processes. Although it originally arose from a parallel inspiration as Cultural Production (Marxism), it diverges from Cultural Production in its primary purpose and stance—the education scholar as an activist rather than as producing knowledge. Similar to Cultural Production it holds a fairly static and dim view of macro educational culture as normally perpetuating oppression. Unlike Cultural Production and Cultural Construction, Liberatory Pedagogy seems not to specify a particular ontology of culture; seemingly out of an immediacy of the challenges in culture it does not focus on cautious intellectual analysis and instead moves to subvert and change the culture.

Liberatory Pedagogy has a broad goal of liberating students from oppressive forces such as class, race, and gender, which can operate through traditional "banking" subject matter instruction. It has a critical orientation, which in some ways may be shared with Cultural Construction: Liberatory Pedagogy is attempting direct and subversive activism in changing classroom practices, Cultural Construction attempts to function as activism in calling for change through scholarly publications.

Liberatory Pedagogy appears to have a critical epistemology, in its focus on the connections of truth and power, and a sort of "standpoint" epistemology, where individuals are empowered to create and find healing theory to understand oppression in their lives. It also seemingly to be post-epistemological, at least in that the task of producing sanctioned scholarly knowledge in and of itself is too conservative and inactive for the challenges at hand. Instead, the focus is on subverting oppressive systems, empowering students, and changing the status quo of education (which could be seen as a form of normative culture).

***Methodology and Phenomenon of Interest***

Having outlined the three frameworks for culture and marginalization STEM education in terms of their overall theoretical commitments, scholarly foundations, and researcher orientation, I will now revisit each of the three approaches in terms of the methodological details of classroom-based research. Rather than purely citing methodologies in the abstract or pointing to incommensurate details of specific and disparate studies, I will conduct a "thought experiment" of sorts by positioning the research as typified by prominent scholarship inside the classroom context in Chapter 3 of this dissertation. Thus, this section functions as a preview of a methodology which I fully take up in the subsequent section, and positions it within a range of choices of methodology I could have taken up instead. Each section will consider a likely focus (e.g., identity, ability), and discuss a set of methodological steps typically taken in terms of the primary research context of Chapter 3.

*The Cultural Production of a Programmer Identity in an Alternative Introductory Course*

In this Cultural Production study, an alternative introductory programming course for electrical engineers is seen as a potential site for novel cultural production. The traditional cultural image of programmers is as nerdy, White or Asian, men, slavishly typing away in their bedrooms (Margolis & Fisher, 2003); the cultural image of engineers is similarly White and masculine. Similar to Carlone's studies in science classrooms which began by identifying dominant cultural images of White male scientists in lab coats (Carlone et al., 2011, p. 464), it would be important to begin by identifying the hypothesized tendency of oppressive cultural reproduction which we would expect to play out in an undergraduate programming classroom. We can also chart the educational policy such as the Accreditation Board of Engineering and Technology as requirements which structure engineering classrooms as major forces at play, as Carlone did in examining national science standards (Carlone, 2004, pp. 394–395).

Dominant cultural images can then be connected to dominant classroom norms; in traditional programming lecture focused on abstract tasks rather than real world applications, masculine norms like individuality and technocracy are valued above feminine norms like collaboration and solving real world problems. Perhaps we have also identified competition as a norm supporting masculinity in a classroom (Bird, 2016). Drawing on classroom research on the status quo classroom culture, we start from an assumption that this meso classroom culture serves to perpetuate macro cultural norms related to engineering and programming as white, masculine, technocratic, individualistic, and competitive. An ethnographic site of a traditional lecture based programming course can form a comparison context where these forces will be expected to play out as usual.

In contrast to the dominant macro cultural forces, we can identify counter-culture macro cultural forces: new ABET requirements emphasizing collaboration, new pedagogical developments, and new NSF initiatives. The purpose of the grant funding my dissertation study was to determine the impact of a new active learning pedagogy on programming instruction, with equity and demographic implications as one hypothesized affordance. Parallel to Carlone's focus on instantiations of reform standards, the grant forms the catalyst for a possible new cultural production which subverts dominant norms of undergraduate engineering classroom. We embed the research inside a space where these new pedagogies are playing out in order to document them and assess the impact.

Cultural Production very often draws on theories of identity and sociocultural learning in a community of practice (J. Lave & Wenger, 1991), where assessing the differential identity development of students in the class becomes a primary metric for assessing the power of new cultural production. I note that an obvious choice for this thought experiment is to select programming identity as a primary phenomenon of interest because it is a very common choice (Carlone, 2004; Carlone et al., 2011). However, since identity is not one intrinsically required to pursue Cultural Production work, it may also be that Cultural Production has some unexplored explanatory power if new phenomena of interest were explored.

The next step in our thought experiment Cultural Production study is to observe and demarcate meso classroom culture in the respective undergraduate classrooms. We would take up several parallel forms of data to gain insight into the classroom culture. We would conduct semi-structured participant interviews to ask students about the shared cultural meanings in the classroom. Critical in these interviews would be asking who the programmers (or perhaps, “real” programmers) in the class were, whether they were a programmer, and what it takes to be a programmer. These participant meanings would be supplemented with fieldnoted classroom observations and other collected artifacts which connect the pedagogy to identity formation. In summarizing this large dataset, the ethnographer would emphasize shared student perceptions of programmer identity (demographic or attributional patterns), and descriptive themes which capture the pedagogical norms. The goal would be to characterize and compare the primary cultural features of the two classrooms and their consequences for identity formation.

Finally, in analyzing and presenting the data, the researcher would look for evidence of the ways the macro cultural forces identified are shaping meso culture in the traditional and alternative programming courses. We would ask who is gaining access to identities of legitimate participation? When are macro cultural stereotypes reinforced and reproduced? When and how are novel cultural productions made available? The final presentation may categorize meso classroom themes into those which align with oppressive cultural reproduction and those which subvert it via novel cultural production.

Although I did not conduct my study this way, I can map several salient aspects of macro culture and meso (classroom) comparisons on to this research model. At a smaller grain size, within the individual lab section, there also appeared to be moments where a dominant competitive class cultural norm was subverted by an individual team or disrupted by a substitute lab instructor who supported student work and collaborative discourse. Perhaps Cultural Production as a framework would give tools to think about the course level forces which affected the novel production of lab classroom culture. This might represent work which falls in between Cultural Production and Cultural Construction, since in general, a grain size at the level of classroom interactions is a bit closer to the norm in Cultural Construction (Cultural Production is more often carried out at grain sizes of society on the one hand and classroom pedagogical initiatives on the other), but a focus on the factors encouraging novel anti-oppressive cultural productions is more aligned with Cultural Production (Cultural Construction is more often focused on unpacking educational problems, as the next section elaborates).

*Cultural Construction of "not cut out for" Engineering in Introduction to Programming*

The Cultural Construction study is not a thought experiment, but the approach taken in Chapter 3. No ethnographer enters a classroom as a "blank slate," and an orienting knowledge of engineering culture, classroom norms, novel pedagogies, and other macro level forces likely infiltrates one's observations. Nevertheless, the practical first step is not researching and documenting the macro cultural forces at play to look for an opportunity for novel production—a process I would characterize as seeing how top-down cultural forces play out. Instead, in Cultural Construction, the first step is to identify an "educational fact" which has salience in the local classroom context. This fact probably maps onto an educational problem, a labeling in an institutional system or an interactionally-noticed deficit. It probably bears significant meaning for local stakeholders and has connections to student outcomes and broader narratives. An educational failure grounded in an educational hierarchy is the typical phenomenon of interest, in the case of my study, the research focus was launched by a student who after a term of being the slowest programmer in a competitive course culture confessed to me he "just didn't have the brain for programming."

The emphasis on ability and hierarchy, instead of identity, seems to characterize work which has a Cultural Construction influence. Some work which blends the Cultural Construction and Cultural Production sees identities nested inside hierarchies of trajectories as identities in communities of practice (e.g., "not Calculus-ready" in O'Connor et al., 2015), and other Cultural Production work notes the harmful influence of ability hierarchies as a contribution to identity rather than a central phenomenon of focus (Carlone, 2004, p. 407). Cultural Construction, instead, seems a bit suspicious of identity as an overly individualized American conception (Varenne & Mcdermott, 1999b, pp. 1–4), and instead chooses to emphasize the collective interactional process which create consequential ability hierarchies.

The next step of a Cultural Construction study (or an emerging first step, in tandem with identifying the educational fact in the first place), is to observe local stakeholders constructing the educational fact as a shared cultural reality. It is key to look for the consequential actors and interactional events which contribute to the educational problem. In participant interviews, I engaged several students around the topic of programming or engineering ability, informally probing students about which students could and could not do programming. It was important that students came to rough agreement about the educational fact of who was seen as fundamentally struggling, just as Carlone needed agreement when probing science identity and McDermott needed to ascertain (through other means) that Learning Disability was a salient classroom reality. Some amount of agreement on basic interactional events and cultural interpretations was necessary as well: if students had contested the assessment of my focal student as struggling or whether class time was being spent on advanced questions, it would have reduced my view of these elements as salient and cultural.

However, it was not important to collapse student impressions into a set of unifying themes as Carlone did; rather, similar to McDermott, a scenario of the classroom could be played out where each player has a partial view of and a partial set of contributions to the educational fact. For instance, when looking at the pedagogical and interactional factors constructing the fact it was apparent that students viewed elements very differently on the basis of privilege, and also differently from me as a partial outsider researcher. When first asked if lab seemed "competitive," Becca, the focal student immediately said no. However, when asked to elaborate it was clear what she meant in this answer revealed an underlying competitive culture: 1) no, the class was not significantly more competitive than most of the other sophomore year classes she was struggling in, and 2) since she was so behind in programming lab it was beside the point whether the "boys" were competing with one another, she certainly wasn't competing. Though on a surface level the interview participant would not have agreed with a cultural norm of competition, from a holistic ethnographer's view what she was revealing was a heavily competitive culture which permeated the institution and excluded her. On the other hand, some of the higher-programming-experience boys found amusing an interactional pattern where they asked advanced questions to distract the professor. I retained a skepticism of this game during my accounts of it, rather than, for instance, taking the dominant students' impressions as reality.

Additionally, in my Cultural Construction work I relied more heavily on interactions and field observations than on interviews. In cultural production it seems interviews often function towards substantiating the meso culture. In Chapter 3, although interviews constituted an entry point to examining the interaction, and shared impressions of the class setting (perhaps a meso culture) were sometimes culled to support the analysis, these were not the analytic focus. This seems to have drawn me towards smaller "strips" of interaction (McDermott & Roth, 1978) than if I had been trying to pool across the collective and conscious experience of students. For instance, looking carefully into interactions to understand why (in an interview) Becca had said she felt "lost" and "like a nuisance" in lab, helped me uncover the interesting and important moments of knowledge transmission and assigning credit, moments Becca may not necessarily have been able to fully "see" or recount in an interview. If I had instead tried to establish a meso culture based primarily on collating interview themes, I might not have seen these smaller idiosyncratic moments and taken-for-granted elements that in fact turn out to be highly revealing about culture.

The final step in cultural construction analysis and writing is to use the observations about educational facts and interactions to make commentary about educational culture. Generally, this means presenting salient and representative interactions as evidence of the impact of culture on students' lives and the facts that become consequential in educational settings. The educational facts are presented and deconstructed to present them as more dubious than otherwise interpreted and viewed in typical educational cultural settings. By upending the educational fact and highlighting the educational culture which helped produce it, the research becomes a cultural critique of the shared broader educational culture which undergirds and produces the facts.

*A Pedagogy of Liberation in Electrical Engineering*

Liberatory Pedagogy would likely not engage the same intellectual debates around identity and ability in the engineering classroom. The positionality of the researcher would become that of the teacher-scholar-activist, where research and pedagogy blend towards liberation of the students, without a central goal of knowledge production. This is a positionality I did not have with respect to the classroom space.

Furthermore, even if a teacher-scholar-activist wishes to take up a Liberatory Pedagogy project, it may be quite difficult to begin it inside the context of a traditional institution, since embedded within the work of Liberatory Pedagogy is the need for the teacher-scholar-activist to upend the oppressive norms and structures of traditional education. At a bare minimum this would probably include not giving grades related to traditional measures of performance in subject matter content. If grades were required, perhaps an instructor would elicit student self-assigned grades based on a self-actualized sense of growth (Rogers & Freiberg, 1969), or assign a sort-of grade which awarded student political action to liberate themselves from oppression, or once again subvert the system and give everyone A's. But grades would only be the smallest and first subversive action. The teacher-scholar-activist would need to have a great deal of agency within their classroom and to take a great deal of latitude to stray from conventional educational norms. This is probably why much Liberatory Pedagogy work comes in the form of informal learning settings (Blikstein, 1990) or in liberal arts institutions which can find a sense of pride in upending convention (D. Riley, 2003). As such, the setting in a fairly conventional university engineering department, with a pedagogical development not centrally focused around liberation, would probably not qualify as an appropriate site for enacting liberatory pedagogy.

Once finding an appropriate instructional setting and taking a different positionality in the classroom, a Liberatory Pedagogy curriculum of programming for electrical engineering might begin with co-learning with students towards embedding programming and electrical engineering within systems of society which perpetuate class oppression, such as Blikstein did with low-income students around electrical energy in their home communities of Brazil (Blikstein, 1990). The precise curriculum would need to draw on knowledge which is relevant and liberatory to the student population, perhaps engaging significant differentiated project work if the student community has a diverse set of trajectories for liberation and self-actualization. The pedagogy would very likely need to remain highly flexible and responsive in order to engage with student realities which cannot be known and predicted in advance (e.g., Blikstein's alteration of his project when realizing energy conservation was not as salient as energy safety in makeshift electrical wiring scenarios).

On the other hand, if a scholar-activist were to take a more relational form of Liberatory Pedagogy, per hooks' Teaching to Transgress (1994), perhaps participant interviews and interactions in the original research setting could become a site for a more personal form of liberation as growth and understanding, even in spite of a fairly traditional and oppressive set of institutional constraints. In Chapter 5, I explore a relational form of theory-building which emerges out of qualitative research with a participant who in fact was experiencing institutionally and disciplinary normative forms of pedagogy. So perhaps in our thought experiment, rather than walking out of the classroom and finding a setting more conducive to individual liberation, the Liberatory Pedagogy scholar engages participants, asking them to reflect on experiences in oppressive culture, and encouraging them to build theory and to resist the norms of the class.

***Implicit Critiques and Affordances***

The section on scholarly lineage showed three parallel traditions which were well-grounded to approach and respond to marginalization in education. It also revealed an apparently parallel but insular scholarly lineage where scholars can draw on their close peers and predecessors without comparing their approach to those from other traditions. This leaves a gap of understanding in the literature and makes it difficult for someone examining disparate research approaches to determine their affordances and limitations. It also does not challenge researchers in parallel traditions to develop tools and improve methods which respond to the critiques that could emerge from such conversations. Thus, the following section places these three traditions in conversation with one another, and begins to develop those implicit critiques and respective affordances of each tradition.

*Critique of Cultural Construction; Affordances of Cultural Production*

One critique of Cultural Construction comes in the ontology it assumes, or chooses to focus on. Cultural Production seems to ascribe to a view of culture embodied by the framework Culture-Structure-Agency, where it is critical to name the aspects viewed as culture versus structure. (I heard this critique in discussant feedback from Margaret Eisenhart, during an AERA session, April 2016). For Cultural Construction, the distinction seems blurred or ignored. When naming cultural forces at play, McDermott often names institutions (testing services, government, educational bodies) which structure events in a culture as normative. It may also be that this distinction is more about substance than about nomenclature—McDermott's tendency to move analytically upward from an interaction to a culture supporting the interaction may bypass a step in the Cultural Production analytical playbook, which wants to account for structural level mechanisms (e.g., NGSS or ABET) for production or reproduction. Empirically and analytically, Cultural Construction focuses less on these organizing bodies and structures, and more on unpacking interactions which construct educational facts.

Other recent trends in Cultural Studies seem to progress beyond this dichotomy and perhaps to split the difference, Varenne's (2016) then-now-next version of Cultural Production describes looking at the interactions of those in power who are constrained in a system and culture and must decide “what to do next.” This seems very much to draw on his work unpacking the role of interactions in constructing cultural realities, while turning attention to those in power and comprising the work of “structure.” Likewise, Cultural Production and figured worlds studies of instructors assigning grades and discussing students have unpacked the interactional work of those in power to create educational facts about students’ failures (Horn, 2007; O’Connor, Peck, Cafarella, & McWilliams, 2016).[10]

Another primary critique of Cultural Construction comes in its purpose: the focus on marginalization and educational problems is by some Cultural Production-ists seen as already known, depressing, and/or unproductive. Cultural Production work implicitly places a higher value on documenting and accounting for positive shifts in culture. (I heard this critique from Heidi Carlone and Angela Johnson during an AERA session, April 2016.) Although this can be dependent on the affordances of the research context, as the thought experiment above showed, there are ways in which taking either guiding theoretical approach will shape the view of a particular context. In the end, this may come down to taste and purpose, since reading Cultural Construction work has always been inspiring rather than depressing for me, and apparently has the exact opposite effect on others.

As a corollary of this distinction, I think Carlone and Eisenhart’s Cultural Production has a methodological tendency towards accurate or positive characterization of a class as a whole. By culling across several students to generate authentic accounts of

[10] Kevin O’Connor draws on the Cultural Production of the Educated Person in his writing, but Varenne does not. It may be that Varenne is influenced by but not directly engaging a proverbial conversation with the Holland, Levinson, Eisenhart, and Carlone Cultural Production scholarly community.

a classroom culture towards a framework of production or reproduction, their goal is to create a reasonable and accurate assessment of educational settings. In their focus on novel cultural productions, they may tend to elicit partnerships with instructors whom they have reason to believe are enacting productive transformations of pedagogical culture in their classrooms. The tendency for Cultural Production to find positive settings and stories and tell accurate stories about them may produce final products which are fairly agreeable and understandable by practitioners and stakeholders in the class.

On the other hand, Cultural Construction work has a tendency to look for marginalization, it is less theoretically inspired by explaining positive productions. It seems for Cultural Construction the moments of resistance are usually positioned as fleeting moments of agency, which a broader culture of marginalization can and likely will wash away. Not only is Cultural Construction focused often on marginalization rather than positive stories, it does not set its sites on the most egregious and agreed upon forms of marginalization, but seeks out the subtle interactional moments many would have not noticed or would have interpreted as mundane. And it attempts to counteract a set of views or interpretations held by many in an educational culture, a process which may be challenging to stakeholders. In short, Cultural Construction work may feel to cultural insiders or local stakeholders like it is upsetting, unfair, or like it is imagining problems. My initial experiences presenting this research to participant instructors has borne this out. My consultation with other Cultural Construction-inspired scholars have suggested member checking and participant authenticity is not always fully engaged in; in order to have a greater measure of honesty in a broader cultural commentary one may not be able to have as easy or comprehensive a member check to those inside the system.

This is a challenging implicit critique and tradeoff for research which is critical of culture.

*Critique of Cultural Production; Affordances of Cultural Construction*

I subscribe to Cultural Construction in Chapter 3, thus having taken up the framework myself and engaged with other scholars' Cultural Production research I can levy some implicit critiques from my own research's perspective onto Cultural Production.

As with the critique from Production towards Construction, one critique is ontological. Cultural Production necessitates an ontological distinction between meso and macro culture, in order to assess whether production or reproduction is occurring at the meso level. In general, this seems plausibly justifiable, though I generally see more value in Cultural Production work which unpacks mechanisms for production or reproduction (O'Connor et al., 2016; Varenne & Koyama, 2016) rather than a priori identifying the macro level forces which will have impact and seeing whether and how they play out.

However, I am particularly concerned about the work which sees classroom interactions as constituting a stable meso culture. There appear to be several limitations of seeing a classroom as a culture exhibiting novel production or reproduction in the way the social reproduction tradition meant it. Classrooms are local interactional spaces, students do not live inside the classrooms at all moments, they come and leave. Classrooms do contain norms and locally shared meanings, and those are embedded within broader shared cultural norms which leak into the classroom. But some Cultural Production work seems intent on finding hope in creating new culture one classroom at a time, a goal which still seems swamped by the overall educational culture. Perhaps it also has to do with the educational context and participant demographics: Cultural Production work in a 4th grade classroom can focus on creating a classroom culture where students take up certain local beliefs about scientists. Students live most of their day inside this classroom and therefore the local beliefs and norms do come to operate in their lives. In undergraduate engineering, the students are not primarily living inside one stable local classroom set of norms and meanings throughout their day, but are moving between the norms of classes, campus, social settings, and broader US educational culture (perhaps a description more akin to nested figured worlds). The beliefs about programming identity of undergraduate students may be less pliable than the science identity beliefs of 4th graders, the cultural norms they operate within are more interconnected. Furthermore, classrooms are also contested interactional productions which can shift as often as they stabilize. By attempting to find stability and coherence perhaps Cultural Production can turn a blind eye to the “smaller strips” of interaction (McDermott & Roth, 1978, p. 324) which make up the day to day of even the novel cultural productions they document.

I believe some of the most salient aspects of marginalization in undergraduate engineering contexts seem to be the interactional and cultural construction of failure. The participant in Chapter 3 was not having an identity mismatch and was not feeling out of place because of gender. She was not building a programming identity but this would not have deterred her much from her eventual goal of being a building-focused electrical engineer. What did deter her was a daily experience of interactionally constructed failure, and the consequences in her educational trajectory. Perhaps this is a difference in context, and in 4th grade classrooms identity as science person easily emerges as the primary salient force contributing to student trajectories and well-being. But I also see that a focus on the phenomenon of ability construction is noticed and alluded to in Carlone's work, and could become a primary focus in K-12 work (Gresalfi et al., 2009). I point to the hierarchical critiques of Kevin O'Connor for possibilities of what a research lens combining identity, Cultural Production, and interactional construction of ability can provide for insight into marginalization in education (O'Connor et al., 2016).

Overall, Cultural Construction seems to make a stronger argument for *interactional mechanism*s of the reproduction of hegemony than traditional Cultural Production work which sets out to characterize productions or reproductions. Cultural Construction also potentially reaches out towards wider implications of culture, since it did not assume from those cultural forces a priori as in some Cultural Production work.

*Comparison of Cultural Construction and Production with Liberatory Pedagogy*

Liberatory Pedagogy would seem to regard much of the work of both of the prior two cultural frameworks as valuable, but ultimately useless unless taking action with students in a liberatory educative process. It may regard much of my ontological and epistemological debate about the best way to conduct ethnography as academic esoteria. It may levy a critique that Anthropology has a history of explaining and exoticizing the marginalized and downtrodden to bring itself glory in producing interesting knowledge about "primitive peoples." This is a point of privilege which does not give back equally to the populations it studies.

While I resonate with the sense of urgency motivating Liberatory Pedagogy, I also worry that an activist political stance does not allow us to think deeply and understand cultural educational settings before diving in to fixing them. Although many examples of Liberatory Pedagogy do show the teacher-scholar-activist embedding in and coming to an understanding about a local culture, they nevertheless do not spend equal time explaining the contours and mechanisms of the culture and issues of marginalization they respond to. This can leave the work of response somewhat opaque, and look as if it hinges on the superhero stance of singular teacher-scholar-activists. Perhaps new forms of participatory ethnography incorporating elements of all three cultural frameworks will represent a new paradigm for education research which is as critical and careful as it is committed to creating change.

***Researcher Identity and Purpose***

This commentary has been both scholarly and embedded in my work, and I have attempted to reveal both the critiques which would be leveled at my own work as well as the critiques my work would bring to others. This final section brings the scholarly to the personal, looking at relationships of the researcher to the research process and claims, and using this to consider what my own relationship to these traditions is and how I will proceed. First, I will discuss a pattern of researcher identities I have observed amongst the scholarly communities I have discussed and how it may relate to the work they do.

*Demographics of Scholarly Communities*

We may not always talk about the social demographic identities of scholars, but as I was thinking deeply about the scholarly communities I was comparing, it occurred to me that demographic patterns were apparent and may be shaping the work people do.

The Cultural Production framework was developed by predominantly by White women, and motivated by a feminist purpose to unpack and understand the entry (or lack thereof) of women into STEM careers (D. C. Holland & Eisenhart, 1990). More recent applications continue to show themes of documenting and responding to gender marginalization in STEM education (Carlone, 2004; Carlone et al., 2011; Eisenhart & Finkel, 1998; Hegedus et al., 2014; Tonso, 1996, 2006b). This is likely incidental (e.g., the shared interests of friend groups of scholars, lineages of advisees and advisors who enjoy working together) rather than entirely deliberate, but for whatever reason, the pattern persists, with a few notable exceptions (B. Levinson & Holland, 1996; O'Connor et al., 2016).

The Cultural Cultural construction framework, on the other hand, was championed by Ray McDermott and Herve Varenne—who are French and Irish-American, White men. Their nearest colleague during the interaction studies work was Hugh Mehan (2015), and Kevin O'Connor may also be placed into this community (although he bridges the Cultural Production community as well). Many of the originating and prominent scholars are American White men, who carried a good deal of education privilege (associated with Stanford, Columbia, and University of Colorado Boulder, respectively). The authors are somewhat conscious and reflexive about their privilege, but are often examining forms of meritocratic oppression rather than pursuing feminism or investigating racial or class oppression directly.

Critical liberatory pedagogies were developed by Paulo Freire, a Brazilian Latino man and bell hooks a Black lesbian feminist in the US. Freire's work is fundamentally invoking Brazilian identity and class struggle, and hooks' identities are public and salient in her work. Most of the intersectionality, culturally relevant pedagogy, and liberatory pedagogy scholars are women of color or queer White women (Delpit, n.d.; Ladson-Billings, 2000; C. D. Lee, 1995; D. Riley, 2003). These scholars are in general not as normatively academically privileged and draw heavily on non-dominant identities in the course of their more analysis.

*Truth Claims and Author Voice*

Cultural Production employs classic ethnography, and is interpretivism which employs standard methodological tools to establish credibility. It meticulously lays out participant observation and interview patterns to establish what the cultural practices are and bolster its findings. It relays the views of participants as a shared cultural realism.

Cultural Construction is more reflexive, post-modern, and post-structural interpretivism than Cultural Production. It is inherently suspicious of and constantly contesting received meanings, though it does not take an infinite regress approach to post-structuralism (e.g., Spivak, 1988) where all meanings are continually contested. It nests participant interviews, observations, and interactions within a cultural framework assumed to be continuously shaping the received meaning of events.

Liberatory Pedagogy is positioned actively within the struggle of marginalization. Its focus is not on making truth claims or producing knowledge, but on subverting oppression and power dynamics. The scholar engages as an activist, not as an ethnographer but perhaps as a participant action researcher. It leverages knowledge in solidarity with oppressed peoples.

Recognizing that it may be unnecessary or unproductive to essentialize scholarly communities in this way, I wonder how the identity of the researchers were historically and are still salient in the way their knowledge claims are heard and taken up. I have demonstrated the valuable insight of all of these traditions, but bell hooks is sometimes viewed as unscholarly and not appropriate to cite in an academic paper. McDermott on the other hand represents a sort of pinnacle of academic insight. If McDermott were a Black woman creating the same prose and observations, would it be taken as pure scholarly insight, or as a less scholarly feminist and critical race invective? In other words, does McDermott draw on his flowery language, White male privilege, elite institutional privilege to make more esoteric mind-bending claims?

If a relatively privileged person were to take up hooks' and Freire's liberatory pedagogy work would it shift the nature of solidarity and bring in power dynamics (or the perception of power dynamics) in the way the work is received? Is it still worth doing, or what risks and drawbacks would need to be considered?

Did Eisenhart and team historically feel the need to draw on more ethnographic realism in order to make claims about power, to reduce the feeling of this being political feminist research? Has Kevin O'Connor (who cites both Cultural Production and Cultural Construction traditions) gotten a bit more leeway in his empirical methods in order to make truth claims?

*Questions for Relatively Privileged Researchers*

Finally, I ask myself a few questions about my relation to these scholarly traditions, the researcher identities I hold, and the nature of the truth claims and researcher position the respective traditions engender:

- What does it mean for me if I draw on similar forms of interrelated privilege: flowery language, institutional status, prior professional status as engineer, and White male identity in order to pursue work in McDermott's tradition? If there is value in such work, it seems almost required that an insider and privilege sharer do the commentary, otherwise it could be heard as objections of someone incapable rather than a critique of capability. But it is questionable whether I should access a scholarly position on the basis of access to privilege.

- What does it mean for me to move away from the slightly more post-positivist and interpretive realism work of cultural production? Is there a mutual hierarchical positioning of the paradigms-- one as more sophisticated, the other as more empirically justified-- and is this positioning partially gendered?
- What does it mean for me to take up hooks' work? I am internally motivated by solidarity in oppression, but to a large extent my sexuality is hidden / masked / passing in most educational settings. In that I work closer to race and gender in most of my scholarship, I embody dominant identities. How does one engage political solidarity work without as much "skin in the game"? How does it change the nature of the work?
- What does it mean to take up hooks and McDermott in parallel? Both take a critical perspective and shift the received categories of the cultural worlds they live in. Both see the macro in the micro, and power in the individual action. But McDermott may be speaking truth to power from the position of power itself—rather than the positionality of the oppressed.
- If one is also gaining privilege and academic status by making critical cultural claims, should those gaining privilege take active steps to dismantle that privilege, and if so, how? Solidarity in political resistance may be one answer, a necessary counterbalance to ivory tower critical

> commentary work. Likewise, critical commentary work may support political activism work in naming and interrogating the cultural system.

I will return to these questions in the conclusion when thinking about the next steps for my research, which frameworks I will take up, how, and why. The next chapter presents the empirical paper often referenced in this overview, on the cultural construction of ability in an introductory programming course.

# Chapter 3:

# "Turning Away" from the Struggling Individual Student: An Account of the Cultural Construction of Engineering Ability in an Undergraduate Programming Class.

## Introduction

This chapter presents research previously published as co-authored conference papers at the American Society of Engineering Education (Secules, Gupta, & Elby, 2016) and American Educational Research Association (Secules, Gupta, Elby, & Turpen, 2016) annual meetings. It is in a second round of reviews for publication in Journal of Engineering Education.

The following is a brief description of the development of the project and contribution of each co-author. I conducted all empirical ethnographic work for this study, as a graduate assistant funded by a National Science Foundation grant (DUE-1245745). As in-field ethnographer, I selected research participants and conducted participant interviews. In this work, I marshaled training in anthropological research methods and experiences as a student and instructor in engineering departments. My insider perspective in engineering was complemented by an orientation towards equity and culture fueled by exposure to literature and colleagues in the education department. Throughout the research process I was advised by Ayush Gupta, Andy Elby, and Chandra Turpen to help refine the approach to data collection and analysis.  Gupta has been an instructor in an engineering department for several years, and Gupta and Elby have significant experience in video interaction analysis of educational settings. Turpen, who has significant familiarity with cultural research in STEM education, was invited to join the team at analysis and authoring stages, particularly to help refine the analysis of culture and discussion of the relevant literature. I was primary author for every section of the chapter, with significant input, advice, and revision from each of the other co-authors.

***Culture in Educational Problems***

> Culture is not a past cause to a current self. Culture is the current challenge to possible future selves.
>
> Ray McDermott and Herve Varenne,
> in Reconstructing Culture in Education Research (2006a, p. 8)

> There are these two young fish swimming along, and they happen to meet an older fish swimming the other way, who nods at them and says, "Morning, boys, how's the water?" And the two young fish swim on for a bit, and then eventually one of them looks over at the other and goes, "What the hell is water?"
>
> David Foster Wallace in *Infinite Jest* (2009), and others

This research proposes to study the production of an educational problem. A concern with educational problems (such as retention rates, poor performance, disengagement), and the challenges of creating policies to ameliorate those problems, is at the heart of much educational research. But there are different ways of doing research, and they differ in the extent to which they treat the "problem" as the phenomenon of interest. Our research attempts to take a familiar educational problem and to grapple with it in an unusual way, by focusing on the many mechanisms by which the problem is culturally produced.

Invoking the word “culture” here could conjure for readers something other than we intend. If “culture” is associated with something more about “foreign” countries than our own, more about “unique” aspects than what is pervasive, more about the past than the present, or more owned by a category of “other” people than by ourselves, it misses our mark. On the other hand, we don’t mean to say that culture is instead owned by the native, the normative, or the powerful. The first meaning of “culture” signifies a fascination with explaining the exotic; the second risks veering towards a superficial, self-congratulating take on culture—in our nation, perhaps looking at the celebrations and traditions which make us most proud, in engineering, perhaps uncritically extolling values of “meritocracy” and “creativity.”

These commonsense understandings surely are pieces of culture, but they are only the static and easily visible elements that tell us what we already know about ourselves and our relation to others. Instead, consider that the vast majority of culture is the “water” we as fish cannot see ourselves swimming through. It is always present and shaping our perspective, though it is invisible; it is always affecting our actions, though we operate without needing to think about it; it is flowing and shifting around us, though it is inherently always already there. It is much bigger and much more amorphous than the pieces of our world of which we are usually conscious, and as such it is harder, and all the more vital, to interrogate.

This chapter investigates the culture, the "water," shaping the production of the educational problem that some students are "not cut out for" engineering. Drawing on the notion of cultural construction (McDermott & Varenne, 2006a) this chapter aims to make visible and to interrogate how the actions and interactions of many people, as well as institutional policies and societal values, work in concert to "produce" the fact of someone not cut out for engineering. In doing so, we aim to suggest an explanation that locates the cause of such problems in broader cultural practices rather than in the individual students or their backgrounds.

### ***Literature Review: Addressing Struggling Students***

Amongst the various purposes of research in education—to develop new pedagogical theories, to assess instructor training procedures, to incorporate new technologies into instruction (Johri & Olds, 2014)— there is long-standing attention to identifying, analyzing, and remediating educational problems. Responses to educational problems can take different forms, from the theoretical (why is the problem occurring) to the practical (how can it be ameliorated). For example, the problems of K-12 academic inequity and school failure motivate research and policy such as No Child Left Behind (E. Smith, 2005).

In this chapter, we take up the long-discussed problem of struggling students in undergraduate engineering programs. A common concern with this pressing educational problem drives research and reform in several different directions. Traditional quantitative retention research has documented the magnitude of the problem and clarified large-scale inequities in access to higher education in STEM based on gender, race, socioeconomic status (e.g., Ong et al., 2011; Seymour & Hewitt, 2000). This research often draws on a metaphor of the "leaky pipeline" to justify institutional remediation, including support programs for racial, gender, and (recently) sexual minorities within higher education STEM programs. Likewise, retention research highlighting additional corroborating factors in student struggles, such as self-efficacy and cognitive attributes (Marra et al., 2009; Martin-Dorta, Saorín, & Contero, 2008; Wilson et al., 2015), has informed the affective and academic dimensions of some of these support programs. Qualitative research strands that look at identity and marginalization have documented struggles from the student perspective, noting how aspects of self can contribute to or come into conflict with one's progress and prosperity within a STEM major (Danielak et al., 2014; Foor et al., 2007; Stevens et al., 2008). This research often employs a metaphor of "cultural mismatch" or "identity mismatch" to help extend the empathy and perspective of practitioners and those involved in the day-to-day of STEM in higher education, to consider diverse student perspectives more substantially. Research which draws on funds of knowledge, cultural capital, and assets-based frameworks likewise examine the socialized affordances of the individual, often leveraging their analyses to criticize the normative forms of instruction and evaluation (J. P. Martin, 2016; Wilson-Lopez et al., 2016). Likewise critical race theory has been marshalled to highlight the community cultural wealth of nondominant communities (Samuelson & Litzler, 2016). Additional strands of qualitative research using cultural and interactional analysis have conceptualized higher education as a social system, looking at how the interactions and culture of classrooms and institutions work (often unintentionally) to create academic struggles for students (in K-12 science, Carlone, 2004; in K-12 math, Gresalfi et al., 2009; in undergraduate engineering O'Connor et al., 2015; Tonso, 1996, 2006b). In this smaller body of work, we gain insight into cultural mechanisms which create the problem of struggling students.

In line with cultural and interactional approaches, we draw on a perspective advocated by Ray McDermott (McDermott, 1993; McDermott & Varenne, 2006a) to suggest and illustrate an alternative approach to research on educational problems, which they call *cultural construction*, or "turning away" from the struggling individual. By "turning away," he does not mean instructors ignoring struggling students. He means an *analytical* approach (for formal research or informal classroom explanation) of trying to explain the phenomenon of the struggling student in terms of the ways in which many actors within a culture create the educational problem. Thus while we share the feelings of concern motivating the prior research strands, we want to explain how these persistent educational problems get produced and reified, including (potentially) the role that well-intentioned institutions, practitioners, and researchers play. We start from this common place of caring about struggling students, and in asking what can we best do to address the problem, we find that the answer may be, counter-intuitively, "turning away."

***Revisiting the Literature via Three Analytical Paradigms***

Having touched on the breadth of ways that research and institutional programming have tried to address the problem of struggling students in STEM, we now draw on McDermott (McDermott & Varenne, 2006a) more directly to comment on each of these approaches and to introduce our particular approach. For McDermott, all educational problems are cultural problems, and culturally constructed "facts" (Varenne & Mcdermott, 1999b). The production of the educational problem involves many actors; those who ask and those who answer the question in academic literature, those who in practice recognize and those who are recognized as having the problem, and the many more who support the common cultural understanding of the phenomenon as a problem. To help focus the thinking in this framework, McDermott contrasts the cultural construction approach with two other kinds of analysis of the problem.

In *individual trait* analysis, an educational problem is conceptualized as rooted in the individual; problems indicate disadvantages/deficits arising from the student's background and/or traits. Unlike in the past, current educational researchers rarely blame students for the deficits, instead using the deficits to point toward broader problems in schooling and society. However, in these analyses, the student's characteristics are the unit of analysis, and some characteristics are viewed as putting the student at a disadvantage. In *socialized difference* analysis, an individual is viewed as experiencing problems on the basis of social structures much larger than them, and problems are explained as the result of the student's having been socialized by that position in society. In current education literature, these differences are often described as a mismatch between the culture/expectations of a given institution, such as an engineering program, and the student's "home" culture and other aspects of their background. McDermott places *individual trait* and *socialized difference* analysis in contrast with *cultural construction* analysis[11], in which the educational problem is viewed as created only via the concerted (though usually unintentional) effort of many actors in a culture which imbues meaning on the problem; any problems which are able to be discussed must have been noticed, measured, compared to a norm, reported, discussed, and accorded a shared meaning and importance. We argue for the value of pursuing research in the *cultural*

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[11] Individual trait analysis, socialized difference analysis are our terms for what McDermott has variously called Stage 1 and Stage 2 (McDermott & Varenne, 2006a), Cultural Deficit and Cultural Difference (McDermott, 1993; McDermott & Varenne, 1995) respectively.

*construction* paradigm to add new explanations to complement the research conducted from *individual trait* and *socialized difference* perspectives.

Applying McDermott's framework, we can see new facets of many common approaches to studying the problem of struggling students in STEM. In quintessential retention research, institutions and researchers define the terms of success and failure (e.g., persisting in a certain major, institution, or career; achieving a certain GPA; exhibiting a sense of disciplinary identity and efficacy), and find the aspects of students which contribute most to success or failure (e.g., gender, race, socioeconomic status, high school GPA, self-efficacy). In this analytical ontology, the individual is the site, and their attributes or backgrounds are the source, of the educational problem—an *individual trait* framing. Although researchers working within this perspective usually blame the system, not the students, for the students' problems, the underlying structure of this research is to interrogate the factors effectively "owned" by the individual and use that analysis to draw conclusions and recommendations regarding the institution. By focusing on the disadvantages of struggling individuals, this research can reinforce narratives around which traits are disadvantaging, narratives that become an implicit (though unintentional) justification for a status quo. Likewise, the remediation avenues which open up via this line of research will tend to "fix" the student via support groups, mentoring, and bridge programs aimed at underrepresented and at risk groups. While effective in comforting struggling and marginalized students, such remediation efforts can orient us away from the sources of the marginalization and the broader cultural process of producing the educational problem.

In “cultural mismatch” research, which includes much of the prominent identity research on gender, race, and learning approaches in engineering, the individual is viewed as having been socialized to embody a certain “culture”[12] (or at least, to embody certain socialized traits) which comes into conflict with the norms of the institution in power-- *socialized difference*. The cultural mismatch research often backgrounds the ways in which many experiences of educational problems are not just “mismatches” but are systematically created events of marginalization. For example, Carlone and Johnson (2012) highlighted that the Funds of Knowledge research paradigm is fundamentally looking for cultural differences students bring from their home life rather than, for instance, the cultural production of difference in school spaces. Although *socialized difference* approaches are often successful in advancing a cultural critique and leveraging it to reshape classrooms and institutions to be more responsive to students, the framing of the problem as an innocuous mismatch can still orient us towards mismatched aspects of culture rather than mechanisms of marginalization.

To be clear, we are not downplaying the value of research situated within the *individual traits* and *socialized differences* perspectives, nor are we accusing the researchers of inadequate awareness of culture. Several research programs which have operationalized problems as stemming from *individual traits* or *socialized difference* in prototypical ways, are conducted by researchers who are well aware of the many interactional, systemic, structural, and cultural forces which contribute to and create educational problems. And researchers may choose to take up a predominantly *individual trait* or *socialized difference* paradigm for important reasons. As one

[12] Note the use of the word culture here implies something discrete and embodied by the individual student. This is an intentional feature of quintessential socialized difference framing and one we will diverge from shortly.

prominent example, Seymour and Hewitt (2000) produced one of the most comprehensive early studies about the STEM educational problem of undergraduate attrition. Much of their research findings ground themselves in collating the traits of individuals (e.g. demographics); the corresponding interview quotes implicitly criticize classroom and institutional climate but ontologically treat the problem as a mismatch between individuals and educational norms. This work has been seminal in shaping the conversation about undergraduate institutional change over the past two decades, and it has informed the perspective of the authors of this paper. Nevertheless, the limitations of interrogating individuals as the site of educational problems have led researchers to pursue research within interactional, critical, structural, and cultural paradigms, in order to continue answering the questions that Seymour and Hewitt raised about the educational problem of students struggling within and/or leaving STEM. Indeed, in many ways, our work could not have been undertaken without a clear grounding in the understandings of the problem which emerged from the prior ontologies and methodologies.

Finally, as noted above, the third analytical approach in McDermott's progression is *cultural construction,* an approach relatively uncommon in STEM education. A few studies have adopted this and closely related approaches to cultural analysis. O'Connor, Peck, & Cafarella (2015) interrogates the institutional and cultural work involved with creating and assigning the label "Calculus-ready" to students, instead of viewing "Calculus-ready" simply as a property of well-prepared individuals. Carlone (2004) has looked at the classroom cultural production of the "science person" identity, considering it as a form of resistance or reproduction of larger cultural meanings. Gresalfi et al.

(2009) considered the interactional construction of competence in K-12 mathematics classrooms, work done not by the competent or incompetent individual but by classroom participants in interaction. This work is cultural analysis which, for different grain sizes and phenomena of interest, interrogates the ways in which many actors in a culture work in concert to produce the problems and phenomena identified. Viewing the engineering education literature from the perspective of McDermott's three types of analysis, we note the value of complementing current research paradigms with *cultural construction* analysis, in order to analyze educational problems in undergraduate engineering education from as wide a lens as possible.

We note a family resemblance between *cultural construction* and many parallel strands of research. Critical theory has been marshalled in engineering education to problematize common interpretations of interactions and events concerning women's trajectories in STEM (Ingram, 2006). Likewise, in gender studies, post-structuralist scholars have deconstructed aspects otherwise considered stable aspects of self (being a woman, being transgender) as social constructions, in terms of the categories, meanings, and norms an individual has agency to choose or perform (Butler, 2004). This framework of interactional feminism has been noted within a methodological and theoretical review in the engineering education community (Beddoes & Borrego, 2011), and begun to be applied to understanding gendered team roles (Tonso, 2006b). Other feminist scholars have also noted the boundary work of constructing both the discipline of engineering and gender in the narratives of engineering academics (Pawley, 2008) and engineering workplace norms (Faulkner, 2007).

Additionally, flipping the tradition within racial scholarship of often studying a predetermined “other,” several movements such as whiteness studies and Critical Race Theory have attempted to study that which we take for granted about race, the normative category of “white” and the creation and enforcement of racial categories across history (e.g., Painter, 2010). This approach could potentially be applied to the construction of racial categories in engineering classroom interactions, in institutional policy, or across engineering education culture and history. The engineering education community frequently draws on Critical Race Theory in framing and motivating their studies and in providing context for their conclusions. For instance, a common usage of the framework is in conceptualizing racial categories as not dichotomous (Ohland et al., 2011, p. 232)and as a tool of oppression, or “an artificial device used by those in power to differentiate and subordinate less powerful groups” (Trytten, Lowe, & Walden, 2012, p. 443). However, the engineering education studies citing Critical Race Theory primarily adopt a *socialized difference* framework for analysis of the empirical work, positioning the perspective of a racial minority against the norms of the majority culture, rather than looking at the interactional or historical work of constructing racial categories and difference. Thus there appears to be great potential for continued progress in understanding educational problems within engineering in the frameworks of *cultural construction* and these and other related frameworks.

***Why ability?: Emergent Analytic Focus***

As noted above, we feel the approach of examining the cultural construction of educational (or cultural) problems could loosely apply to many parallel strands of research. One could imagine pursuing a research program organized around the cultural construction of race, the cultural construction of gender, the cultural construction of maturity, or the cultural construction of criminality. In the education research reviewed above, we have seen research on the cultural construction of “science person” and “Calculus-ready.” In this paper, we interrogate the cultural construction of a student as “not cut out for” engineering.

Our choice to focus on the cultural construction of engineering ability emerged from the iterative nature of the research, as initial observations helped guide our theoretical framing which in turn guided further observations and analysis. In the pilot term of the Introduction to Programming course that we examine here, five students enrolled. One of the five, Isaac (all names are pseudonyms), took longer to finish classroom tasks than the course norm (e.g., in lab programming assignments), and two students appeared to particularly excel. By the end of term, the professor and other students could pick out who in particular was struggling, as could Isaac himself, who reflected in an interview “I just don’t think I have the brain for programming.” This happened, in spite of the fact that programming in the professional world is rarely a timed activity with “winners” easily noticed, and in spite of the fact that the students with whom he compared himself had been significantly introduced to programming before the course began. Specifically, two out of the five students arrived through nontraditional paths, and the accompanying registration difficulties appeared to place them in an introductory programming course in spite of their having substantial prior experience. The construction of Issac as a “struggling” student emerged as worthy of unpacking because 1) it seemed to develop from such natural classroom activities and means, 2) it seemed to have such deep effects on student self-perceptions.

How should we describe the phenomenon underlying this educational problem? To invoke another common paradigm, it did not seem like an "identity mismatch." Isaac was apparently white, middle-class, male—demographically, perhaps even more of a normative engineering student than the two students who arrived from nontraditional paths. He was not suffering a culture clash with the educational material or environment, or at least that was not the most direct way of describing the phenomenon. He continued identifying with engineering, intended to persist with the major and felt he had other engineering disciplinary strengths. Though clearly he did not identify as a programmer by the end of the class, more salient to him was the feeling of not being able to do it. The phenomenon we were putting our finger on was related to identity, but with more of the weight of observation and approval, less of the agency of identification. What seemed interesting was that this course appeared structured to be able to observe and confer the "worst" and "best" programmers, and in ways that seemed to surprise no one-- as opposed to, say, the norms of a writing seminar where all are expected to acquire the skill without finding out who is incapable at writing.

What seemed to be coming up in this interview with Isaac was a daily experience of being constructed as incapable in programming (or in engineering). We call this phenomenon the cultural construction of ability, of being "not cut out for" the discipline. The disability at play in this educational fact is not one that often gets labeled or spoken out loud in those terms, though neither is it only living inside one student's head. The sort of ability hierarchies at play here have a mutually acknowledged meaning and institutional consequences. By cultural construction of ability we mean to acknowledge the many levels on which this construction occurs—in the individual's perception, in the shared social space, in the institutional trajectory, and in the broader social substrate within which the institutions are embedded—and to demonstrate that they are inherently connected and reflexively produced.[13] This phenomenon of interest became the guiding theoretical focus for the ethnographic work in subsequent semesters.

***Disclaimer: Maintaining our focus on the system, not shifting blame around***

There may be a temptation to shift blame from individual students to individual teachers, from individual teachers to individual institutions, from institutions to an engineering sub-discipline, etc. We want to resist that in our writing and in its interpretation, on the following grounds.

First, a purpose of this research is to consider how all actors are connected to the construction of this educational problem, and how each actor is constrained within our culture with limited agency, often working with good intentions, and **still** constructing "not cut out for engineering" students. Being constructed to be the "worst" student in class is the most mundane experience of any classroom, but do classes need "worst" students? This is a phenomenon we think is central to equity / representation issues in nearly all classrooms, so we are interrogating it in order to consider how it comes to be and whether there are alternatives.

Second, this is not a paper about mean students, poor instructors, or bad classes. We resist this view on the grounds that such boxing of people is also culturally constructed. Furthermore, we note that the engineering course in this study was fairly typical, and was an above average learning environment for programming if one values progressive pedagogy, student-centeredness, a mix of collaborative and individual work

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[13] This a distinction from social psychology (e.g. Vygotsky, Piaget) who would treat ability as a cognitive reality which has been constructed in the brain as the product of social interactions. We instead examine ability as a constructed cultural reality only.

in labs, and instructor responsiveness to student concerns. We have student survey data (not presented here) which suggest that most students agree with this assessment, and that they enjoyed and valued the course. That is not to cast a shadow on traditional lecture classes either. In terms of the phenomenon of constructing this educational problem, we simply note that relatively progressive pedagogies are not spared the culturally shared practice of constructing struggling students. Rather than seeing the class as a rare exception, we invite readers to consider that the classroom in this paper may hit a bit closer to home—to see the ways in which many familiar classroom practices may be doing similar things.

**Methodological Overview**

The methodological approach for this project emerged from both theoretical (literature) and practical considerations. While the cultural construction literature tends to emphasize theory and analysis, we tried to assemble a robust and consistent methodological approach to investigate cultural construction in a particular setting. While collecting data in the 1970s, McDermott aligned himself with three primary methodological traditions: ethnography, ethnomethodology, and discourse/interaction analysis (Dore & McDermott, 1982; McDermott, 1978; McDermott & Roth, 1978). As an investigation of culture, our work relies on ethnographic methods and approaches, such as the incorporation of multiple qualitative data streams, ethnographic field noting (Emerson et al., 2011), and one-on-one participant interviews. As a study of subtle cues and ways of operating in an everyday educational setting, the methodology also draws on ethnomethodological approaches, similar to seminal work by Mehan (1979)uncovering the common discourse pattern, Initiate-Response-Evaluate, in K-12 classrooms. Finally, incorporating the affordances of videorecorded activities in the lab classroom, our approach draws on fine-grained discourse and interaction analysis approaches (Jordan & Henderson, 1995), wherein culture can be seen as constructing and constraining even small moments of a class interaction. In drawing on these traditions, we acknowledge that the current project is in many ways more focused (e.g., only on the cultural construction of ability) and more constrained than the idealized version of each methodology. For example, within a one-semester class, as well as within McDermott's cultural construction paradigm, there may not be "a local culture" bounded enough to embed oneself in and describe, as traditional ethnographers strive to do.

***Course Context***

This study examines the first post-pilot-phase implementation of a first-semester Introduction to Programming course for electrical engineering majors at a flagship State University with a large School of Engineering. Believing that many potential electrical engineers lose interest in or get weeded out of the major by the first-year programming courses, the instructor applied for and received a National Science Foundation (NSF) grant to create and evaluate this alternative to the usual first-semester course. Like its "traditional" counterpart, the alternative course introduces students to basic programming in C. However, in the alternative course, C programs control Arduino-like devices (Raspberry Pis) to accomplish tasks intended to be more authentic to electrical engineers than standard programming assignments such as creating and querying a simple database or playing a game like backgammon. The alternative course also employs many "active learning" strategies drawn from the engineering and science education literatures. The research and evaluation component of the NSF-funded project focuses on students' interest and retention in electrical engineering, students' views about the role of programming in electrical engineering, and students' performance in the (traditional) second-semester programming class.

As described below in more detail, class sessions consisted of weekly lectures attended by all 29 students, and 10-person lab sections to allow students to apply their learning to engineering tasks. Of the 29 students, all were White, Asian-American, or first-generation Asian immigrants. Three were women. Most were first-semester freshmen taking their first required electrical engineering class. Some were community college transfer students or upperclassmen who needed or wanted to take the class. Several seats in the course had been opened for "University Major" students, the label for State University students who have not yet been accepted into the School of Engineering.

***Data Sources***

We now list our primary sources of data and how they were used:

- 9 students were interviewed early in the term and again during finals week, and 3 students were interviewed for follow-up reflections during the subsequent semester. (See Appendix B: Preliminary Interview Protocol for Chapter 3 study for more information). Interviews were videorecorded. We used these interviews to help focus the analytic gaze during the taking and revisiting of fieldnotes and video data from the classroom, and to find what aspects of the course were salient to the students in producing a particular personal experience or reputation (say, of being incapable). We purposefully sampled both men and women, and both electrical engineering majors and students not yet accepted into the major. Consistent with McDermott and ethnomethodology, we use interview quotes sparingly, since our focus is on revealing culture in interactions and systems. Individual perceptions are an entry point, but not the primary evidence, to conduct such analysis.

- In lab, we videorecorded specific students working individually and in pairs. This interaction data was central to understanding processes of cultural construction. Content logging helped establish patterns over time, and highlighted episodes for closer examination and transcription. We took an ethnographic approach to "field noting" the scene in the video, beyond literal transcription of speech events, to include strong emotions, gaze and posture (e.g., a student slumped over her station), and so on. In this sense video data was an extra set of eyes and ears for the ethnographer, rather than an objective data source to document frequency of events.
- Expansive fieldnotes were taken, particularly in lecture and in lab moments not captured on video, to provide a rich description focused on guiding questions such as, Who is positioned as capable or incapable in this setting? How is one's "ability" becoming public in this setting? What are the consequences for participants' self-perceptions? What are the consequences for opportunities for learning? The first author generated approximately 50 typed pages of fieldnotes from these observations. The fieldnote documents were open-coded; these codes were not used for quantitative analysis, but for qualitative and ethnographic accounting of emerging themes.

***Analytical Flow***

The analysis progressed through assembling several analytic memos. These memos incorporated episodes of videorecorded lab interactions, fieldnotes, and interview transcript into accounts centered around particular students (e.g., all of one student's lab partners), cultural categories and their meanings (gender, academic status), and patterns of interaction (competition in lab, out-of-scope student questions during lecture). These analytic memos built up towards the Empirical Results subsections below, since they tended to focus attention on factors contributing to cultural construction of engineering ability. These interpretations were continually discussed amongst the research team and with other colleagues at research meetings for considering alternative interpretations, leading to the evolution of and increased robustness of the argument via a process of iterative refinement (Schoenfeld, 1994).

Triangulation (or crystallization) of different data sources and interpretations was important to the analytic process. For example, a student quote was not taken at face value but was used to help us notice aspects of classroom interactions and to inform a holistic consideration of the dataset. However, we do not think triangulation leads to the one "true" and "objective" interpretation, and the analysis did not limit itself to the objectively "provable." Acknowledging the role of researcher interpretation in ethnography, we sought to develop a credible and compelling account of cultural construction. The fact that others could interpret the data differently actually contributes to our agenda: We know that analyses of students' academic problems often draw on commonsense intuitions about the role of students' background and abilities. We sometimes marshal these commonsense interpretations in our analysis, contrasting *individualized differences* and *socialized differences* accounts in order to persuade the reader to consider *cultural construction* as the more complete and accurate account of events.

These comparative interpretations stemmed from several sources. First, as is expected in ethnographic work, our collective experiences as students, researchers, and educators in engineering grounded all our observations and intuitions. In particular, Secules and Gupta have been instructors in engineering departments, teaching first-year students. They drew on perspectives and impressions from fellow faculty, sometimes voiced behind the closed doors of a faculty meeting or in private conversations, or from the kinds of arguments with which we are familiar from the engineering education literature (e.g., low self-efficacy versus identity mismatch). Second, some alternative interpretations came from participant perspectives voiced in the course of the research, in interviews and also in side conversations. And third, additionally fruitful perspectives were voiced by fellow researchers during group video analysis sessions (Jordan & Henderson, 1995).

***Illustrative Example of Methodology***

Since the final form of the data analysis presents a narrative of cultural forces, it inevitably masks some empirical work which in other paradigms would be presented upfront for consideration by the reader. In an effort to increase analytical credibility and plausibility, we offer this illustration of how our analysis drew on and entangled multiple streams of data to generate claims presented as subsections of the Empirical Results section of the paper. In particular we show here how we build the broad claim that interactions with peers in the lab played a role in the construction of Becca's programming ability, and the sub-claim that she felt lost in the lab.

1. *Participant selection.* Becca was one of nine students invited for a one-on-one mid-semester interview. Our initial interest in Becca arose from her locally marginal demographic statuses: female, University Major, and no programming background. Becca slowly became a focal participant as the ethnographer (in his fieldnotes) became increasingly aware that her position as struggling in the course was salient to the instructor, fellow students, and Becca herself.
2. *Video data collection.* Becca's individual and partnered labwork was captured on videotape with an aim to capture a clear audio and visual account of the lab.
3. *Interview approach.* Becca was interviewed mid-semester. She had been reluctant to interview thinking non-engineering majors were ineligible for this study. The interview protocol began with simple questions about how the course was going. When a description of her or others' background or ability came up (e.g., early in the interview: "And it's difficult too that everyone in my class except for two other people have programmed before, in some way shape or form."), the interviewer would ask for more information on how this impression formed.
4. *Analyzing interview content.* We noted Becca brought up how experiences in lab contributed to her impressions of her being behind, and examined interview portions, such as the passage below, to attune ourselves to salient features of the lab interaction:

   > Becca: "Ok well individual labs are always more stressful for me. Because I feel like the TA instead of helping what is it like 5 groups he's helping 10 people. And so then he's more busy and then I feel like people like fellow classmates feel less like they want to help me when I do get stuck cause they're

> just like 'I want to get out of here, it's Friday like-- We don't feel like dealing with you.'"

5. *Revisiting video*. With this interview content in mind, lab video was reviewed in order to explore the interactional construction of Becca's "ability." A content log determined the richest moments of Becca's videorecorded interactions. Figure 1 shows the process of direct transcript and fieldnote (created within the Inqscribe software environment) related to a day of Becca's labwork which was carefully analyzed. Video was shared with the research team and other colleagues in order to explore multiple possible interpretations (Derry et al., 2010).
6. *Analytic memo*. Video analysis, interview transcript, and fieldnotes were synthesized into an analytic memo which focused on this day in lab, and its consequences for constructing ability for Becca. Several interactions were transcribed to establish patterns, and then particular events were selected for memoing.
7. *Written analysis.* A long form written account was developed piecing several analytic memos together for coherence, before trimming down to a length appropriate for a journal paper. This analysis formed a portion of the current paper subsection, Individual Labwork Constructing and Co-opting Engineering Status. In particular, it contributed to allowing us to make the following sub-claim about the impact of knowledge flow in lab interactions:

   > So Becca often asked Diana what her next step should be, or Diana would look at Becca's circuit to try to help see where it went wrong. Thus the direction of knowledge flow and implicit expert positioning among students also went in predictable patterns related to programming background and status. This pattern

had unfortunate byproducts, Becca said she often felt lost and constantly in need of help from others who were trying to complete their own individual labs.

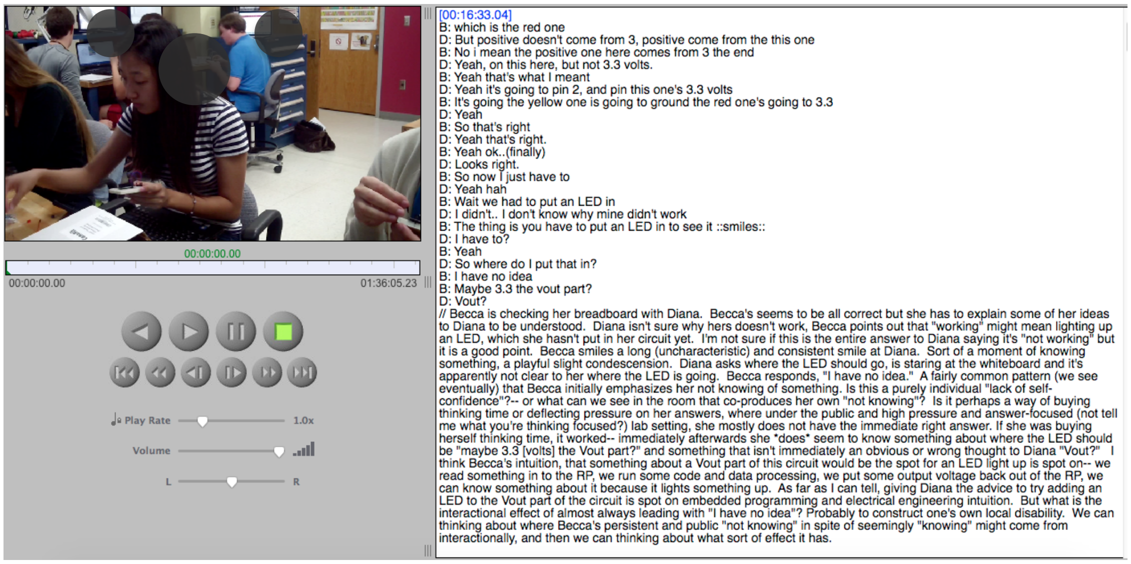


*Figure 5: Videoclip, transcription, and fieldnotes of interaction.*

We offer this analytical example in order to illustrate our empirical process for making and substantiating claims. For several reasons, we do not present this kind of evidence for every claim. These reasons include space limitations, the recursive nature of analyzing the influences contributing to phenomena where contributing events and supporting evidence can themselves each be unpacked, and consistency with ethnomethodology and McDermott (who did not typically present participant interviews as data).

**Data Analysis: Three Paradigms of Cultural Analysis**

Now we return to the educational fact in question, that of the failing or struggling engineering student, and place it in the particular context of the institutional and instructional setting in question. As explained in the section before, *individual trait* and *socialized difference* analyses capture two forms of commonsense wisdom which connect to theoretical perspectives on culture in education. In this paper, we do not conduct a complete *individual trait* or *socialized difference* analysis; however, we do outline those approaches to contrast them with *cultural construction*, the theoretical perspective guiding our full analysis. In *cultural construction* analysis, we “turn away” from the individual struggling student so that we can better examine the role of various cultural forces, settings, and actors in constructing a student as “not cut out for engineering.” (See Appendix C: Long Form Cultural Construction Analysis for further details.)

***Individual Trait - Individuals have problems because of disadvantages/ deficits.***

In an *individual trait* analysis, we focus on characteristics of the student that might put her at a disadvantage, to gain understanding of why some groups of students disproportionately struggle and thereby to inform interventions. An abridged *individual traits* analysis of Becca might look like this:

> There is a persistent problem in introductory engineering classes where students with certain academic backgrounds can’t keep up with the rest of the class. Becca, unlike almost all other students in the programming class, went to a vocational high school where she simply didn’t have the opportunity to take programming, advanced mathematics, and other “academic-track” courses that might have better prepared her for the course. Of course, since students in vocational high schools disproportionately come from lower-income families than students in college-prep high school, a large-N analysis would be needed to tease apart income effects from vocational-background effects. But still, a case study of Becca might grow out of attending to her deep affective reactions and apparently low programming and engineering self-efficacy:

> "I could never like fully be like feeling accomplished or like I want to stay in this class I, really, like this entire semester I've been like I hate electrical engineering, I'm not doing this, I'm not even in it and I wanna quit."
>
> "I should not be in this class…[but] I don't really have a choice in this."

Such a study could help identify ways to boost her confidence, or particular deficiencies in her academic background that hinder her learning in the programming course (Milne & Rowe, 2002). This information could inform the creation of tutoring and bridge programs aimed at students from vocationally-oriented high schools, to help fill the gaps in their background. However, the research might not provide much help to programming course instructors of students like Becca. These students ask a lot of questions in office hours, they work slowly, they seem lost in laboratory sessions. If they are struggling so deeply and so early, perhaps they aren't going to make it. We feel bad for them and would like to help, but aren't sure how to motivate them or catch them up. Do they need even more office hours? But there's not time to help everyone, and the problem seems to run much deeper. We might think, *Poor students, it's not their fault, but if they can't keep up with the rest of the class there's not much we can do about it once they're already in our courses.*

So, an *individual trait* analysis looks bleak for Becca: if her problems are characteristics of herself and caused by her disadvantaged academic background, she seems bound to learn, sooner or later, that she is "not cut out for engineering."

***Socialized Difference - Societal forces and culture clashes to produce problems for individuals.***

In a *socialized difference* analysis, we broaden our view to see that struggling students have backgrounds (cultural and otherwise) that are "mismatched" with typical engineering programs and the courses therein. Thus we can examine whether the performance of students is affected by culture clashes with the institution, due to gender, race, and socio-economic class, among other categories:

> The in-school and broader American culture is such that girls typically grow up with less computer and technology access than boys, at home and in informal learning settings (Margolis, 2008b; Margolis & Fisher, 2003). Although being the only girl in a technical field was not a concern of Becca's ("I loved it"), she had zero background in programming, and zero exposure to the informal computer "geek culture" in which many of the men had participated in high school and earlier. The culture of her vocationally oriented high school, emphasizing practical knowledge, also differed from the academic culture of the college-prep-oriented high schools attended by most of her classmates. Becca herself attributed some difficulties to her different background in the first interview:
>
> > "But there's certain things I still have difficulty with-- which is somewhat like my background. Like the little breadboards I have a lot of difficulty with that 'cause I went through an electrical careers program in high school. So I'm used to big schematics and big wiring diagrams. Not these like little oh you have to memorize this little pin."

She also seemed uniquely unaware amongst her classmates that programming was a component of engineering. This mismatch is associated with socio-economic status; students from lower-income school and communities often feel out of place in college STEM programs (Strutz, Orr, & Ohland, 2008), in addition to having limited access to programming background and geek culture (Margolis, 2008a). So, by this account, Becca's troubles in the programming course arise in part from cultural/background mismatches associated with gender and socio-economic background (though of course, not all women and lower-income students struggle). This mismatch is not viewed as Becca's deficit or disadvantage in a global sense; in other contexts—learning to draft plans for wiring a house, and doing the wiring—Becca's high school apprenticeship as an electrician would likely give her an advantage over other students in her electrical engineering program. An instructor might try to leverage Becca's funds of knowledge connected to her culture and background (Wilson-Lopez et al., 2016) to help her learn programming; but that would be hard to do for all students. And more broadly, as practitioners and researchers, we might think, *Too bad society puts women and working class students at a disadvantage when it comes to learning traditionally masculine subjects; perhaps we can undertake institution-level efforts to make the culture of engineering programs more welcoming to women, low-income students, and other historically excluded groups, and/or efforts to help ease historically excluded students into the culture of the engineering program*.

Even with these kinds of initiatives in place, however, Becca might have trouble; with programming course being a fast-paced place where some students are shown to be better programmers than others, Becca is substantially at risk to become "not cut out for engineering."

***Cultural Construction - "Turning away" towards the cultural construction of the problem***

Finally, in *cultural construction* analysis, we "turn away" from the struggling student. Students do not own or bring educational problems into the classroom. Instead, the individual student is just one of many actors operating to produce and recognize an educational problem such as "not cut out for engineering." The individual student often has limited agency to subvert this process, constrained within a culture designed to systematically produce and notice the problem. In this approach, by analytically turning away from the individual student, we redefine our task as figuring out how a category such as "not cut out for engineering" is (re)produced in the first place and how the category "recruits" students such as Becca.

**Empirical Results**

*Cultural construction* analysis constitutes the rest of this paper and the actual empirical contribution of this research. This kind of analysis presents a challenge both to write and to read, because individual pieces of the argument can look unimportant or even unconvincing on their own, but gain power when combined with the other pieces. McDermott (1993) used the metaphor of "fibers in a rope" to help clarify that pieces (fibers) of a complex system may look meaningless unless the whole (rope) of what the fibers are working together to construct is held in mind. Yet, in order to understand the rope, we must analytically break it down to the level of fibers and re-twine it. It seems an inherent feature of this work that it is non-linear and always leaves something else to unpack, and we hope to convey it within the scope of a paper that is short by ethnographers' standards. In the interest of conveying the rope, we present here a brief holistic analysis, with the hope of unpacking further detailed aspects in subsequent publications. The form of this analysis can also look less conclusive than typical engineering education research. Since the primary goal is to reveal and question the cultural foundations which influence the phenomenon, we often summarize the point of the analysis with a series of questions we intentionally do not answer but pose to the reader, as a member of the culture and system in question.

*Deconstructing Social Labels*

Social labels associated with *socialized difference* explanations (woman, University Major) do *not* connote fundamental traits explaining Becca's behavior. It would be more accurate to say they connote the categories our culture has attuned us all to perform, notice, and ascribe with meaning, next to dozens of other possible cultural facts and categorizations we could notice about people but don't. And in engineering classes, some categories are bound to be noticed instead of others. Simply by our (*socialized difference*) awareness of which categories of students are normally "at risk" in engineering, we all (students, researchers, instructors) become bound to a world wherein academic struggles are part of, or are an exception to, the common storyline of a demographic group.

In an *introduction* to programming course, it may seem counterintuitive that labels of "programming background" and "no programming background" became particularly salient. Although programming knowledge was not a prerequisite, an optional placement test meant students arrived with a wide range of backgrounds, from none to extensive experience with C and Java. The normative student was assumed to have some, not extensive, programming background. As such, “no programming background” became a “deficit” category for individuals like Becca who were “acquired by it” (McDermott, 1993).

Each of these labels took active work to instantiate in the classroom, from many actors and sources. As post-structuralist feminist scholars (Butler, 2004) argue, biological sex does not equate with gender, and our gendered interactions are largely on the basis of what we (consciously or unconsciously) perform and project to others. One could imagine that an educational setting which expected androgynous gender presentations from all students could render gender immaterial or unobservable; yet in this predominantly masculine engineering space, projected androgyneity would “feel” equally out of place to projected femininity (Cech & Waidzunas, 2011).

For the University Major categorization, by contrast, the institution was a primary actor creating and requiring the use of that label. This label exists in the tension between the dual institutional identity of a flagship public state university with a democratic goal of providing education for many (though certainly not all) and also an elite-seeking goal of achieving status amongst the competitive research institutions in STEM. The label has beneficent and inclusive intentions, enabling the inclusion in engineering classes of students otherwise outside the bounds of engineering departmental admission cut-offs. But, until the students fully get absorbed into an engineering department, the label is also a signifier of their current status as not an engineering major. It is a label that gets printed on the roster, inviting it to permeate into the classroom discourse and structures in ways that undermine its intended beneficent role.

These labels became even more public amongst students in the less constrained social space of the lab, in ways which may also be present in dorm rooms and hallways). Becca's identity as University Major, and her vocational academic background and lack of programming background sometimes became public knowledge in lab interactions amongst students and TAs. One day during lab, Becca's lab partner asked "Didn't you *do* this before? Weren't you like an electrician's apprentice?," a couched reference to her vocational background which undermined and forced her to defend her status as a student (she noted her expertise was more on things "in the walls"). Students also commented on femininity or masculinity in the classroom, for example another of Becca's male lab partners, Sam, jokes, "You have an *interesting* choice in pants," a reference to her patterned yoga pants (and essentially, her femininity) being out of place for a masculine or engineering norm. Becca retorted, "You're probably the only person on campus wearing corduroy pants," drawing on broader social norms to defend her dress against local norms. Since gender, University Major, and programming background carry their own narratives and connotations of power, the constitution of the labels in the classroom discourse contributes to the construction of ability.

Some might argue that the prominence of the "no programming background" label in the course points to the need for enhanced ability grouping, in order to separate those with less background from those with more (e.g., via classroom difficulties, Milne & Rowe, 2002; via novice cognitive differences, Robins, Rountree, & Rountree, 2003). While tracking schemes have some practical affordances, O'Connor et al, (2015) examined this sort of tracking in a math preparatory sequence and found that the tracking labels which acquired students carried major unintended negative consequences for identity development and institutional trajectories. Additionally, this paper argues that many factors come together to construct "not cut out for engineering," and hence trying to disrupt one of those factors might not prevent the construction of that educational problem. Even in a class where no one has programming background, "ability hierarchies" could get constructed around other factors such as math background, general academic "prowess," and so on. Enhanced tracking alone would be only a partial solution.

But the categorization of students with the associated stereotypical narratives was only a first piece of the construction of ability. Although programming background need not have become a relevant category in an introduction to programming, many subtle aspects of the classroom interactions constructed one's programming background as significant and preemptive evidence of one's lack of "ability" in engineering.

*Bodies in Seats*

In lecture, students' actions were more constrained than in lab, but gender (always visible) and programming background were no less salient. From day 1, students were well aware that all 3 women in the class were sitting towards the rear/left of the classroom, a visible representation of a broader pattern that found students with less programming experience (both men and women) sitting towards the rear/left, while students with more programming experience (men only) sat towards the front/right nearest the projected lecture slides (Figure 6). This arrangement lasted the entire term.

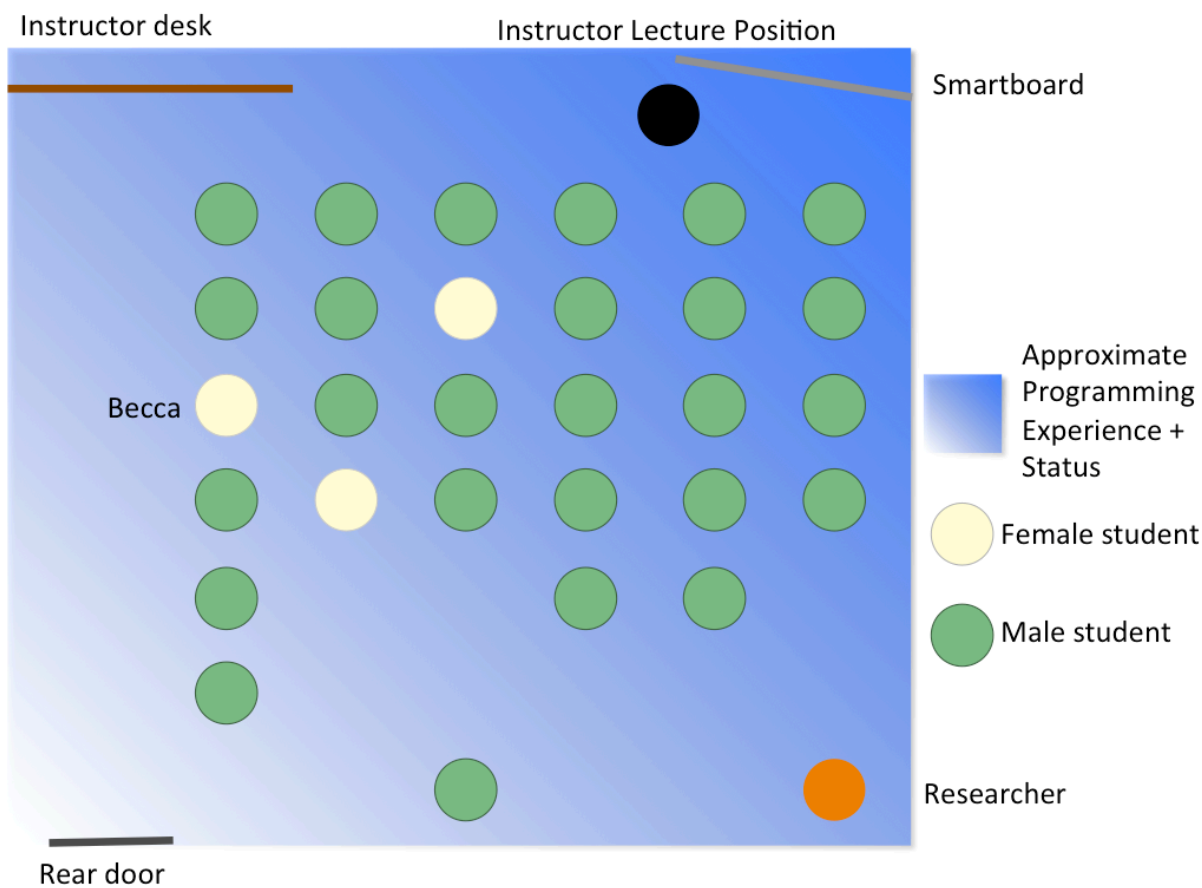


*Figure 6: Typical lecture seating chart.*

*(Darker color represents more programming experience and status.)*

Seating patterns functioned to map out and mark dimensions of status and power, and they contributed to differential experiences of the lecture content, fueling micro-inequities that can widen, rather than reduce, any inequity seeded by programming background. Sitting at the front, advanced students would stay in easy conversation with the professor, murmuring unofficial replies when questions were posed to the whole class. Sitting at the back, instead, requires one to draw the attention of the professor and speak louder when asking a question. Thus meaningful class participation was substantially easier and less socially risky for advanced students than beginning students, and they were likewise the students the professor heard most from. This pattern seemed to sustain and be sustained by the seating arrangements divided by "ability."

Although the classroom was small, some screen text was quite small for students in the rear left. This became particularly salient in the switch from PowerPoint, for which the instructor used font sizes legible by all, to code implementation, which used the default font sizes of a programming Integrated Development Environment (IDE). An unfortunate educational micro-inequity, since many students attest in interviews that the code implementation portion is a particularly useful and interesting part of lecture.

Insiders to engineering classrooms would know that looking for status among the seating chart wouldn't be an ironclad rule of thumb, but if one had any doubts whether "good students" (traditionally defined) had taken the "good seats," further clues were available as soon as the lecture began.

*Lecture materials provide a "crash course" "introduction" to programming*

*In lecture PowerPoint presentations, the instructor took a "crash course" approach to the first two weeks, intended to give a flavor for the language before diving into specifics and to prepare students for authentic early labs that would draw on material from the whole course. However, given the pace and content-level, it was significantly more understandable by those with some programming background. For example, a slide from the first week shows that by Slide 27 (covered on the first or second day), the second example of a full program features a fairly high level content (*

Figure 7, left). If the slides are difficult to comprehend for readers less versed in programming syntax, so it is for the student without any programming background.

| Slide 27 | Slide 29 |
|---|---|

```
/* example #02 electric field calculation
* Written by Phil
* Version 1.3 Last updated Sept 3, 2014 */
#include <stdio.h>
#define CHARGE -1.602e-19              /* new feature */
#define EPSILON_0 8.854e-12
#define PI 3.141592654
Slide 28
int main(void) {
   float e_field, radius=.0025;    /*new feature */
   e_field=CHARGE/(4.0*PI*EPSILON_0*radius*radius);
   printf("Electric field at a radius %f =
%f\n",radius,e_field);
   /* this printf has more than one argument */
   return 0;
}
```

```
#define CHARGE -1.602e-19              /* new feature */
#define EPSILON_0 8.854e-12
#define PI 3.141592654
```

Pre-processor directive “define” generates symbolic constants. Constants are replaced in code by numeric values before compilation.
No equal sign and no semicolon
Convention for constants: use all uppercase letters
Good programming practice: use symbolic constants often!

*Figure 7: Two example slides from "Crash Course" lecture material.*

*The subsequent slides aim to break out parts of this code and add vocabulary and conceptual lessons (*

Figure 7, right). Here instructional goals included introducing vocabulary students would encounter in the second-semester programming course (and programming more generally). However, students with no programming background reported having trouble following when explanations quickly used disciplinary vocabulary to explain programming concepts.  And this issue persisted past the crash course, since disciplinary vocabulary continued to be heavily used in the PowerPoint slides and spoken lecture content.

Although the instructor’s goals and dilemmas are not part of cultural construction analysis, we have alluded to them in this section to emphasize that different instructional choices could not have completely “solved” the problem of differences in programming background becoming salient in lecture.  Instead, different instructional choices would merely lie on a spectrum in how and to what extent they would function to construct ability hierarchies within the broader culture.  Our purpose here is not to critique instruction. It is to help the reader get a feel for what a student like Becca with no programming background experienced early in programming lectures. In some sense, the lecture slides like these function to highlight for those students their lack of background; instead of increasing understanding, they generate anxiety.

In addition to being dense with vocabulary, lecture slides moved quickly and were often overwhelming for Becca and others with less programming background. But in this matter, Phil, the professor, is also constrained by his position in a system: as an "alternative" first-semester programming course, the course had to meet the expectations for what students would learn from the typical introductory programming course to prepare them for the second-semester programming course, while offering its new content in addition. Engineering departments are often conservative in this way, as perhaps many educational institutions are—new content on cutting-edge technology is welcome and encouraged, but not at the expense of any of the previously-held fundamentals, particularly not ones built into the traditional course progression.

*Lecture Games*

The daily PowerPoint-based lecture was appraised, in general (in surveys and interviews), as fun and student-centered, with apparently high rates of student participation.  However, a lecture interaction pattern was sustained where high programming background students asked advanced questions only tangentially related to the current content. As an illustration, take this field-note-based account of one day when the professor was prepping a lab and got sidetracked with student technical questions:

> Phil is introducing servos and duty cycles for the upcoming lab. A student interjects with a seemingly related question, which is actually a diversion from the lab discussion: "How does the clock work?" Phil responds with a tongue-in-cheek admonition of the student:
>
> > "My god, take another class. [Lists advanced course numbers]--I'm not sure what is taught in each of those depending on the lab. There are different ways. But it's way beyond the scope of the class. Basically there are certain types of crystals that are unstable so they go up and down and you can connect them to create a high and low switching state forever…"
>
> After several minutes and additional advanced questions, he cuts off the conversation by saying "That's as far as I go on a good question but outside the scope of the class. No more questions outside the scope of the class today." Several students laugh.

Phil is conscious of not wanting to waste class time, and in his joking exasperation he acknowledges this has become a pattern of student questions that ends up wasting time. He admonishes the students in a way that contains little connotation of disapproval (perhaps because he doesn't want to discourage the advanced students). In effect this response also contains a public confirmation of the advanced student's ability" to ask questions the professor notes are "good."

Some advanced students were conscious of playing a sort of game and found it amusing to distract the professor, though it seems likely that many students were asking their tangential questions in earnest. Given the nature of the questions (as beyond the scope of the class) only a small portion of the class understood the content of these questions and answers. Thus this question and answer session functioned as projection of ability: students noticed who had the "ability" to play the game in asking this sort of question. For the programming beginners like Becca, it was also a period of confusion and a reminder of just how far behind they were (Interview #1).

This lecture discourse pattern may have increased inequity for the students with no programming background, for two reasons. First, advanced questions seemed to preempt more basic questions, since questions about what a basic concept means would seem embarrassingly low-level in comparison. Second, the advanced questions and answers meant less class time for the planned basic content.

Yet again, we note this is not a simple criticism of instruction, but representative of common cultural practices. Phil is employing a responsive pedagogy, his class is fun and engaging, some students are genuinely curious and it is not clear at all that shutting down student curiosity is something to advocate for.[14] Eliciting questions that students would likely recognize as "low-level" (terminology clarifying questions, for example) could mark the question asker as "beginner"—there's no simple way to "turn off" the construction of ability in a culture focused on constructing it. On the other hand, it raises the question, given the constraints of a classroom, whom should we be responsive to, especially in the case that students have different needs out of lecture? How can we be

[14] In a subsequent semester of the course, this lecture pattern of extensive advanced questions and answers hardly arose; but for all the reasons throughout this paper, ability hierarchies were still constructed.

responsive to a student who is not speaking? Can we (students, teachers) empathize with other students' perspectives enough to notice when a student is being left out or made to feel bad? Are we, in the culture of engineering education, so accustomed to seeing these ways of participating in a classroom that we are unable to see them as noteworthy and troubling?

*Individual Labwork Constructing and Co-opting Engineering Status*

Ability hierarchies were strengthened in lab, where in a novel pedagogical approach for computer science classes, students learned to program by working on authentic lab-based electrical engineering tasks. In general, lab was a much more public space than a dorm room or lounge where a student might typically complete programming assignments. Students are packed in close to each other while working, either individually or in pairs. Particularly on individual lab days, everyone can see who is walking up to get the materials for the next step in the lab, who has finished early and left already. Familiar patterns of which students finished first could be observed, patterns which provided another visual reminder of students' prior programming background and status in the class. Likewise, if the room is quiet, the mere sounds of other students cursing their equipment or celebrating successes inevitably send messages of where others are on their assignments. Alongside the unique affordances of the space for collaboration and authenticity, in this setting everyone ends up knowing how everyone else is doing: the public display of "ability."

Here is an example of this pattern. For several labs, another woman in the class, Diana, sits next to Becca and tends to guide her through the work. They enjoyed working together, and like many of the students they tended to talk as they completed their individual labs, collaborating and sharing ideas within the bounds of what the course counted as doing individual work. Diana usually moved somewhat quicker through the lab, having had some previous programming experience with Arduino. So Becca often asked Diana what her next step should be, or Diana would look at Becca's circuit to try to help see where it went wrong. Thus the direction of knowledge flow and implicit expert positioning among students also emerged in predictable patterns related to programming background and status. This pattern had unfortunate byproducts. Becca said she often felt lost and constantly in need of help from others who were trying to complete their own individual labs. Additionally, the information being shared was often practical and solution-oriented (e.g., Diana suggests a needed command, Becca asks what's wrong with her circuit) rather than how or why to approach a problem in a certain way. This pattern was common throughout lab, appeared to be a natural and agreeable way to work for both Becca and Diana, and in some ways makes sense—an engineering course may typically be more solution-oriented than theoretical. On the other hand, it may prevent the students receiving quick-fix solutions from accessing more powerful content knowledge about strategies and underlying concepts. And since those with no programming background are much more often the recipients, this interaction pattern could be seen as a missed opportunity for ameliorating those gaps. Becca would have less opportunity to access these strategies as she approached future projects and interactions.

In this setting, particularly dramatic or surprising successes would garner the attention of much of the lab, perhaps winning applause or cheers from across the room. Diana won one such moment of praise when she helped troubleshoot a problem in the example code, a problem that had stumped all other students and even the TA. Becca nearly had a similar moment. A few minutes before Diana's final breakthrough, Becca was considering the fact that they appeared to have been given fundamentally broken example code. She realized, "Wasn't there like a lab before ours?"—that is, if the example code were really irreparably broken, wouldn't Becca's lab have been warned by the prior lab's TA? Becca announced this, quietly, and to Diana. When Diana asked her what she had said, Becca repeated it even more quietly, as if embarrassed to make her thoughts public in the lab space which was particularly quiet at that moment. A more advanced student across the room, Sam, immediately and loudly asked the same question of George, the TA. George responded, to Sam, "good question." Whether George heard Becca too, and whether Sam was consciously or unconsciously restating her question, it is Sam rather than Becca who is constructed as a "good question asker" and "smart student" in this moment.

This effect was not produced by some general lack of confidence or a shy feminine speaking style causing her to be overlooked, those descriptions did not fit Becca in other settings. We see Becca's situational quietness in this moment as a natural response to being in a public competition where she feels she lacks the resources (programming background) to really compete. Just as it is Becca's quietness which prevents her recognition, it is Sam's confidence and social standing which let him feel free to share his (or others') intellectual thoughts with the TA without second-guessing himself.

On ordinary days, one's status in lab just came down to how quickly you finished a step, or finished the entire lab, how often you came up with uniquely correct insights. Becca was never well-positioned to win that game. But it was not inevitable that lab became a daily experience of failure for her. In a performance-focused meritocratic educational culture it is taken for granted that there will be best and worst products, and therefore students; and that quickly produced products are what must be measured, even if it illogically congratulates students for things they already knew before this class's lessons began. The category of *slower student* comes to "acquire" Becca, but not of her own doing. In order for the work of producing a slowest or worst programmer to consistently take place, it takes instructors constructing[15] assignments with just the right level of time constraint and difficulty to (in effect) separate the weak and the strong; it takes other students engaging in the race and taking these metrics seriously; it takes all students and instructors noticing or ignoring performances in a concerted effort[16]; and it takes everyone in the culture to take this performance for granted as a measure implicating only the individual's programming "ability." Instead of Becca's flaws, this analysis reveals an oppressive meritocracy which systematically privileges those with prior academic advantages.

*Status and Inequity in Group Labs*

Group labs took some of the pressure off of students like Becca. Since students were supposed to work in pairs, individual students didn't face the worry of being behind and lost all alone. But producing one joint implementation of the assignment also meant lab pairs had to share or divide intellectual and physical tasks. Students with less

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[15] While we note that instructors are consciously constructing assignments student performances, we do not presume that instructors *intend* for their assignments to construct failure. Their intentions are likely to maintain rigor and challenge their students. The assignment structure around normative students, however, becomes a key component of the construction of lack of ability.

[16] While we see instructor and student actions as concerted and coordinated in effect (McDermott, 1978), we again do not presume that this is what instructors and students think they are doing when observing student performances.

programming experience typically did less of the physical programming and circuit-building within their teams. They also did not usually set the overall strategy for the team at the beginning of the assignment or at key decision points. Programming is a process of putting forth ideas and debugging them, finding out why they didn't work. Thus the fact that beginning students' ideas were not put forward decreased the potential that they could respond to their mistakes and improve as coders. Of course, there is potential for the reverse to be true; a student could learn by observing an expert at work (Rogoff, Paradise, Arauz, Correa-Chávez, & Angelillo, 2003). However, in programming, where so much of the expert's approach can be idiosyncratic, unexplained, or even simply on a computer over which you are not given control to read and follow along at your own pace, the effect is often that the "observer" student receives much less educational benefit.

In addition to creating potential inequities in opportunities for learning[17] programming, group lab pairings also communicated a status hierarchy. When paired with Sam (the more expert student from the prior interaction) Becca was frequently "mini-lectured" to, a positioning that becomes another public instantiation of ability and status. Sam typically had full control of the lab circuitry and the keyboard for programming. Becca took on a spectator role, including the posture of an onlooker. Becca's computer monitor stayed off, Sam stayed at the center of all of the technical

[17] We note that some colloquial words like "learning" (anxiety, etc) may invoke a similar set of assumptions about student behaviors as the words ("ability," "not cut out for") that this paper and McDermott's framework attempts to resist. We note that in our framework evidence for "learning" would consist of a series of performances on tasks valued by individual instructors, course structures, and disciplinary culture, and would not be seen as a readout of a mental state. Inequitable access to enact this set of performances represented a major contribution to the inevitable construction of "ability" in this course.

work. Sam typically explained all of the actions he was taking and even explained the how and why of his thinking, as a teacher might think out loud about a strategy:

> Sam: We need to calibrate each axis. The way to do that is to get 3 points on each axis. Known z is like this. Mmhmm. Like this. So the axis is based on this. Right now z is pointed this way. Exactly. Exactly. So what we're going to do is start with 3 points…

Becca asked a follow up question after this explanation, and after Sam's answer she finished with a good-natured compliment "You're good at that part." This was not a contested interactional positioning on either side; Becca does not take offense that Sam assumes a teacherly role towards her, and Sam does not protest that Becca should contribute or think more for herself. Both have stabilized the status positioning in this interaction, and one might argue it was for good local (who knows what to do in the lab today) and broader (who has status in the class and institution) reasons. This pairing was a welcome relief for Becca, who much preferred being taught to feeling lost or ignored when working alone.

By contrast, when Becca was paired with Diana, who had limited programming background (though not as little as Becca), Becca's intellectual and physical role on her team increased. She put forward more ideas and was challenged to contribute meaningfully to solving the problems the group encountered. Yet when it was announced a few weeks later that Becca would be paired for a second time with Diana, Becca complained, half-joking but plaintive, that they will be lost because they "don't know anything." Although Becca's role while working with Diana would perhaps lead to more opportunities for learning, as a pair they were slower overall and still competing with the other teams completing their work. Thus there is a trap inherent in what are the only two available teamwork options for a student with no programming background like Becca. If paired with a student with a good deal of prior expertise, she does very little of the intellectual work, but she feels comfortable and secure in her lab work; if paired with a student closer to her experience level she is challenged to engage in more substantive learning, but she is worried and stressed about falling behind. It is the fact that this course can become a race to finish that produces this worry and makes it well-founded. In an alternative universe where everyone is encouraged and enabled to make progress at their own pace without risk of failure, this worry would not come up.

The worry over this potential inequity in paired lab work was shared by Phil and the TAs. It has also been addressed by education researchers more broadly, who note that a method of paired-programming with regularly alternating roles could lead to more equity in contributions from all participants (McDowell, Bullock, & Fernald, 2006; L. Williams, Yang, Wiebe, Ferzli, & Miller, 2002). However, McDermott and Varenne (2006a, p. 19) made observations about gendered programming pairs and noted that physical control and intellectual contribution were not one and the same, and that cultural and interactional subtlety could overwhelm the best-laid and most equitable plans of instructors.

One could look at this scenario and claim that Becca is lazy or not trying, that she prefers teams on which she is expected to contribute little. Or one could blame the advanced students for dominating the computer and never letting the novices work. But instead, consider how all of this appears perfectly natural-- in engineering settings where the final product is valued, where we don't have a robust understanding of what learning will look like other than successful final performances, and where we don't scaffold students to tackle deep issues of equity in their team learning and participation, of *course* we would have the stronger and more experienced programmers end up with higher access to the work and the rewards. And of *course* two novice programmers are slower and more stressed, when they are inevitably compared to the two experienced programmers at the next desk. The naturalness of these actions within this setting belies an underlying competitive and meritocratic culture which measures results over learning.

Instructors, students, and Becca herself developed more or less shared impressions of her weak ability, of her essentially being not cut out for engineering. Becca switched majors and avoided other engineering-related fields because she did not want to encounter more programming classes. Was something different about Becca versus her other classmates? Surely. But that is only the smallest piece of what constructed her educational problem. The point of the cultural construction analysis is that *It takes many actors working within the classroom interaction, constrained by institutional and disciplinary forces, and given meaning by the culture in which it exists, for Becca's lack of ability as an engineer to be constructed. Let's restructure the world so that the persistent problem of students "not cut out for engineering" stops coming up.*

***Epilogue on the student trajectory***

We, as researchers, do not want to overstate the power of this research to pinpoint why one individual's life takes the path it takes. Nevertheless we, as authors, recognize that readers often want to hear a story's conclusion, how things worked out for people. Becca ends up abandoning her dream of being an electrical engineer. She is more or less forced to, by institutional gatekeepers and grades earned in Physics and Chemistry in particular. If she had more positive experiences in engineering, and if her family could afford for her to try again, perhaps she could have tried another engineering major at State University or transferred to a different university to be an electrical engineer. She considered these options. She thought about trying again with mechanical engineering, perhaps a better fit for her. But she realized mechanical engineering also required programming (in Matlab), and after her experience in this course she wanted a major that wouldn't require any more of it, even though she received an A- in the class. In our follow up interview, she brushed her good grades off as the professor being generous with her for having tried hard and the fact that the final was open book and she had brought copious notes. To her, a high grade hadn't signalled any real ability in programming or engineering. She decided on a math major instead, which she saw as rigorous and valued in society but which, importantly, required no more programming. (And also, less gatekeeping—one can register as a math major at State University immediately, without playing a waiting game in the institutional limbo of University Major.)

So officially, Physics and Chemistry and institutional requirements pushed Becca out of engineering, not the programming class. But, effectively, the day-to-day emotional strain of being found an incapable engineer (in this and other classes) was the primary pressure cooker that built a classroom "ability" into an institutional trajectory, and turned the day-to-day experiences of marginalization and degradation into a destiny. The fibers became a rope.

**Discussion**

***Revealing Equity Landmines in the Mundane***

Using McDermott's theoretical lens of "turning away" from a particular struggling student who is deemed "not cut out for" engineering, we have turned our attention to the ways that many other actors (students, teachers, societal labels, engineering culture) contribute to and construct this student ability in everyday moments. Although Becca had noteworthy Individual Traits like her lack of programming background, and Socialized Differences like her experience in vocational engineering education, those aspects of Becca represent only the smallest piece of the work that constructs her ability. Why should prior programming background be such a salient dimension in an introduction to programming course? The answer is it potentially need not and should not be, but contributions from many actors inside and outside of the instructional setting make it so.

In a time-honored ethnographic tradition, this work attempts to "make the familiar strange," and calls into question seemingly mundane pieces of cultural work—the language of the PowerPoint slides, the seating position in a classroom, the moments of recognition in lab—as constructing ability and inequity. We could include many more examples in our list depending on where we cast our gaze: the tests, grades, GPAs, student questions, student answers, tones of voice, course sequences, majors, honors, school pedigrees, and disciplinary pedigrees on which educational life in America runs. These pieces of "normal" hierarchical meritocracy are a major part of the systems which create educational problems of failure, the "water" (the unseen culture) of that educational problem.

***Grappling with the culture***

If our research reflects an authentic picture of the culture which created the educational problem, we, as a discipline and society, will need to ask and answer real and fundamental questions about the work we do. Perhaps some will see a legitimate reason to being meritocratic, exclusive, and elitist—if everyone were an engineer then no one would be, and engineers occupy a particular position in a society grounded by meritocracy and capitalism. Perhaps it would not be shocking to learn that higher education is functioning primarily to reify an elite based on prior skills and performance rather than to foster learning and growth for all. Perhaps engineering educators feel they rightly focus on products and performance over supporting learning.

But education is also bound up with goals of democracy and opportunity, and we pride ourselves on creating spaces of learning and growth where hard work will pay off. Educational institutions need not be in the business of constructing educational problems, creating failure and reifying preordained success. The business of sorting students is an unambitious goal for an educational system, and it inflicts a great toll on the many Beccas caught up in the process of being deemed “not cut out for” it. But disrupting “normal” systems of inequity and living without hierarchies of meritocracy in education would require a radical restructuring of life in America. Our findings are consistent with Amy Slaton’s (2015) call for a reconsideration of the meritocratic and technocratic culture of engineering education. Slaton voices a central tension we see in our work, a clash between the democratic ideals behind many diversity initiatives and the unexamined meritocratic assumptions of the field. We share inclinations towards increasing demographic diversity and improving the experience of women and underrepresented minorities, and we ask the field of engineering to consider diversity along more experiential dimensions than pure numbers (Pawley & Slaton, 2015). It may be that to make further progress on demographic diversity will require a critical awareness of students' intersections with engineering educational culture.

We, the authors, suggest grappling with the tension between our lofty goals and the reality of our education system, between accepting and seeing the world as we know it now, and envisioning and enacting radical possibilities for change. We suspect that only by appreciating the full weight of the intractability of the current system and norms in engineering education will we develop the will and the tools to change it.

***What can be done?***

We, like McDermott (McDermott & Varenne, 2006a; Varenne & McDermott, 1999), want to largely resist the urge to make specific suggestions for straightforward instructional intervention. If we are right about the pervasiveness of the cultural construction we have identified, it will take from each of us more reckoning with the problem and more ingenuity to find ways to change the system.

Nevertheless, two specific recommendations come to mind, one for practitioners and one for researchers. In each case, we offer not prescriptions but recommendations for changing how we orient to the educational problems in our lives. This change in gaze, we feel, could help generate implications that are tailored to a specific instructional or research environment.

As noted, among instructors the *socialized difference* tendency to look for differences in students' background as an explanation for their struggles is pervasive and tempting. But once we zoom in on only the individual struggling student and their background, there is almost never any material left with which to reasonably address the problem. Instead, perhaps the theoretical approach to "turning away" (analytically) could become a pedagogical intuition. When concerned about a "struggling student," perhaps instructors could develop a habit of reflecting back on what has gone into constructing the student as struggling. Perhaps, then instructors would ask: Are my instructional practices fair to this student? How could things be different so that this student isn't a student that "needs help?" Are my instructional materials understandable by this student? Are students creating a hierarchy amongst themselves in ways that I could interrupt? Engaging in this reflection will require the instructor to grapple, as we did, with the tension between what is and what can be, and question the often hidden foundations of why the system works the way it does. Instructors are often multiply constrained by parts of the institutional system, thus their effective questioning of the system would require questioning and conversation from many other stakeholders.

Likewise for researchers involved with diagnosing and addressing educational problems in undergraduate engineering, we once again put forward the unusual analytical approach of the *cultural construction* paradigm, and in this case look at what has been gained by "turning away." Many of the research findings reported above grew out of eliciting the first-person perspective of the marginalized student via one-on-one interviews, a familiar starting point in qualitative research addressing identity and equity issues in engineering education. However, guided by the orientation to "turn away" from the individual, the analysis substantially moved past the individual interview to look at *in situ* interactions and systemic forces, using the interviews to help cast our analytical gaze on what elements of the educational system were at play in the construction of the student's ability. We believe the orientation to look outward from the individual, with an ethnographic approach that pools interviews, classroom interactions, institutional labels, systemic forces, and culture, has led to a more robust and powerful analysis of the educational problem. Relying only on interviews may be asking students to do all of the work of noticing the "water," when that which is mundane and pervasive may be just as difficult to notice for students as for educators.

***Construction of Ability as a New Frontier in Equity***

Our focus on the cultural construction of ability, on the construction of students as not capable, is not brand new (in STEM education Gresalfi et al., 2009; McDermott, 1993). Yet, this perspective has been taken up much less than paradigms focused on the construction of identity, in the sense of either demographic and group identity (e.g., racial/ethnic, gender) or sociocultural learning and participation in a community of practice (J. Lave & Wenger, 1991). Why might this be, and what would be the value of pursuing this agenda further?

In the conclusion of her influential 2010 book on racialized mass incarceration, Michelle Alexander finds herself wondering why more civil rights activists had not taken up the problematic systemic racism in the production of the US criminal: "...civil rights advocates have long been reluctant to leap to the defense of accused criminals. Advocates have found they are most successful when they draw attention to certain types of Black people (those who are easily understood by mainstream Whites as "good" and "respectable") and tell certain types of stories about them" (Alexander, 2010, p. 129). For example, Alexander finds civil rights lawyers often focus on more easily winnable cases of employment discrimination and affirmative action cases involving model citizens, than on the bigger challenge of defending the civil rights of those who society perceives as criminals.

We wonder whether a similar effect may happen at times in equity-focused education research. We have heard conscientious qualitative researchers introduce minority research subjects as, for example, “eager,” “enthusiastic,” “well-prepared,” and “able” to do the work required, and then to go on to reveal how many actors in a culture have created unnecessary problems for the research subject(s) through many moments of marginalization. This is important work and an understandable approach. However, we think that battles may be waged and won and lost through the very words (eager, enthusiastic, well-prepared, able, etc.) used to justify the students as worthy of consideration. What happens when an instructor and students legitimately see a fellow student as unenthusiastic, underprepared, and incapable of their work? Is it reasonable to expect a student to remain enthusiastic through a process of being told they are unprepared and incapable? What even counts as preparation given the wide range in the kinds of experiences people have access to depending on their social class, race, gender, etc.? How does one ever truly separate preparation from ability within the confines of classroom performance? These students may be more challenging for education researchers to defend, but such systems of merit and categorization may be the unexamined front lines of our collective struggles towards equitable representation and against marginalization (Slaton, 2010b, p. 208). We think our work contributes to this project, taking up a careful, critical, qualitative analysis of the commonplace fact of a student being deemed “not cut out for” engineering.

In conclusion, we return to McDermott's reframing of culture, not as "the past cause" to a given student's educational status. If we are to truly grapple with the nature of our educational problems, we must acknowledge that culture, our culture, is "the current challenge" to any future we hope to create.

# Chapter 4: Uncovering the Historical Context for Engineering Educational Culture

## Introduction

The previous chapter was a critical ethnography of current engineering educational culture which attempts to reach up towards and implicate a wider and wider influence of actors in the construction of an educational fact. While it expands the view of the classroom by reaching into several dimensions of the metaphorical space constructing culture, one dimension which it does not interrogate is time, at least not in terms of a broad historical timescale. After this critique was pointed out to me, I came to recognize it as a generative way to make further intellectual progress on the prior work. McDermott's and Varenne's accounts of culture were also apparently sometimes criticized as ahistorical (as noted during AAA 2016 session on Varenne & McDermott, 1999). Parallel to my own direction in this chapter, McDermott saw a history of the progression of cultural norms as important and consistent with his work (McDermott, 2004).

In the previous chapter I presented a co-authored account of the cultural construction of "not cut out for" engineering in an introductory programming course for electrical engineers. The methodological technique we used in the chapter was "turning away" from the traits and socialization of the individual to the many actors and interactions at play in constructing the educational fact. We consistently noted how these events were not purely idiosyncratic but endemic, and how many widely shared culturally meanings and practices were undergirding the construction of “not cut out for” engineering. The metaphorical movement of “turning away” is continued in this chapter, now expanding to include a turn away from the present day to the histories which have shaped our present day culture. If culture is the taken-for-granted norms and stable features of life, it was history which helped structure these features, and it was an obscuring of that historical context which made them taken-for-granted.

Next I return to some of my own ethnographic data to name and illustrate a few particular cultural norms of engineering education.

### ***Refocusing the Account of the Engineering Classroom***

Here I will draw on and elaborate on certain features of the engineering classroom named in the prior chapter. The prior section focused on the ways in which certain interactions and features of the classroom colluded in the construction of an educational fact about Becca. Here, I want to retread the ground and instead zoom in on the other students in the story, to identify some of the salient cultural norms undergirding their most consequential interactions. Next I will revisit two accounts from the prior chapter, about the norms of lecture discourse and lab interactions, respectively.

#### *Men Playing to Win in Lecture Games*

Recall that a pattern developed in class related to dominant male students with prior programming background asking questions “way beyond the scope of the class.” As I would find out, at least some of these students were consciously playing a game in these moments. One White male student, Brad, commented in a private interview on how it was fun seeing how far they could get the professor to go astray from the day’s lesson. From his point of view, the game involved finding an advanced word or concept or "crazy questions" you think probably relate to the day's content, and then finding a way to "weave it into the discussion." Playing this game was more fun than lecture, winning at this game had the added benefit of projecting one's own ability to ask an advanced question.

Sam, another White man, was good at playing these sorts of games (whether he was actively trying to or not). On the first day I observed in the lecture, there were some dense equations written on the whiteboard from the class that met in that room before this class. While the professor was erasing them, the students and professor were discussing how difficult they looked, how they weren't even sure what they meant or what subject they were. Sam interjected casually, "It's 370," a much more advanced engineering course number. How did Sam know what all the other students and professor were wondering about? Did he simply know that the course which came in before theirs was 370? The implication was that he had somehow deciphered and was familiar with the equations, he knew what they meant, he knew where they were located intellectually and who would be writing them. It was a prominent early moment in making ability visible. Throughout the term, Sam showed himself to be consistently able to perform his ability. And he could do so in a most effective way, casually and confidently; he didn't always need to raise his hand if he knew his question was good or his answer was right.

Other students noticed who was winning at the classroom games. Peter, a White male, who felt mid-range on the class's ability hierarchy, described to me in an interview how he saw ability in the room:

> The professor will ask a certain question and someone will have their hand up and they'll answer it and give them-- or ask a very in depth question that shows not

> only do they have the grasp of the knowledge but they are very far ahead. Um, also there's certain attitudes that I think a lot of people put on-- like-- it's the way they sit-- there are certain people in the class who are leaning forward with their pencil and looking at their board, cause they want to know everything that's going on they're hanging on the professor's every word; and there are certain students who are kind of laid back and will just call shots.

Peter is acutely aware of how, in his view, a student constructs ability in this classroom. Peter sees: some questions aren't really questions, some questions are statements of the ability to ask a question. Some answers aren't students answering questions they think they might know the answer to, they are ways to sneak in vocabulary words and talk in depth on a subject that is more than a student in this class is expected to know. The game is effective at revealing that there are students who "lean in," and students who lean back and "call shots."

Although Peter perhaps feels an insecurity related to programming, his acute knowledge of the function and the rules of the lecture game to construct status seem to enable him to be a constant force for creating more competitive and hierarchical classroom interactions. Similarly, in lab, he would often call out his progress or interject into other students' work a comparison of progress. I was particularly interested in interviewing Peter in order to understand more about what drove him to operate this way. Later in the interview, I ask Peter about his sense of whether the class is "real" engineering or not (expecting he might make connections to the role of programming work with respect to the engineering discipline). Peter instead notes the lack of a large enough sense of pressure in the course for it to be "real" engineering, comparing this course's pace to a more intense project-oriented class he took the term before. The process of becoming an engineer, he says, should be "kind of like boot camp." When asked to explain further, he conjured authentic scenarios where Apollo 13 astronauts were "under pressure to do something-- you go ok, this is what I have, how can I make it work." Thus, Peter's interactive work constructing a competitive classroom environment seems reflexively tied to his views of engineering disciplinary authenticity, which in effect marginalizes non-dominant students by perpetuating localized hierarchies of ability.

*Men Creating a Competitive and Gendered Lab Space*

Recall that individual lab interactions were particularly effective at revealing a perceived ability hierarchy which closely mapped to prior programming background, and that lab pairings were fraught with difficulties for productive learning for a student without prior programming background. The prior chapter traced those issues to a competitive culture which subsumed the learning opportunities of lab interactions with opportunities to reveal and reify educational hierarchies. It should be noted, as in lecture, that certain men in the lab section would create this competitive interaction and benefit from the hierarchies constructed, while women and other men would not participate and feel like they were losing or excluded from the competition. A common theme from my interviews was non-dominant students noting that others were competing, and they either couldn't compete based on their resources for the course activities (Becca), or chose to ignore it and not engage (Jillian, who is introduced below).

Recall also that lab space was a less structured space where student identities related to gender, institutional status (Letters and Sciences), and prior schooling background could become publically acknowledged in the student discourse. In particular, lab could be seen as a space where men made gender prominent, moments that sexualize lab space so that it feels like a locker room or frat house—I conceptualize these as reifying female students' marginal position on a status hierarchy in engineering. I don't expect students, teachers, or people to ever truly be "gender blind" but if gender and sexuality becomes particularly prominent in lab, these moments function as reminders that the men are in control in engineering, both in numbers and authority.

My most prominent example of this came from the other lab section that Becca did not attend. There is one female student in that lab, Jillian. One day several weeks into the term, Peter and the other male students in the lab section spent a long time guessing at Jillian's name—"Ivy," "Jessica". They were joking but also serious—they did not, in fact, know it. The way in which they seemed to put Jillian on display, to acquire her attention and time, to know precisely who she was through her essentialized identity as the only woman, without at all knowing her as a person by this point in the term—this struck me, and Jillian upon reflection in interview, as somehow strangely gendered and constructing a weird power dynamic.

On another day, Jillian left lab early—(she was often quick and pragmatic about her lab assignments and was often seen finishing first)—leaving 9 male students, their White male TA, and me (a White male researcher). Minutes after Jillian left the room, Peter and the other male students left slipped seamlessly into sexual jokes and innuendo. Their backs were turned to each other, they didn't need to turn around to find out if the one female student had truly left or if any authority figures in the room might have minded. My fieldnotes just became a popcorn of disembodied sexual comments, called out casually into the ether while multi-tasking with the programming in front of them:

> Stabbed the wires so it was looser.
>
> That's what she said.
>
> That's what he said.
>
> Either way someone said it.
>
> ...bowling pin…
>
> Anything's a dildo if you're brave enough.

Several seconds later, after I missed some overlapping dialogue, it became clear that the male students still had their minds on sex and/or gender, and that it connected back to which bodies were in which of their university STEM classes:

> I'm in a (Calculus?) section with all guys, no girls
>
> Are you surprised?

All of these comments seem to have the effect of reifying the boys' club that STEM can be, once the minority of female students leave the room, or maybe while they're still there— after all they're a minority and not in control. Gender is "in the air" as I suggested in Chapter 3—it is on the tips of the tongues and fresh on the mind of the undergraduate engineers here. And when wielded it can connote status and power in engineering.

In more subtle and less sexist ways, gender[18] was made prominent in the form of 'othering' the student from the norm. The norm for dress in this lab was a White male,

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[18] This chapter references gender frequently, but gender is also conceptualized as connected to sexual orientation, since gender non-normativity can be an key lived

probably wearing a 'uniform' of t-shirt and khaki pants with tennis shoes, maybe wearing flip-flops and shorts in the warmer months. Dress can connote insider status, but women's dress will mark them as an outsider either way. Engineering is basically a straight White male cisgender space. A woman who dresses in the White male 'uniform' above would be seen as violating parts of that norm, while a woman who dresses in a more feminine way will be violating other parts of it.

Becca's dress became the topic of conversation at various points during the lab. Sam called across the room at one point, while Becca was wearing grey- and black-patterned spandex leggings, "You have an interesting choice in pants." It was a minor moment, Becca defended her fashion choices as normal and made fun of Sam in return, "You're probably the only person on campus wearing corduroy pants." Their mutual joking deals in the a set of hierarchies—Sam makes fun of Becca for clothes that don't fit into the lab uniform, Becca makes fun of Sam for more or less adhering to it. Both have some leverage here—Sam has academic and local social status and his comment can jokingly point out Becca's status as an outsider or other. Becca has more broad social status and capital at the university, and can defend herself on this ground. But in this lab space, social status and fashion sense can be a deficit—the more serious students have less of it.

***Emergent Cultural Norms of the Engineering Classroom***

I want to draw attention to three particular themes which seem to emerge from the prior vignettes. In doing so I aim to position them as cultural norms which I think would

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experience of and interactional expression of sexual orientation (Cech & Waidzunas, 2011, p. 5).

seem familiar to insiders to engineering education settings, and to offer this as a starting point in order to mark and question these norms.

*Competition*

Pervading the above story is a sense of competition, whether coming in the form of academic pressure which we need to be doing “real” engineering, or a seeming need to outdo or outshine one’s neighbor with showing the ability to ask a question. We might not even always be clear what we exactly mean by “competitive” (the students I interviewed weren’t always sure if I asked), but if we’re honest we can probably agree that engineering classes *feel* somehow more competitive than creative writing classes, or foreign language classes, or yoga classes. Where does that feeling of competition come from? Why does it seem to be so sticky in engineering?

*Masculinity*

Masculinity as a cultural gender norm is distinct from, yet related to, the presence of biologically male humans in interaction. By naming masculinity in this narrative, I mean to point out that there may be narratives and performances expressed here which tap into deeper cultural meanings of being a man in society. If we see men playing a game of asking advanced questions or sexualizing lab space, are these the random actions of students who happen to be male, or are they embodiments of masculinity as a cultural norm? Without essentializing all men, what can we learn about the norms of the classroom when thinking about the fact that men are often the normative and dominant majority in engineering?

*Whiteness*

As noted in the conclusion of the prior chapter, race was largely unmarked in much of the ethnographic data with White and Asian racial and ethnic group participants. This did not continue into the subsequent semester with non-Asian racial minority students, when the two African American students in the class became an early spotlight of concern in much the same way Becca had the previous semester. (Plausibly, Asian students may be being perceived within model minority narratives, or may be a normative expectation for this engineering department.) Just as masculinity as a norm can be seen as distinct from the presence of male bodies, the normativity of whiteness and construction of unmarked race can be seen as a distinct aspect of, yet related to, the presence of demographically White (or normatively raced) people. Does the unmarked racial and ethnic normativity of this setting speak to a cultural norm of whiteness? If so, which other features of this classroom are expressions of whiteness as a cultural norm?

*Dominant and Competitive White Masculinity*

Parsing the emergent classroom culture into the three distinct norms of competition, masculinity, and Whiteness is an arbitrary choice to gain clarity about certain features. It may not be the only or most accurate way to describe the classroom culture, particularly when the primary characters who dominate in the story are, in fact, White men competing with one another. Perhaps it is equally as accurate to position these interactions as a holistic rather than dissectible intersectionality. Non-dominant masculinities, perhaps in relation to a queer sexuality or non-normative gender presentation, may indeed exhibit less dominant and competitive interactions. Plausibly, non-White masculinities may also be non-dominant or non-competitive in some significant ways in this and other engineering settings. Perhaps Asian-American masculinities, although not underrepresented or connected to disenfranchising narratives of performance in STEM, do not participate equally in the aspects of social dominance which this chapter attempts to identify and critique. With this caveat in mind, I will continue to treat the forces of competition, masculinity, and Whiteness as relatively dissectible norms in order to explore their confluence and mutual origin stories.

***Impact of Engineering Educational Cultural Norms***

In my retelling of the setting of the programming classroom and naming the cultural norms of whiteness, masculinity, and competition, I have suggested that these norms were salient to the cultural construction of "not cut out for" engineering which I documented in the previous chapter. I made a case that this aspect of cultural construction was connected to marginalization and represented a new frontier for addressing equity concerns related underrepresentation and attrition of diverse groups in engineering.

In addition, these cultural norms have been noted in other ethnographies of engineering education, and seen as consequential in perpetuating various forms of marginalization. Karen Tonso looked at how gender mediated by available campus identities came to structure the team roles and classroom interactions of an engineering design class (1996, 2006a, 2006b). The consequences of this gendered phenomenon was missed credit for female students' work (in a way which parallels the Becca/Sam eavesdropping moment of Chapter 3), and ultimately, the deferment of engineering career options and trajectories. Alice Pawley (2008) looked at the boundary work of gender and engineering in the narratives of engineering stakeholders, revealing how participants marked certain practices and institutions as feminine or masculine, as engineering or not engineering. In effect, her participants' narratives paint a picture of how the norms of engineering and gender position many aspects of femininity outside of the bounds of engineering, making them a consummate "other." Foor, Walden, and Trytten (2007) revealed several cultural norms in the narrative of their focal participant, including racial and gender "othering," and meritocracy which constructs failures as an individual students' own fault. O'Connor, Peck, and Cafarella have looked at competitive meritocracy as an underlying norm shaping instructor discourse assigning grades (O'Connor et al., 2016), and constructing student identities "ready" or "unready" to begin the engineering course sequence (O'Connor et al., 2015).

In short, there is significant support from the scholarly community for seeing norms of whiteness, masculinity, and competition as 1) broadly and specifically cultural with respect to engineering, and 2) for focusing on and unpacking these norms as potentially consequential to stories of marginalization and damaging to student selves and trajectories.

**History in Engineering Education**

This chapter makes a case for historical context as important for an accurate observation and understanding of present day culture in engineering education. While museums and documentaries memorializing a history of US engineering accomplishments abound, there are fewer well-known histories of engineering education. Engineering education researchers and practitioners may have different relationships to history. Some may feel they have an informal sense of history, having been in the field for several decades and having stayed informed about the main events of the discipline, whereas others may be new to the field and be unsure of where to look for history (Wisnioski, 2015). In general, I think engineering education backgrounds history, culture, politics, and context in order, for example, to find “generalizable” “best practices” across space and time.

A few prominent historical accounts of engineering education present major shifts and developments in pedagogical approaches (for similar accounts in science education see Deboer, 1991). Seely (1999) showed the major historical shifts of emphasis between an industry-focused curriculum which emphasized project-based pedagogy to teach design, and research-focused curriculum which emphasized a textbook-based pedagogy to teach engineering science. Wisnioski (2014) presented a historical case study of a unique design challenge embedded in the fears of the Cold War: to reconstruct American society and culture in response to an apocalypse. While these accounts are useful in expanding our understanding of ongoing pedagogical debates and of influential historical events on education, they do so from a primarily uncritical perspective regarding the cultural norms of engineering and engineering education, and they do not target the norms of whiteness, masculinity, and competition. In fact, Seely discusses the historical development of problem-based curricula without mentioning a key aspect of many modern engineering iterations of problem-based curricula: a competitive challenge (Reynolds, 1992).

On the contrary, critical history can work to deconstruct cultural norms related to oppression, often by problematizing the received categories treated as objective truths in modern society. Nell Irvin Painter (2010) problematizes racial whiteness in a history which traces the definition and redefinition of the category in modern US society, the myths and pseudoscience undergirding those definitions, the historical progress and alternative racist work of the people (European ancestors) who would eventually be labeled “white,” and the utility of the category for perpetuating oppression. McDermott (2004) traced the progression of the category of “genius” through several redefinitions, eventually aligning with eugenics-influenced IQ tests which worked to perpetuate ranking and oppression. These critical historical accounts show the potential for oppressive cultural norms and meanings to be reconfigured.

Whereas McDermott and Painter do not interrogate STEM disciplines, scholarship in Science, Technology, and Society (STS), which discusses the interplay of human actors, social systems, and culture on the definitions, uses, and progression of technology, may have a unique potential to problematize the relationship of technology to social oppression. Comparatively few STS scholars, however, analyze the societal development of education or discuss the impact of their findings for present day engineering education research, practice, or institutions (e.g., Slaton, 2012 on the NAE grand challenges). Several of the critical history and STS scholars whose work directly or tangentially speaks to engineering education are the source material for this chapter.

***Importance of History for Ethnographies of Engineering Education***

I return again to consider the audience of ethnographers of engineering education, as the primary scholars focused on examining, describing, and critiquing culture within education scholarship. In reviewing the literature, it is clear some ethnographies are embedded in a relevant historical context which situates the meaning of the modern day events to be discussed. Before discussing modern day boundary definitions of gender and engineering, Pawley (2008) lays out a history of gender exclusion through the historical definition of women’s and men’s technical problem-solving work. Men’s problem-solving was based in masculine-dominated industrial settings and carried a profit motive;

thus this sphere of activity, engineering, connected to capitalism, meritocracy, and social status. Women's problem-solving was based in feminine-dominated domestic settings and did not connect to a profit motive. Although this sphere of activity, home economics, clearly performed a social good, it did not connect to capitalism and did not connote equivalent social status. Likewise, Foor (2007, p. 105) and Tonso (2006a, p. 274) both briefly situate their work with citations to documented historical contexts for gender oppression.

Most ethnographies focus more on the present day, although it is clear that the scholars writing them recognize the importance of history in general. As noted, this was a critique received by myself of the work in the prior chapter (Secules, Gupta, & Elby, 2016), and motivated the extension of the work into situating an appropriate historical context for the cultural norms. McDermott's work was sometimes critiqued as ahistorical, though not because he disavowed the impact of history on culture. He employed history as a metaphor to think about the culture of which we are not aware: he tells a story of a 19th century forgery of a Roman architectural discovery, which was not found to be a forgery until certain aspects particular to 20th century architectural style were noticed by 20th century archaeologists (1999). Seminal work on developing an engineering identity (Stevens et al., 2008) and meritocracy in engineering (Stevens, Amos, Jocuns, & Garrison, 2007) also took a largely present day lens. Although O'Connor does not situate his account of membership trajectories in broader histories of oppression, he does discuss how institutional histories are inscribed into course sequences which shape student trajectories (O'Connor et al., 2015, 2016). Thus these scholars show an appreciation for the importance of history, but their written analyses of history connect less often to the forms of history discussed by historians and STS scholars. Perhaps McDermott and O'Connor, focused primarily on the oppression of meritocracy, are more limited in their access to historian corroborators than Pawley, Tonso, and Foor, who focus more on gender and racial oppression, which are more often given historical treatment. Perhaps in lacking thorough critical histories of meritocracy, McDermott's work to place the modern construct of "genius" into a historical progression which problematizes it (McDermott, 2004, 2006), is his own contribution and response to the ahistorical critique.

In pinpointing the presentation of history or lack thereof, I mean to prompt other scholars to consider its importance, rather than merely critique its omission. Each of the ethnographies have their own foci and strengths, and I will readily acknowledge that not every piece of scholarship can or should address all things. Still, as ethnographers of engineering education we must take account what is being said and what is not being said in a situation; we must consider whether events are empirically self-evident or whether a historical context would problematize and shift our interpretation and the meaning of events. Like the locked door in Chapter 1, our familiarity with histories of oppression are a useful backdrop to the interpretation of work on realities of underrepresentation in engineering education. Likewise, in writing for readers and consumers of education research, ethnographers have the task to tell as compelling and accurate a story as possible, and the meaning of our story is highly contingent on the choice of context in which we set it.

***Importance of History for Broader Engineering Education***

As discussed in Chapter 1, an understanding of history has potential to shift our status quo diversity context to have a more accurate and urgent orientation towards the facts of oppression in engineering. I want to move past a view of history as an intellectual activity for insiders, where when a particular historical interpretation or fact is revealed, it is presumed to have been revealed once and for all, since everyone could hypothetically go read it. I want to envision value for many in the work of engineering education to retell and resituate history for one another, for new audiences, particularly for the education researchers and practitioners who may be less familiar. Parallel to a call for greater conversation between history and engineering education (Wisnioski, 2015), this work retells and repositions the work of scholars who are formally trained in history, in order to speak to audiences of stakeholders in present day engineering education on the issues of greatest relevance.

My purpose with this work is to situate the scholarship and the observed cultural norms of engineering education into an appropriate historical context.

**Methodology**

The methodology of this paper draws on several secondary sources which reveal new context for diversity in engineering education. Thus the historical research presented is not my own, but is cited and synthesized here for relevance to an education-focused audience. The literature bodies investigated were largely Science Technology and Society and critical history scholarship. In that I drew on several disparate literatures this work was necessarily less systematic and more idiosyncratic than is a traditional literature review methodology. It grew out of conversations and reading suggestions from several colleagues, and represented a learning experience for myself as well.

This work has resonance with a methodology outlined by Foucault (1977) called “history of the present,” or historicizing, where the cultural historical context for present day events is interrogated to shift and enhance an understanding of present-day meaning. Foucault's historicizing has been applied in science education by Kirchgasler (2016) to situate the discussions of diversity in the NGSS standards.

## A Critical Historical Context for Engineering Educational Culture

The following sections present my critical historical context for the present-day engineering educational culture.

### *Defining Engineering and the "Other"*

There is a simple story we tell ourselves about engineering. A US national culture story, and an engineering story. Engineering is the quintessential productive force behind the industrial revolution. A modern invention, a capitalistic invention. It thrives in a capitalistic democracy such as the US. Engineering is rational and technical. As such it escapes the worst injustices of US history. It has little to do with racism and sexism; is quintessentially colorblind and class-blind and gender-blind—it just happens to be occupied consistently by middle-class straight White able-bodied men. It has driven American economic growth towards exceptionalism and domination, and conversely it has not been responsible for any of its setbacks. How can this be?  It must be, so goes the narrative.

In *Making Technology Masculine*, Ruth Oldenziel has suggested the narrative for women in technology and engineering is as "*deae ex machina*" (1999, p. 18)-- as a relatively novel phenomenon of women succeeding in a fundamentally male-dominated discipline, springing forth fresh in the late 20th century from 2nd wave feminism and affirmative action, without having been a concern at any prior period. This unexplained arrival via attention to affirmative action statistics applies equally well to racial minorities and other minority groups of recent concern.[19] Thus the historical account of demographic representation seems to start at the point when the engineering discipline collectively began to notice and care about minority groups (Lucena, 2000).

Another common engineering narrative is the disembodied nature of the engineering discipline as a body of knowledge. We are clear that engineering is a knowledge domain and an identity navigated within a community of practice (Stevens et al., 2008). Engineering as a subject matter clearly delineates the population as those who participate within it (as students, professionals) and those who do not. This delineation includes certain epistemological continuities (e.g. using math and science to solve real world problems), as well as institutional legitimation, industrial and commercial interest, professional licensure, etc. But if engineering defines engineers and non-engineers, who has defined engineering? Who collectively has defined it in the past such that it is an "always already there" of our present day? Whose actions (intentional and unintentional) continue to define engineering in the present day?

In short, the disembodied engineering and arriving *deae ex machina* narratives are flawed. Engineering is not a white, male, middle class, straight American discipline by happenstance. It shares much of its history with mainstream American professional life, a history and culture which is often observed to be racist, sexist, classist, etc. Even simply tying the engineering discipline to these forces of oppression is a disruption of the simple engineering story—troubling an important part of the narrative that engineering is purely technical, disembodied, and therefore free from any of the interpersonal "isms" and

[19] I am choosing to link various diversity concerns in this paper in order to show continuity between the forces which shaped the gender, racial, socioeconomic, and cultural norms and narratives of the discipline.

disconnected from US historical events such as slavery, Jim Crow social control, class abuse, and forces (e.g. anti-suffragist) which kept women in their place. Furthermore, engineering predominantly and in particular carries a deep set of power dynamics in its demographic representation and cultural norms that has a more complex relationship than its ties to oppressive US demographic trends in general. The definition of engineering disciplinary knowledge and practice was not and is not disembodied or arbitrary, but directly related to social positioning and power (Foucault, 1982). Those who held relative social power and specific power in the institutions associated with engineering defined engineering, and they defined it in order to secure and consolidate power. As the next section will elaborate, social exclusion and domination in engineering have always been fundamentally inseparable from other disciplinary features.

*The Professional Formation Work of White Middle-Class Men*

The word "technology" first appeared in the early 19th century and gained prominence over the course of the 19th century (Oldenziel, 1999). The invention of the words "technology" and "engineering" marked a process of active boundary formation between old ways and new ways of organizing labor and industry. The older term, "the useful arts" conjured a different image for the activities that would later come to be known as technology and engineering (Oldenziel, 2006). The "useful arts" emphasized craftsmanship over the systemasticity that engineering as "applied science" invoked, and learning the useful arts conjured an image of an apprentice in a trade over formal education requirements which were being put in place as engineering training. Notably with regards to our central question about the demographics of the discipline, the useful arts also applied to a wider range of industries, including cooking and textiles, whereas engineering would come to be associated narrowly with steam engines and boiler rooms. In the strictly divided gender roles of the time, whereas the world of "useful arts" was a gender inclusive term, the term engineering referred to settings which were almost entirely off limits to women.

Thus vocabulary was but one piece, a definitional boundary piece (Klein, 1996; Pawley, 2008), of the active work of demographic exclusion in the discipline of engineering. Although the defining term united the engineering discipline in opposition to other work, its professional formation was also driven by disparate and interwoven industrial, labor, governmental, and academic forces shaping the character of activities of civil, mechanical, chemical, electrical, and other branches of engineering (Zussman, 1985, p. 4). In general, over the course of a few decades, engineering became a discipline which required a formal education, and spurred the creation of engineering departments. Activities like the building of buildings that had for centuries been learned as apprenticeship in craftsman tradition (think of the architectural and structural wonders of the ancient world), now became formalized as structural engineering. A separation was created between the building work and manual labor (skilled or unskilled) involved with the creation of technology and the built environment on the one hand, and the now rarefied discipline of the engineers designing the technology (Oldenziel, 1999; Zussman, 1985).

Viewed through a certain lens then, the events of the late 19th and early 20th century look like an inadvertent realignment: a shift from a gender neutral discipline towards a masculine one, a shift from a term associated with skilled labor to one associated with elite higher education.  But the STS narrative for professional formation argues that this should not be viewed as an accidental realignment, but as the active boundary work that white, middle-class, college-educated men performed in order to secure a social and economic position (Oldenziel, 1999; Wajcman, 2006). Consider the relative upheaval that democracy, capitalism, and the industrial revolution were posing at the late 19th and early 20th century. Consider the rising trend of Marxist revolt in the labor classes. Indeed, consider how threatening abolition and the extension of voting and other civil rights (to women, to unpropertied White men, to African Americans during the brief window of Reconstruction) must have been (Roediger, 2007). More than an inadvertent realignment or the pressures of market forces, middle class White male engineers carved out a role for themselves in a new economy and social order.

The (White) middle-class professions were a relatively new invention of the time, and it was a position they still needed to secure and establish in terms of social status (Zussman, 1985). As such, engineers undertook the active work to justify a position for themselves between Labor and Capital, as an image published in 1924 in *The Professional Engineer* (Oldenziel, 1999, p. 75) shows[20]. The engineer in the image was easily identified by readers at the time by the professional uniform of the site engineer. It should not seem accidental that all characters in this scene, including the Engineer, are White men. The positioning of (White) masculinity as fundamental to the role of the engineer was corroborated in other professional writing of the time (Frehill, 2004) and was part of the active work to secure a social and professional position for those individuals forging an identity as engineers.

***Racialized Social Control and Exclusion in Engineering***

[20] This image has not been included in this dissertation for copyright reasons.

The sphere of technology and engineering was bourgeoning (slowly, or in fits) across the globe throughout the 19th century. The industrial revolution in the late 19th century also coincided with a great social upheaval specific to the US-- abolition. In these ways, slavery comes to be associated with antiquated industries, and engineering comes to be seen as modern. But just as the recovery of the term the useful arts showed us the continuity and boundary work of industry before and after redefinition, this is as much a fabrication and utilitarian narrative as it is a reality. The industrial work of the pre-abolition period was agriculture, mining, manufacturing-- these are the same industries which were growing to be considered engineering over the course of the century. In that engineering is tied to the history and growth of US capitalism, and the argument that slavery was not profitable and the capitalist industrial revolution overtook it positions engineering as simply a more efficiently organized form of capitalism. Considering the counter-argument—that slavery was in fact highly profitable for those who used up Black lives, and could only be ended by a war of competing interests (Baptist, 2014; E. Williams, 1964)—one wonders if western engineering and technology developed partially (or at least regionally) because of the lack of a free labor force.

Abolition did not end racialized social control in this country, nor did it end the profitability of using a free labor source (Alexander, 2010). After a period of Reconstruction, Southern whites inflicted a sweeping set of social controls which turned back progress to something akin to slavery. They stripped land owning rights, and made blacks beholden to the whims of a White plantation owner, working the land as sharecroppers to return a small piece of profits. They stripped away nearly all civil rights-- voting rights, jury service, public office-- often through subtle means that limited the public appearance of racism, for example a literacy test and poll tax could prevent essentially all blacks from voting, while a grandfather clause allowed poor and illiterate whites to continue to vote. Insidiously, by removing legal rights, blacks could essentially be accused of any minor or fraudulent infraction and acquired for the purpose of profitable manual labor in all of the industries which had suffered since pre-abolition. Between the roles of share-cropping and prison labor, some form of forced labor was essentially still a life sentence.

Systems of mass prisoner leasing became an open secret across the south (Blackmon, 2009). Prison camps and sharecroppers once again produced agricultural wealth in the south. Fueled by the industrial revolution, prison camps became heavily involved in the work of mining and production of natural resources such as timber, copper, lime, and steel. This process of profitable, industrial racial social control is not ancient history; it continued from the 1860s period of abolition nearly uninterrupted by any significant government sanctions well into the 20th century (Myers & Massey, 1991). The last prison mines were finally outlawed by FDR in the 1940s directly after the bombing of Pearl Harbor, arguably because of the embarrassment it might have caused in fighting a war of moral superiority on race issues (Blackmon, 2009). It is also not a minor or exclusively southern history, as it implicates US Steel (an amalgamation which included Carnegie's famous steel corporation). It appears to be a fundamentally US national, industrial, and capitalist corporate history.

When considering the burgeoning industrial interests in mining and natural resources, a nascent engineering springs forth from the prison labor accounts: mining engineering, agricultural engineering, civil engineering of railroads-- the engineering fields which defined the nature of labor-- as well as mechanical engineering, electrical engineering-- the fields which created such an imminent demand for free labor. Advances in mining lime kiln were still incredibly dangerous for workers, consistently killing or maiming workers (Blackmon, 2009). One of the byproducts of prisoner camps as opposed to slavery was that the worker was not valued property, but a cog in an industrial system and an individual swept up and out of society; the cost of leasing a prisoner plummeted compared to the prior cost of owning a slave. So the system in which mining was enacted, and engineered, at the time and in the region was without regard for the life of the worker. Mortality rates were often up to 20% *per year*. The work of the mines was engineering, and a technological advance, but the human lives of Black prisoners were not regarded in the calculus. US corporations (e.g. US Steel, which grew out of Andrew Carnegie's corporation) we typically think of as fundamental success stories of American capitalism and engineering industrialism have inherited the profits of this process we obscure and divorce from those stories and do not see as reverberating in the present day.

When overlaying the historical narratives of engineering professional formation (Oldenziel, 1999) and racialized forced labor (Blackmon, 2009) I see a group of White middle-class men who have taken social control by defining and defending a new social position: the engineer. White engineers, White corporations, and White paid industrial laborers set out to profit in the ways opened up by the industrial revolution and new forms of industry (Oldenziel, 1999; Roediger, 2007). Although a few notable exceptions of Black men were able to make progress in inventive work (Wharton, 1992, pp. 1–20), by and large Black workers were not only prevented from sharing in the social position and wealth accumulation of White men, but they were used-- their collective forced labor and literally their lives-- were used for the political and social gains of American middle and upper class White men in engineering enterprises. American engineering is fundamentally connected to capitalist industry, and many capitalist histories would likely look like the use and abuse of a certain group for profit if looked at in a certain light. In addition, American history and American industry have a prominent strain of perpetuating White supremacy. It is perhaps unsurprising that pulling on a thread from America's engineering industrial past reveals ties to racial abuse and profiteering.

It becomes another piece of a little known origin story for engineering, and one that perhaps contains a parable for our modern conceptions of engineering: it is always a practical reality within the work of engineering that we prioritize certain stakeholders in the scope of work, without equally considering every and all possible stakeholders on which the task may have effect. Within that process it is always possible to ignore the stakeholders who are culturally distant, or devalued as less human. Should we see grueling and life-threatening mining processes as embodying and perpetuating racial oppression? To what extent have we maintained the use and abuse of working class / people of color within the design of the engineering processes they labor in? To what extent do the client and end user benefiting from engineering work continue to be predominantly White people? To what extent have we retained or shifted the category of stakeholders (low socioeconomic status, overseas populations, animals, nature) whose use and abuse we ignore for the profit of others?

*Engineering Education: Separate But Not Equal*

Another prominent way in which engineering should be seen as having a relationship with racial oppression is through unequal educational access. In the US, the doctrine of "separate but equal" speaks to a particular rationale for racial segregation during the Jim Crow era. Justified by the Supreme Court during the court case Plessy vs Ferguson, it had ramifications throughout nearly all aspects of society, from swimming pools to public transportation to educational institutions. What is commonly understood from this period is that "separate but equal" was in practice in almost every case a myth White society told itself in order to justify the propagation of unequal and lesser provisions for the Black population. The 1950s Brown vs Board of Education decision reversing Plessy vs Ferguson is memorable as the key event in the end of racial segregation of public schools in Jim Crow era. But even engineering educators familiar with this history might nonetheless be surprised that engineering education was a fundamental player in propagating "separate but equal" policies and myths, that engineering education was uniquely resistant among professions to recognizing the inevitability of integration. And that the ripples of this protracted period of systematic racial exclusion are the relatively recent backdrop that modern day affirmative action initiatives should be seen as responding to.

Amy Slaton (2010b) provides a revealing account of the University of Maryland from the 1930s to the 1970s. During this period, UMD, a land grant institution received particular benefits from the federal government and the state of Maryland, and in return assumed certain responsibilities to educate the public and conduct research for the benefit of society (in particular, originally related to agricultural science). In the Jim Crow era, any higher education institution which received this level of public funding was required to maintain a "separate but equal" companion school for the Black population. In Maryland this was Princess Anne College (later University of Maryland Eastern Shore). As with most of the segregation schemes of the era, Princess Anne was poorly funded, never fully staffed with qualified personnel, and never had proper investment in infrastructure. Parallel to the public education enterprise, the inequality of the system was propagated by racist and intransigent stakeholders and justified through various legal loopholes and racist cultural assumptions.

One particular aspect of inequality between the two systems was access to professional training in specific career paths. In the 1930s, this was brought to the fore by a legal challenge to the UMD law school in Baltimore. The result of this legal challenge was a new separate-but-(more)-equal law school at Morgan State. The legal ramifications of this precedent were clear—a White institution which received public funding would now be required to maintain equality for the companion Black institution in the dimension of each individual subject matter offered. In spite of this obvious logic and receiving pressure from the local NAACP and others, UMD's College Park campus and its prominent engineering professional school resisted correcting either their admission policy or their funding, staffing, and infrastructure deficiencies in Princess Anne-- *for the next four decades*, past the famous 1950s Brown vs Board decision, and into the 1970s (Slaton, 2010a). Not only does engineering education have a particular relationship with our national histories of education segregation, it can be seen to be uniquely resistant to progress. The struggle for equal educational access for engineers in the UMD system parallels similar struggles to gain access at other universities, David Wharton (1992, pp. 33–80) details similar struggles at Howard, MIT, Hampton Institute, etc.

The UMD engineering department's close ties to meritocratic allotment of military and industrial research funds exacerbated the inequality. As the College Park campus grew and prospered in their position at the cutting edge of science and engineering knowledge, the Princess Anne campus continued to offer only subject matter effectively towards becoming a polite and obedient agricultural worker. One of the collective myths put forth by many southern segregated engineering departments was that not enough Black individuals were qualified and interested in engineering to justify offering the subject matter, and any individuals who were could simply attend Howard University (i.e., the one HBCU that had attained an engineering department). This last point shows how engineering meritocracy and a racist cultural view towards Black engineering students' potential justified and perpetuated a structural inequity which provided self-serving evidence for this view for decades.

***Normative Preservation of Engineering Masculinity***

Around the turn of the 20th century there were clear structural barriers and cultural norms against women participating in the discipline of engineering.  Women were not admitted to study engineering, they were not given jobs in engineering, they were constrained from all but a very few professions-- (e.g. seamstress, midwife).  The solving of problems in the domestic domain, namely home economics, was given a subordinate gendered role in educational institutions (Bix, 2002; Pawley, 2008). But the structural barriers were contested comparatively early on (e.g., by early female engineers who in spite of being ignored and unsupported made technological advances and a strong case for their own importance in the field), and the events of World War II and the 1960s protests brought strides, albeit contested, for available educational and professional options for women (Bix, 2000; Oldenziel, 2000). Over the 20th century, however, cultural norms perhaps came to dominate the forces working for gender exclusion. Even when included in the engineering profession or engineering education, women were consistently marked and marginalized as “Engineeressess” or “Girl Engineers” (Bix, 2004). Engineering seemed by definition to require a particular masculinity in order to do it properly-- engineering mixed a shop floor working class masculinity with a rarefied higher-educated middle-class masculinity (Oldenziel, 1999). In the role of the industrial shop floor manager, masculinity and class identity allowed the engineer to sit (or purport to sit) between the two forces it had defined its role as linking (Oldenziel, 1999, p. 75).

In addition, the engineering discipline arguably inscribes gender into its technologies and tools (Wajcman, 1991; for similar arguments related to science see Noble, 1992). If men are doing the work of engineering, and men are culturally permitted to get dirty during their work and (at times) physically predisposed to lift heavier equipment, then men can design their engineering tools to require being dirty and lifting heavy objects. This effectively prevents women from engaging within the profession since it would be culturally impermissible to do so. If women had been involved in the profession from the start, the cleanliness and physical accessibility of tools would have been engaged with from the start, and several engineering processes may have looked drastically different. Parallel arguments can be found related to physical disability-- when people with physical disabilities are marginalized from society and the collective design process, the things we use are designed so that these people are disenfranchised, thus normative culture is synonymous with their disability (McDermott & Varenne, 1995). In cases of a large enough disabled population or a carefully integrated disabled stakeholder is appealed to, systems are designed which normalize and assist people with and without disabilities (e.g., the sizeable deaf population in colonial Martha's Vineyard, McDermott & Varenne, 1995, p. 328). In the progression of the engineering discipline, initial explicit structural exclusions based around gender gave way to a set of more hidden cultural norms which continued the effect of gendered exclusion and subordination for several decades.

The inscription of gender into engineering practices suggests a relationship to a broader theory of the sociology of gender. The theory of homosociality from the sociology of gender suggests that several norms of a discipline may relate less to intrinsic aspects of the discipline, and more to the maintenance of masculine participants (Bird, 2016; Lipman-Blumen, 2016). As a limited social theory, this scholarship positions itself as an explanatory theory for the patterns in several masculine-dominated disciplines, without presuming to be exhaustively predictive for all settings. The theory goes: men enjoy interacting with other men, and their interactions and cultural norms can function to preserve masculine exclusivity. This enjoyment is non-erotic, and primarily conceptualized as a force among dominant/hegemonic masculinities (so "effeminate" or homosexual masculinities may be suppressed or excluded by the activities, similar to femininities). Thus, disciplines which are more masculine have a tendency towards certain features: including more individuality, more emotional detachment, more heteronormative sexualization of interactions, and more competition and competitive interactions.  These features can function in real time as an inclusion mechanism for dominant masculinity and an exclusion of femininity (and non-dominant masculinity).

If many of the above features of homosocial masculinity resonate with our associations with engineering, perhaps none more so than the subject of the final section: competition.

***Engineering as A Grand Meritocratic Technocratic Competition***

Several voices have named and critiqued meritocracy and competition as a value in areas related to engineering education. Frehill (2004) points to a historical vision for the formation of professional engineers as proving manhood as intimately tied to the early origins of the modern "weed out" process. Emphasis on endurance, physical vigor, and academic rigor drew on militarized and masculinized images to reinforce the particular sense of engineering meritocracy. Slaton (2010b) argues that it is the engineering discipline's particular cultural values of meritocracy (promoting the best of the best) and technocracy (caring only about results/products and not who does the work) which entrenches its opposition to racial progress and blinds it to its own role in perpetuating a racial hierarchy.  She further argues that this cultural framework continued to have effects throughout the progression of the 20th century and up until the present day. Likewise, in engineering's technocratic meritocracy, diversity initiatives are seen as peripheral to the work of the engineering department (Slaton, 2015).  They do not shift content and do not attempt to disrupt any of the dominant groups of the engineering department.  Instead they work only at the margins of engineering departments to promote only the "best and the brightest" from underrepresented groups.  The lack of an acknowledged engineering origin story of demographic exclusion may contribute to this half-hearted attempt at inclusive reform, resulting in slow progress instead of systemic change.

McDermott makes similar comments about the culture of education in the US. He argues that the American ingrained cultural value of meritocracy fuels the construction of success and corresponding failure in everyday classroom interactions (Varenne & McDermott, 1999). Education as constructing failure appears to hold explanatory power in engineering undergraduate classrooms as well (Chapter 3). How does the engineering context extend McDermott's arguments for the principle meritocratic function of US school? The technocratic, product-focus Slaton has highlighted may provide one answer.

In addition, a critique of the culture of competition particularly in education came during the late 20th century (Kohn, 1992). Kohn argued a distinction can be made between structural competition (i.e., activities construed as mutually exclusive goal attainment), and intentional competition (i.e., a personal orientation towards competition in interactions and mindsets). Structural competitions can sometimes emerge from a scarcity of resources, and in other cases can simply be in order to pursue a prize or recognition. Even in the sense of a scarcity of resources, a structural competition is a specific choice to enact, since there are other frames (cooperation, individual-but-not-competitive work) which are possible even within scarcity. On the other hand, intentional competition is something which can be undertaken whether or not a structural competition has been enacted (e.g. when a person wants to make even the simplest activity into a race). Kohn sparked a conversation on these forms of competition as mutually interlinked and far from being inevitable, they are in fact undesirable forms of structure and interaction for many aspects of productivity, learning, affect, interpersonal community, and even ethical behavior. Kohn (and McDermott, e.g. "kill thy neighbor" game (Varenne & McDermott, 1999) ) sparked a conversation in 1990s K-12 education where many considered whether other non-competitive structures and interactions were possible and desirable. Although influential in K-12 education research, neither McDermott nor Kohn have been cited in the Journal of Engineering Education.

So engineering education seemingly missed the conversation and the opportunity to reflect on the value of competition in its pedagogy and culture. Thus exploring the element of engineering culture as competitive is more challenging to do in a historical review. Competition is something many in engineering education would acknowledge, in many meanings of the word, yet few would feel the need to question, problematize, or even document it. Indeed, it seems few have: I have not found incisive historical ethnographic accounts of the development of competition or competitiveness in educational or professional settings to the same extent as other cultural and structural features. Several meanings of “competitive” conjured in the literature are distinct, overlapping, and mutually interrelated. This section will explore the contours and development of competition and competitive culture in engineering education, to the extent possible through the current methodology. To make my point, I often draw on journal articles and national documents, noting what they say, and what they don’t, about competition.

*The Many Unexamined “Competitions” of Engineering*

One way in which engineering is competitive relates to the concept of a discipline deeply embedded in a capitalist industrial marketplace. Publications which set out a national agenda for engineering frequently appeal to the need for U.S. engineering to respond to “stiff competition” (ASEE Task Force, 1987, p. 7) and for U.S. engineers to maintain their “competitive edge” (National Academy of Engineering, 2004, p. 41). This grounding of engineering education within capitalistic competitive frames is not the only available framing one can take for professional vision (e.g., the less capitalistic emphasis in human-centered design, Engineers Without Borders), but it is a reasonably logical one. These sorts of imperatives are felt, responded to, and revoiced by individual industries and corporations, who are seen as primary partners and stakeholders in engineering education.

Competitive national and industrial pressures filter into educational standards and priorities (Deboer, 1991; Lucena, 2005). They also shape pedagogical choices, where specific courses are developed to meet needs for industrial competitiveness (Dutson, Todd, Magleby, & Sorensen, 1997; Todd, Sorensen, & Magleby, 1993). One industry-based Council on Competitiveness once concluded with pronouncements for education such as: “We can only obtain a long-term competitive advantage by learning faster than the rest of the world” and “Product development is the next competitive battle ground” (Frey, Smith, & Bellinger, 2000). Re-thinking Engineering Education (Crawley, Malmqvist, Östlund, & Brodeur, 2014), a prominent agenda-setting document, seems also to use language which elides industrial competitiveness and authenticity with pedagogical structured competition “Courses based on competitions have aspects of design-build-compete.” The industrial resonance of the phrase “design-build” seems to imply that competition in education will prepare oneself for competition in industry ” (Crawley et al., 2014, p. 102). As is typical in the literature, the structured course competition here is mentioned as a simple description of pedagogical programming, not particularly explaining or interrogating the role of competition as worthy or productive. The similarity in phrasing and the lack of parsing a distinction in different “competitions” suggests how a link may be commonly inferred-- the engineering international and industrial marketplace is and must be "competitive," so the way to prepare engineers is to have them "compete." I question the simplicity of this elision, as the scales of and experiences of competition in these two senses-- an industrial capitalist competition offline between countries or companies, and a head-to-head student-to-student competition based on timeliness and effectiveness of solutions-- are quite different. If in some sense we need the engineering industry to be "competitive" it may not follow that we need to educate students via "competition."

A simple and common way that pedagogical competition is discussed is to contrast it with paper-based pedagogy. The Re-thinking Engineering Education publication continues, "In contrast with traditional 'paper' design courses, the essential feature of such experiences is that students actually build the design and verify its effectiveness" (Crawley et al., 2014, p. 102). This is a commonly explored dichotomy and tradeoff. On the one hand, industrial interests suggest a need for training in solving real world problems which is delivered as problem-based learning principally conceptualized as a design competition. On the other hand, research funding interests present a need for conceptual knowledge which are principally delivered as textbook learning in engineering science. For example, this dichotomy of education via textbook engineering science or industrial project is examined within one prominent history of engineering education (Seely, 1999). Competition does not, however, represent the opposite of textbooks. There are several available active learning participation frames that are more collaborative or non-evaluative in nature. As support for these alternative frames, a study on the affordances of active learning in its different forms (Prince, 2004) concluded that collaborative and cooperative learning environments in engineering result in more learning than (individually) competitive environments. Unexplored within this scope of research is a reality that many of the collaborative and cooperative active learning environments in present day engineering education are actually nested within and framed as competitions. When other disciplines (e.g., my PhD home department of education) enlist students in a collaborative learning activity, they rarely frame it as a grand competition.

Another common rendering of competition is as a motivator, as a form of being responsive to student interests and letting students have fun. Yet we also know from literature that not everyone is enjoying their education as a perpetual competition, the diversity in engineering literature has frequent mentions of "competitive culture" as an aspect which alienates women and leads them to leave (Foor et al., 2007; Seymour & Hewitt, 2000). This form of competition may also refer to competition in a meritocracy, competition for a scarcity of grades and positions-- yet the idea of engineering courses as consistently competitive in both interaction and in structure seems plausibly at play as well. Yet even when posited as a cause for a lack of gender diversity, competition has not come under much deep scrutiny. Perhaps it is the way in which the engineering discipline views competition as a fundamental cultural norm, so fundamental that it cannot be seen or lamented, that has prevented further analysis of this aspect of ourselves.

***Culture and Demography***

We know from history that certain disciplines have maintained certain gender norms over time, and that others have shifted. Computer programming was originally a women's discipline, seen as lowly and technical work. Over a short time, the intellectual demands of the discipline did not change, but the gender representation in the discipline did, as did the esteem and pay for the discipline (Ensmenger, 2010). It is now a male-dominated field, famous for its head-to-head hack-a-thons to compete for positions. Education went from a man's discipline to a woman's, and became a field less intended for the brilliant individual, less esteemed, more associated with caring, and less associated with individual brilliance ("those who can do, those who can't teach.")

Engineering has had no such shifts. We know engineering is a White and masculine discipline because of historical formation, social control, and educational exclusion. We know that certain normativities (dirtiness, physical demands) maintained the normative masculinity throughout the past century. If competition is a known masculine homosocial normativity, is it a force perpetuating masculine engineering demographics? Is engineering competitive because it is authentic to the requirements of the discipline and a pedagogical good? Or, is engineering mysteriously competitive simply because it is occupied by (White) men? And, is it intransigently masculine because it is competitive? If so, what other of our engineering disciplinary features have we inherited with the historical baggage of masculinity and whiteness?

## Discussion and Implications

Having presented an initial cultural historical context for engineering education, I will conclude by discussing the historical account in terms of its value and impact for several projects in engineering education.

### *Taking Stock of the Historical Account*

This wide-ranging account can be seen as a starting point or as continued progress towards developing a way to accurately contextualize demographics and culture in our engineering education system. It drew on scholarship rarely discussed in educational settings (STS, critical history of race, sociology of gender). Perhaps because this scholarship is somewhat challenging, dense, and not published in the standard disciplinary journals (many of the citations here are books, not Journal of Engineering Education or Engineering Studies), it is often only known by an insider few with connections to these communities. One contribution of this chapter is to help blend these worlds. This aligns with and builds on movement on the one hand from some in STS and historical communities in order to discuss present day engineering education (Seely, 1999; Slaton, 2011, 2015; Wisnioski, 2015), and on the other from education researchers who investigate and situate the way historical context plays out in the present day (Pawley, 2008). The frameworks and findings presented from the STS and historical scholarship continue to present powerful resources for conversations on diversity and marginalization in engineering education which push past our accepted present day realities.

Another contribution comes in the blending of disparate social issues and historical accounts, which intersect one another but are often treated separately. Due to the depth of research and specificity of arguments, the scholarship I drew on sometimes stays siloed into histories specifically on gender, race, class, engineering, academia, industry, meritocracy, or criminalization. Some scholars find rich new territory in combining two of these in an interlocking account, such as Amy Slaton in considering race and meritocracy in engineering education (2010b). Likewise race emerges in accounts of gendered engineering histories if one reads between the lines (Oldenziel, 1999), and engineering emerges similarly in the backdrop of racial histories of Jim Crow prison labor (Blackmon, 2009). But we can also gain from seeing how several pieces intersect and interlock in the social history of engineering. In the wider scope this chapter attempted we can consider how demographics interact with cultural norms, how gender oppression and White supremacy reinforce one another in our material realities, and how both forms of oppression inscribe engineering with some of its deepest-rooted practices. Approaching a comprehensive understanding of the history of oppression in engineering, and then presenting and representing it to new audiences, is an ongoing project I see for myself and other scholars, and to which this chapter begins to contribute.

*Areas for Further Progress*

This historical account of engineering can be seen as a starting point, and there are limitations to what I have presented, which can and should be developed further. For example, the story of gender exclusion focused more heavily on culture than did the story of racial exclusion. If the account of gender is indicative, racial normativities (the norms of whiteness) must play a role in the perpetuating of engineering cultural norms. This is an area for further conversation and suggests the utility of incorporating critical whiteness theories in histories and studies of engineering education (Zuberi & Bonilla-Silva, 2008).

The account also focused heavily on gender and race, whereas other demographic intersections (e.g., socioeconomic status, sexuality, racial and ethnic identities outside the Black / White dichotomy) were mentioned in passing or omitted. As noted, I see these and other further intersectionalities as highly intertwined with the histories presented, for example, between class and gender, where a class hierarchy between capital and labor was central to the gendered professional formation of engineering (Oldenziel, 1999), or between gender and sexuality, where masculine gender norms have impact on queer engineers who must either perform (to some extent) a non-normative gender performance or “pass” for straight engineers (Cech & Waidzunas, 2011). There may be a history to write around why and how Asian-Americans became an unmarked or model minority racial identity in engineering, and how this is distinct from and still subject to histories of White domination. Thus, there is great potential for further work around additional forms of oppression and their intersections with the engineering discipline, both in the actual sociological historical work and in research on present-day educational norms.

***Providing Historical Context for Ethnography on Marginalization in Engineering***

Next I consider how this historical account may strengthen, complement, or problematize the present-day emergent and phenomenological classroom ethnography of Chapter 3, and which is sometimes represented in the education literature.

*Revisiting the Classroom Culture*

As an example of demonstrating the value of knowing the historical context for ethnographic research subjects, I revisit features of the classroom which I presented at the opening of this document, and allow the historical context to speak to the classroom.

The cultural construction account I presented is over-determined: students who are dominant and demographically privileged also outnumber the students who are non-dominant, and find themselves in positions of power such as happening to sit next to where the professor is presenting and being able to control the flow of discourse to their advantage in status positionings. This is a specific classroom issue, but is it also a broader pattern of gender marginalization? Would an introductory programming class which consisted of a majority of female and gender non-conforming students operate the same? I may have my own opinions but I would struggle to provide ironclad proof to a reader because the sorts of scenarios I encounter in engineering classes have such similar features (majority masculine, competitive interactions, reifying status).

The lens into engineering as *originally* a form of claiming white, middle-class, masculine identity, and then *continuously* reproducing cultural norms associated with it provides an extra clue. We need not levy claims of individual sexism or maliciousness on male students in order to see practices of classroom domination as continuous with historical patterns. In a way, knowing that the actions of male students echo a historical pattern makes them perhaps more alarming, but also more comfortable for us to name and transgress. As an example, I remember stifling a judgmental response to Brad, the male student who in an interview recognized the advanced questions he thinks were "funny" might be harming students with less programming background. What aspect of empathy was broken in Brad and some of the other men in the classroom, that causing pain and preventing learning for fellow students was "funny"? Elby (co-author) would sometimes point out during moments of collaborative analysis the emphasis not to ascribe malicious intent to the question-asking process writ large, that it should be seen as a broader unintentional cultural pattern. The historical account seems to support this intuition. If masculine meritocracy-based domination has always been a key component of engineering, the unempathetic approach to the question discourse may be fundamentally masculine, but it is not individually malicious.

Further, theories of homosocial masculine norms help provide new clues to other features of the classroom story we may have seen as disparate, and uncomfortable for women, but not necessarily the tell-tale common features of groups of men interactionally constructing an in-group for fellow men and excluding women. Groups of men tend to sexualize interactions, not homoerotically, but heterosexually, with women as an object of imagined or interactional attention. The sexual comments about a bowling pin seem to be a form of sexualized discourse as a homosocial masculine norm. Had Jillian remained in or walked back in the room at the moment this discourse broke out, she might have been tempted to protest, or to walk back out again. Or she could have participated, but as a woman in a heterosexual sexualized masculine discourse, it would not have made her an insider, but an object.

Groups of men also use competitive interactions to signal a homosocial bond. I used a cursory literature review to trace many relevant meanings of competition which overlap in engineering education. Engineering is embedded in industrial and international and academic competitions, it is replete with pedagogical competitions, and it perpetuates competition interactionally between peers. A majority and dominant group of male engineering students and teachers may be perpetuating our many interactional and pedagogical competitions; they may then use necessary industrial and academic competitions to justify it. The patterns in the ethnographic data presented show men perpetuating interactional competition, and women resisting it or being excluded by it—directly corroborating its role as a homosocial masculine norm in this setting.

The broader "marked" nature of femininity in the engineering classroom, the idea that gender is "in the air," seems a shade less mysterious or far-fetched after reading the historical scholarship of gender in engineering. Engineering has always been masculine, and femininity has always been constructed to be an anomaly. We are only several decades past the time when female engineers were "engineeresses," and we simply have not transgressed past the period where they remain an anomaly. The claims about the impact of such social labels in the Chapter 3 analysis was necessarily a bit more a theoretical orientation than an empirical case, and thus the historical context provides some additional robustness to such claims.

Finally, the classroom description, both mine and the accounts of my participants, tended not to interrogate race as much as gender. I have already pointed out (in Chapter 3) that the lack of attention to race may represent both a methodological choice or oversight, as well as a feature of participants and the cultural setting of the engineering classroom. Perhaps then, in practice, whiteness as domination functions differently from masculinity as domination. Masculinity can maintain power through an overt attention to masculine self-image and gendered interactions. Gender is “in the air” of the student’s all-male Calculus section, as it is for the mostly-male engineering class, as it would be if an unexpectedly large number of women were present. And although this could be for many reasons it is noteworthy that for masculinity the attention to and performance of gender in the classroom seems only to reify its power.

Modern day whiteness, on the other hand, often maintains its power by being unmarked, normative, and expected, in contrast to other racial identities and presentations. So a racially normative class section (all White students, or in Engineering: White and Asian students) is unmarked; a subsequent year’s class section with a non-normative racially identified student is not felt as racialized as a whole, only the student in question is marked and raced. In effect, race is not “in the air” in the Engineering classroom, but somehow it is hovering invisibly and lands on the person of color as soon as they enter the scene. If race were to be consistently “in the air” of an engineering classroom, it may reduce or change the nature of its power, with a more self-reflexive, less “colorblind” awareness among White normative identities. With the way whiteness currently functions in engineering education, in research, in publications, in historical accounts, race is not only possible but easy to exclude, unless pursuing a racialized study of people of color. Although the comparative hiddenness of race in the White classroom may come about from an influence of many circumstantial reasons (e.g., patterns of race in student social patterns, experiences spurring the development of racial consciousness), the pattern nonetheless parallels the hiddenness of race in engineering history and historical accounts (e.g., the otherwise little known connections of engineering to slavery, Jim Crow, and separate-but-equal policies).

The idea of the non-racialized classroom is, of course, not true, in either case—both the Engineering classroom and the history of Engineering are heavily racialized, and the pattern in which race becomes revealed and relevant upon the introduction of non-White members belies that fact. It is, however, part of what makes the further methodological work of marking the practices and narratives of whiteness in engineering so challenging.

### *Methodological and Practical Implications of Historical Work*

I note the following methodological and practical implications of this and further historical contextual work for communities and stakeholders in engineering education:

#### *Ethnographers*

I particularly focus on ethnographers because of the power demonstrated in my own example to enhance understanding of a cultural context. Ethnographers also seem like the most ready consumers of the chapter. If some relevant piece of historical social context can shift the meaning of classroom events, it is critical for ethnographers to become aware of it for the sharpening of their own instruments of observation, and then to have the option of revealing (or not revealing) the historical context to their reader depending on their purpose (Rockwell, 2016). Although someone reading this chapter might have felt their prior ignorance was bliss, ethnographers will have a particular predisposition to wanting to understand and communicate about the context and culture relevant to their research subject. They will not need to be convinced to view a classroom setting as historical or political space, and they are often eager to consume the insight of fellow scholars who can shed light on new forces they had not considered as operating in their research settings. The fact that many ethnographers do not often incorporate STS or critical historical scholarship is more likely a lack of communication between scholarly communities, an inability to do all things at once in every paper, or a need to spotlight certain other elements of influence for a specific audience or argument. Nevertheless, the more we in ethnographic education research explore connections with history and culture, the more powerful and accurate our accounts will become.

In light of the different purposes and approaches I laid out in Chapter 2, it is interesting to think about how the historical context becomes relevant depending on the project. In part, some of what I found myself attempting in this chapter seemed to be in the service of Cultural Production work: looking at broader historical cultural influences to see where oppression is being reproduced. For instance, a specific gender norm like competition can be reproduced in a local classroom setting, or it can be resisted and subverted. Conceptualizing history as a broad set of structures of influence which often work to reproduce oppressive culture, would be highly consistent with Cultural Production. I think the Cultural Production scholars I cited in Chapter 2 tend not to take up critical history or STS scholarship as influence, but I think it could be particularly valuable to the arguments they want to make.

In other ways though, and as I began this Chapter suggesting, it seems like this chapter was expanding on the methodological move of “turning away” from individual qualities and socializations. Many of the STS and historical scholars focus on creating critical, post-structuralist accounts of oppression. They have a parallel skepticism of received categories such as “technology,” “engineer,” and “rigorous,” and they can become a compatriot in the work of upending present day oppressive frameworks of interpretation. Likewise, in my initial movement, I was reaching up and outwards from the individual interaction towards cultural history, consistent with McDermott’s approach. In returning to understand the classroom, I was relaying theory on top of the interactions. It seems then that the historical scholarship of oppression has something to offer both Cultural Production and Cultural Construction camps. And perhaps it blends the camps so that they are not as different as where they started from, but represent a movement back and forth from the macro influence and the micro interaction. Others already seemed to blend ideas from Cultural Construction and Cultural Production more readily (O’Connor et al., 2016; Varenne & Koyama, 2016), so perhaps this historical exploration prepares me and leads me towards this hybridity between forms of scholarship I previously saw as discrete.

*Fostering Communication Between Education Research and STS Communities*

I have argued in this chapter, and others have pointed to (Wisnioski, 2015), a view that history can speak to engineering education more broadly. If one saw history as a purely intellectual or insider activity, there would be little purpose to the current effort in this chapter: I did not do original examination of new historical documents, the contributions I added primarily came from synthesizing and applying others' work in new ways, not writing down new things about history for the first time. But history is not only valuable to those in the communities who pursue historical research; if the history in question has shaped our realities and ways of seeing the world, history may be a vital source of insight into ourselves. The historical STS community with its strengths of insight to historically situated present-day educational problems, can team with the engineering education community with its direct access to observing and shifting those problems.

*An Appropriate Diversity Context for Engineering Educational Stakeholders*

Finally, there is great potential for dissemination of this and future historical accounts to shift thinking and conversations related to diversity issues in engineering education. We spend a good deal of time (in Chapter 3, in publications, in pedagogical development sessions) trying to shift educational stakeholders out of deficit or patronizing thinking about underrepresented or marginalized students. It can be hard to do so, in part, because classrooms are over-determined—professors can see firsthand when underrepresented groups are in fact more often also the ones without the apparent programming skills or a socialized predisposition to technical subjects, and they can easily construct a deficit narrative. (Though as Chapter 3 demonstrated, this view misses the point of how sexism, gender norms, dominant meritocratic forces in a classroom impact underrepresented groups once they are in the classroom.) It is in these present-day uncritical views of engineering classrooms, or of underrepresentation patterns and statistics, that it is possible to maintain deficit or patronizing thinking which in effect blames the victim for being underrepresented and marginalized. It seems to me we spend a lot of effort just in this rather frustratingly narrow territory, and that some of our interventions (e.g., convincing engineering instructors that women have positive assets towards design work, Svihla, 2016) are themselves frustratingly unambitious and patronizing.

It seems, however, that history is a firm anecdote to deficit thinking. It is hard to continue to blame the underrepresented minority for not showing up on time to the meeting, when we learn how complicit dominant groups were in locking the doors of the culture and system, and how much we in positions of power in engineering still profit from tilting cultural scales in our favor. Perhaps a historical context for diversity will prompt a new level of urgency for stakeholders to take action in response to marginalization. Although it can be personally challenging for a member of a dominant group to come to terms with a history of oppression, it may yet turn us all into activist scholars and equity-minded educators.

# Chapter 5: Supporting the narrative agency of a marginalized engineering student.

## Introduction

This chapter presents a co-authored submitted journal publication, which has previously been presented as a conference publication (Secules, Gupta, & Elby, 2015). It has been submitted for reviews to the Journal of Engineering Education.

The following is a brief description of the development of the project and contribution of each co-author. I conducted all participant interviews which took place longitudinally over the course of three years. Ayush Gupta and Andy Elby collaborated on data analysis, in joint data watching sessions to compare and refine meanings and arguments. I performed transcriptions and coding of the first three interviews in order to provide an initial analysis as a course paper. Gupta and Elby collaborated on revising and repositioning the paper as a conference paper for ASEE. In conducting final in depth member checking, Emilia Tanu (the research subject) offered to name herself and become a co-author on the final journal paper version, in order to write a reflection on the value of the longitudinal interviews for her agency and persistence. I helped Tanu assemble this post hoc reflection, and was primary author on all other sections of the chapter.

## Centering the discussion

> Our search leads us back to where it all began, to that moment when an individual woman or child, who may have thought she was all alone, began the feminist

> uprising, began to name her practice, indeed began to formulate theory from lived experience. Let us imagine that this woman or child was suffering the pain of sexism and sexist oppression, that she wanted to make the hurt go away. I am grateful that I can be a witness, testifying that we can create a feminist theory, a feminist practice, a revolutionary feminist movement that can speak directly to the pain that is within folks, and offer them healing words, healing strategies, healing theory.
>
> bell hooks, *Teaching to Transgress* (1994)

We place this paper into conversation with work supporting underrepresented students in Science, Technology, Engineering, and Math (STEM). Amongst those engaging with this issue are the official and unofficial mentors of diverse students, the diversity program coordinators engaging on the front lines of support services, the concerned administrators who must make difficult decisions for allocating resources, education researchers (like ourselves), and, of course, the students themselves. Underscoring our entree into this conversation is a deep respect for those individuals engaging in this work, and an appreciation for the ways in which that work can feel challenging, constrained, or at risk.

Within this conversation certain strands recognize not just the importance but the challenges of supporting underrepresented students. A challenge associated with intersectionality of a diverse population questions which elements are most supportive for a range of intersecting identities among any supposedly homogeneous demographic group (Armstrong & Jovanovic, 2015). A challenge associated with programming considers whether the goal is “creating a safe space” or “challenging oppression” or "empowering students" or "providing tools for survival" (Arao & Clemens, 2013; Ellsworth, 1989). In a changing institutional and national landscape (e.g. the new possibilities and challenges regarding race in post-Obama America) there lies a challenge in responding to the shifting needs of a new generation of students who experience different forms of marginalization than our prior best practices were perhaps designed for. In the day-to-day work of diversity support there lie such complex questions with nuanced and complex answers.

To contribute to this work as researchers, we can place disparate literatures in conversation with one another to look at problems afresh and to look for new sources of inspiration. In this paper we bring the literature of critical feminist and educator bell hooks into conversation with STEM diversity support work. In hooks' writings (1992, 1994), the work of "theorizing"—the work of naming and understanding one's experience as connected to broader systems of oppression—is central to survival and liberation.

In this paper we offer an illustration of what it might mean to "bear witness to" and support the hooks-style theory-making about the marginalizing experiences of a female student in an undergraduate engineering program, which she often found oppressive.[21] Although *theorizing-as-agency* is resonant and consistent with prior research on students navigating marginalization and with diversity support strategies, it has not been the central focus of prior work. For instance, the student navigation strategy of "combating isolation using peer networks" (Ko et al., 2014) has connected to diversity

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[21] We borrow from the language of critical theory in this paper. In critical theory, oppressive does not mean quite the same thing as it does colloquially-- obnoxious or onerous-- but existing within a structure which consolidates power of a primary axis of oppression, for instance, race or gender or sexuality. We use the word marginalizing nearly interchangeably. Likewise, with the word liberatory, rather than connoting a colloquial understanding of legal civil rights, we are connoting freedom from the aforementioned oppressive forces, or of progress towards that freedom.

support strategies to foster community through clubs and living-learning programs (W. C. Lee & Matusovich, 2016), but theorizing-as-agency may characterize the nature and transformative potential of those peer conversations. By highlighting theorizing-as-agency, we hope to help diversity support workers recognize and perhaps emphasize important elements already present in their programs, while also suggesting new areas of exploration for practitioners and researchers.

## Literature Review

This literature review provides the contours of the current conversation on marginalization and diversity support in STEM education. The first section focuses on supportive practices for marginalized students; the second section highlights agency as an important component of student experience with a promising potential for expanding our understanding of marginalization and support.

### *Support for Marginalized Students in STEM*

For several decades, the STEM education literature has had as a central concern the marginalization of underrepresented groups. Depending on the particular discipline, populations of concern have included underrepresented racial and ethnic minorities, women, LGBT populations, students of low socioeconomic status, first generation college students, students with disabilities, and other populations (Cech & Waidzunas, 2011; Seymour & Hewitt, 2000; J. M. Smith & Lucena, 2016).

The STEM education literature has identified several prominent strategies for supporting marginalized students. For instance, informal mentoring has been highlighted as important for participation in research and for academic progress toward STEM careers (Schwartz, 2012). Mentoring by a role model who shares the mentee's marginalized demographic identity can help students see a STEM profession as inclusive of their demographic (Hammack & High, 2014). The role of co-curricular support programs, engineering student support centers, and living-learning programs have also been shown to be effective at improving retention (Inkelas & Soldner, 2011). Other proven strategies for supporting marginalized students include cultural competence training, accommodations for disabilities, and connecting students for peer support (Morgan, 2013).

The literature on programmatic efforts to support marginalized students has predominantly taken two forms: (i) descriptions of "best practices" and (ii) programmatic evaluation. The descriptions of "best practices" can take the form of specific enacted curricula or of design principles. The evaluations of specific co-curricular support programs often center around quantitative retention studies and student experiences and satisfaction as reported in focus groups and interviews. While this research agenda has been useful for testing and sharing the strategies of particular programs, it has not lent itself to greater theoretical insight into the underlying process of co-curricular support (W. C. Lee & Matusovich, 2016). For instance, while it is well established that mentoring and support programming is effective, we have not made comparable progress in our understanding the nuances of how particular best practices should be enacted, the theoretical understanding of why they might work, and what new models may refine and/or challenge existing work.

While quantitative research has been useful in determining that certain practices are effective (i.e., to label certain practices as "best"), it has limited power to answer how, why, and what else may work, or to cause us to critically examine for whom the practice is “best.” Partly to address these limitations, qualitative research has also addressed problems of diversity in STEM (Cech & Waidzunas, 2011; Foor et al., 2007; Pawley & Phillips, 2014; J. M. Smith & Lucena, 2016) and has added to our understandings of student experiences in marginalization. However, qualitative methods have less frequently been applied to exploring the sociological and discursive aspects of student support, as we will in this paper. Our goal in qualitatively opening up the “black box” of marginalized students’ experiences in undergraduate engineering is not primarily to produce knowledge for its own sake. Instead, we primarily view ourselves as 1) uncovering new theoretical models for practitioners to consider, and 2) having an active role in supporting one student *through* the process of interacting with her as a research participant.

Thus our approach presents an unusual perspective within traditions of qualitative research and research on programmatic support for marginalized students: we draw on theory (bell hooks, as discussed below) in order to conceptualize our research interactions with a student as creating a space in which she could take a form of agency by theorizing about her own oppression. We think some diversity support activities create similar spaces on a daily basis; our contribution is to highlight the aspect of supporting student agency and to bring in a theoretical perspective which may be useful or edifying for those currently providing such support. With this in mind, we now briefly review literature on marginalized STEM students’ agency, situating hooks-style theorizing-as-agency within that literature.

***Student Agency***

Researchers of student marginalization have noted the anti-hegemonic political implications (Pawley & Slaton, 2015) of giving voice (Hutchinson-Green, Follman, & Bodner, 2008) embedded within the researcher's work. This is similar to the way in which bell hooks sees her work of theorizing (and enabling others' theorizing) as liberatory and empowering. We think that these scholars speak collectively to an aspect of *agency* in oppression, to the sense (and reality) of who controls the narrative of a student's experiences in marginalization, and point towards the potential to examine narrative methods as consequential to the process of student support.

Agency has also been highlighted as central to students' persistence through and overcoming of marginalization. Within this research, student agency has usually been connected to personal drive, social supports, and specific tangible acts such as seeking out opportunities. For instance, in a review of research on minority retention, Ong, Wright, Espinosa, and Orfield (2011, pp. 188–189) noted "agency and personal drive" as a major resource for women of color in STEM undergraduate programs, who tap into identity in a marginalized community for empowerment. Similarly, Ko, Kachchaf, Hodari, and Ong (2014) noted several coping strategies employed by women of color in undergraduate Physics and Astronomy programs, including eight navigational strategies identified as significant forms of agency: "seeking an environment that enabled success, circumventing unsupportive advisors, combating isolation using peer networks, consciously demonstrating abilities to counteract doubt, finding safe spaces for their whole selves, getting out to stay in STEM, remembering their passion for science, and engaging in activism."

We note that the form of agency we connected to narrative, student voice, and bell hooks' theorizing has not been foregrounded in the STEM education literature on student agency. Theorizing-as-agency connects to many of the types of agency listed above. For instance, several of the aforementioned components of student agency involve a blending of psychological and behavioral/navigational aspects. When one is "consciously demonstrating abilities to counteract doubt," the psychological comfort of lessened doubt is connected to the active work of demonstrating abilities. Agency, then, is not purely a mental state or a will to succeed, but an active process of asserting and engaging which is connected to mental processes and states. This is similar to the way in which the active work of constructing a narrative can be personally liberatory. Our work highlights theorizing as a form of student agency worth considering by those concerned with supporting students experiencing marginalization.

## Theoretical Framework: Theorizing and Narrative

Having motivated the relevance of bell hooks' theorizing to supporting marginalized students, we now unpack this theoretical framework further and suggest its relation to other work in STEM education. Then, we discuss the construct of *narrative*, which serves a dual in this paper. For our focal participant, Emilia, we argue, constructing and reflecting on narratives about her experiences, and relating those to cultural narratives about engineering and STEM, was central to her theorizing about her oppression. For all of us as researchers (as discussed in the methodology section), parsing Emilia's discourse into narratives helped us spot and document the hooks-style theorizing in which Emilia was engaged and to understand the substance of her stories.

### ***bell hooks' Theorizing***

bell hooks explains and argues for theorizing in her book *Teaching to Transgress* (1994). She first illustrates the framework with an anecdote from her childhood:

> *As a child, I didn't know where I had come from. And when I was not desperately seeking to belong to this family community that never seemed to really accept or want me, I was desperately trying to discover the place of my belonging. I was desperately trying to find my way home. How I envied Dorothy her journey in The Wizard of Oz, that she could travel to her worst fears and nightmares only to find at the end that "there is no place like home." Living in childhood without a sense of home, I found a place of sanctuary in theorizing, in making sense out of what was happening. I found a place where I could imagine possible futures, a place where life could be lived differently.*

She draws from her childhood to emphasize her view that theorizing is natural, innate, and deeply human practice, which can be a critical source of comfort during painful experiences. "Children are natural theorizers," she says, always questioning the world around them and wondering why it came to be that way. Some adults, including her family, appear not to have forgotten how to theorize, but to have other priorities which preclude such questioning:

> *Imagine if you will this young Black couple struggling first and foremost to realize the patriarchal norm (that is of the woman staying home, taking care of household and children while the man worked) even though such an arrangement meant that economically, they would always be living with less. Try to imagine what it must have been like for them, each of them working hard all day, struggling to maintain a family of seven children, then having to cope with one*

*bright-eyed child relentlessly questioning, daring to challenge male authority, rebelling against the very patriarchal norm they were trying so hard to institutionalize.*

In childhood, hooks struggled in a messy space of recognizing and challenging marginalization from those she loved and was closest to. Her family was embedded within broader racial and gender cultural forces which expressed itself in ways (her father's disciplinary norms and her mother's complicity with them and bewilderment with hooks' protests) which caused hooks personal pain. hooks says it was the process of understanding her family's actions within the broader context which gave her comfort and became a tool for her survival. She then developed this process more formally into a general way of living in and understanding the world.

*This "lived" experience of critical thinking, of reflection and analysis, became a place where I worked at explaining the hurt and making it go away. Fundamentally, I learned from this experience that theory could be a healing place.*

In addition to being personally comforting, hooks' theorizing also becomes a form of resistance for oppressive forces, a tool to respond to instantiations of oppression with critical analysis. hooks frames this theorizing as a "change in attitude (though not a completion of any transformative process) [that] can be significant for colonized/oppressed people." (p. 47). hooks saw this form of theorizing as arising from and embedded in lived experience,

*To me, this theory emerges from the concrete, from my efforts to make sense of everyday life experiences, from my efforts to intervene critically in my life and the*

> *lives of others. This to me is what makes feminist transformation possible. Personal testimony, personal experience, is such fertile ground for the production of liberatory feminist theory because it usually forms the base of our theory making.*

hooks thus pushes back against the colonization of theory building as by and for academics and argues for "democratic access to the process of theory-making."

This approach is cited within and consistent with traditions in the broader Critical Theory literature. Critical Theory conceptualizes many inequitable social structures as systems of oppression that control the dominant narrative and the meanings ascribed to the actions of participants in the system (Weber, 2001). For individuals experiencing marginalization there is a power in naming the oppression and theorizing about it (Yosso, 2005).

We suggest that students' experiences in STEM can be viewed as situated within similar systems of oppression—systems influenced by gender and racial dominance, marginalization (Foor et al., 2007), and the construction of students as "not cut out for" STEM (Chapter 3). Like hooks, students are engaged in a day-to-day struggle embedded inside oppressive narratives and systems. Like hooks, students are in intimate proximity with local perpetrators of oppression, with well-meaning teachers and peers who are constrained within broader forces. Like hooks' parents, these local actors are often simply struggling to stay afloat, to keep the status quo moving; they don't see themselves as perpetuating oppression. Nevertheless, the close proximity creates a confusing and painful space for students, who like hooks, still need to belong and succeed with the people who are locally causing them pain. In this reality, the lived experience of critical thinking, thinking about local actions as constrained within broader forces, could become a powerful source of comfort for students. Although some students, like "children," may be natural theorizers, there may be a power in recognizing and encouraging the practice as a way of processing and responding to painful experiences.

***Narrative***

*Narrative* is a construct related to theorizing which has been formalized in some strands of qualitative research. Ochs, Taylor, Rudolph, and Smith (1992) propose the act of narrative construction as a "theory-building activity," wherein the meaning of a phenomenon is explored and developed through story-telling. In a study of dinner table conversations, they show that the meanings ascribed to events are developed or contested over the course of telling a story. Thus, we propose—and our case study illustrates—that a student may affirm or contest the meaning of their persistence in engineering via the story they tell to themselves and others. Working within a different theoretical perspective, Stanton Wortham (2004) has also shown how narratives can become symbolically powerful about both local interactions and broader social structures.

As noted above, there are several oppressive societal narratives in STEM in which we exist and which intersect our lives. In the US, several limiting narratives around engineering have been noted: engineering is hard, engineering is nerdy, engineering is masculine; engineering is an uncreative application of science (Giddens et al., 2008). These narratives work against efforts to diversify engineering by attracting and retaining more students from underrepresented groups (Sochacka, Walther, Wilson, & Brewer, 2015). These narratives can at times become spoken, embodied, acted out, or instantiated in policy. This is the reality in which narrative as theorizing and meaning-making can become empowering—the reality suggested by these limiting narratives can be dissected and counteracted within one's narrative reasoning.

Accounts of this sort of narrative work have been presented in the STEM education literature. For instance, Martin (2007) investigated the counter-narratives of adult African American students in community college math classes, who drew on their racial identities as a source of resistance and resilience in the face of overt discrimination embodying a racial stereotype around mathematical abilities. In addition, Brewer, Sochacka, and Walther (2015) present a project very similar to ours: they identified prominent narratives from American Society of Engineering Education "First Bell" summaries of relevant national news stories publications, and then the engineering student as autoethnographic researcher examined his experience of classroom discourse events where these narratives appeared. While these projects were conducted with slightly different purposes and frameworks, which are not centrally about constructing narratives as empowering or agentic, they do add support to the view of this work as important.

In addition, Seymour and Hewitt (2000) note the prevalence of feminist themes in their interviews with women in undergraduate STEM programs; tenets of feminism seemingly helped the students understand and explain their struggles in STEM in light of broader cultural aspects of gender. Likewise Jane Margolis and Alan Fisher (2003) note the presence of counter-narratives for computer programming amongst female undergraduate students in computer science. However, in general this research does not address whether or how these acts of theorizing can contribute to individual agency and thereby persistence in STEM.

Finally we note that a large body of qualitative research arguably explores the narrative work of a student experiencing marginalization (Danielak, Gupta, & Elby, 2010; Foor et al., 2007; Johnson, 2007; Pawley & Phillips, 2014). These researchers tend to marshal their findings towards knowledge production rather than examining the process of student support, however we note that these researchers may have unreported insights into whether and how the research itself was of value to the student participants. We return to this issue in the Discussion. For now, though, we begin describing the empirical case study use to argue for the existence and power of theorizing as a form of agency against oppression for marginalized students in STEM.

**Methodological Overview**

***Research Context***

Stephen was enrolled in a graduate-level education course, in which an assignment required Stephen to conduct a one-on-one interview, with a goal of understanding student experiences. Stephen had an instructional support role in an engineering design course for first-year engineering students. Students worked in 8-10 member mixed gender teams in this course, and Stephen was noting patterns of gender-based marginalization within teams. Students in the course also participated in seminars geared towards women's experience in engineering and some were part of a support community on campus. Stephen recruited women students from the seminar who were also taking the engineering design course and conducted video-recorded interviews with four volunteers as part of his coursework. Out of the four students originally interviewed, one student, Emilia, organically became the subject of this study. This was due in part to her willingness to participate, as she suggested a follow up to the first interview, saying that she had further thoughts. Also, the research team reviewed interview video/transcript in group meetings and noted emerging themes of marginalization and agency. This preliminary analysis piqued our interest in pursuing these themes further.

Subsequently, Stephen interviewed Emilia two more times over the course of her first year in college. In her second semester, when two of those three interviews occurred, Emilia took an English course that explored pedagogical theories in reading and tutoring experiences. Stephen also sometimes passed on readings which resonated with Emilia's interests and concerns, including a paper on humanistic engineering (Hynes & Swenson, 2013) and a book on design thinking (T. Brown, 2008). Ideas from the English course and additional readings became pivotal for Emilia and for the content of our interviews, as they gave her additional tools for understanding and critiquing her own experiences with engineering pedagogy.

The data and analysis in this paper are based on our first three interviews, conducted in November 2013, February 2014, and May 2014, respectively. Interviews were between 90 minutes and three hours in length. See Appendix D: Preliminary Interview Protocol for Chapter 5 study for further information.

***Participant and Researcher Positionalities***

Emilia: Emilia is a female undergraduate engineering student. She considers herself an Asian American 1st generation immigrant. Her family has Chinese ethnic roots and most of her extended family lives in Indonesia. Her parents immigrated to the US when she was a child. She grew up out of state from the university she attended, and attended an all-girls Catholic high school. This background produced a significant culture clash when she arrived at the university and encountered engineering classes for the first time. In meeting Stephen the first time, Emilia worried she was just ranting in an unjustified way, and left the interview somewhat worried about that as she reflected on the term over winter break and in her next courses. When Stephen contacted her about a consent form, she mentioned this feeling, and he suggested they meet again. It slowly became clear to Emilia that her feelings had validity in our interviews, and that made her look forward to the chance to connect and process events that had occurred between interviews. We (Emilia and Stephen) met roughly once per semester for each term thereafter, until Stephen recently ended the study and we began discussing the scope of our prior conversations.

Stephen: As a White male concerned with equity and marginalization, Stephen was attracted early on in his graduate program to a research model that would allow him to listen to and build understanding of the issues faced by underrepresented groups. Since Stephen didn’t have prior teaching experience, he felt he needed to do a lot of listening in order to develop intuitions before he could leverage those intuitions towards reforms or interventionist research. Stephen came to the project assignment (interview a student about their thinking or learning) having been placed in a teaching assistant role in the same course but different section to Emilia, which sometimes shocked him in relation to gender and racial dynamics, microaggressions, and subtle oppression. When Emilia met Stephen he was still adjusting and reacting to this new role, and testing out ideas for how to improve things. Stephen thinks he occupied an interesting space between empathy and curiosity which fueled some of the way this research played out. In his prior engineering studies, Stephen had many friends who were women in STEM, and it wasn’t hard for him to talk to them and to see their perspective. In spite of this familiarity, he had never really tried to unpack their experience in any formal way. He thinks this personal interest and empathy helped spark the initial organic interest and motivation for continuing the study.

***Narrative Inquiry Case Study***

The longitudinal interview study led to an emergent resonance with bell hooks' writings. While bell hooks provides a compelling account and a few examples of how and when to theorize, she writes towards a more gestalt understanding than practical step-by-step guidance. As such, we developed our own sets of analysis procedures and looked to hooks' writings for inspiration and consistency.

For additional guidance we drew on a methodology of narrative inquiry, focusing on understanding, unpacking, and interpreting the narrative constructed by the focal participant, with the understanding that "human beings, individually and socially, lead storied lives"(Connelly & Clandinin, 2003) and are always engaged in a personal narrativization or "telling who one is" which is central to identity (Sfard & Prusak, 2005). Though the initial project framing was for a semi-structured one-on-one interview wherein interview responses would have been looked at as a read-out of thoughts (Chi, 1997), the project soon shifted to conceptualize the narrative work of the interview process. In addition, though the initial project scope was for a single interview, the project turned into a longitudinal interview research project in which Emilia processed meaning on a range of topics and experiences that seemed important. An affordance of taking an in-depth narrative inquiry approach is it allows for the exploration of how the narrative develops and changes over time. As Stevens, O'Connor, Garrison, Jocuns, and Amo (2008) note, a student's present experiences can shift how they (re)describe past events. Within narrative inquiry, we can also explore complexity within stories, where multiple explanations for a phenomenon appear, and certain narratives are reinforced, refuted, or left in tension with one another. The affordances of complexity and development allow us to see student theorizing as it unfolds and to consider how naming and resisting oppression weave together in the student's overall life story. In highlighting narrative complexity and development for a single student, we intend to complement large-N qualitative research such as Seymour and Hewitt (2000) which can uncover patterns and trends of persistence but cannot treat individual students' agency and meaning making in great depth.

In interpreting Emilia's statements, we are aware that interview responses arise from an interaction between interviewer and interviewee. Though we do not often represent interviewer prompts and responses in our analysis, we think the work of the interviewer was critical in providing space for the narrative construction and validation. We note that Emilia often drove the direction of conversation, going on and sustaining tangents to the direction of her original answer to a question. Interviewer support was often more subtle responding moves: gestures such as nodding or showing sympathy, short verbal encouragements such as "uh-huh" and "yeah," and shared laughter—probably constituted some of the ways that the interviewee felt validated. These responding moves came quickly and overlapping with Emilia's speech, so they have typically been removed in order to focus on linguistic elements of Emilia's narrative construction.

***Analytical Process***

We focused our analysis on Emilia's narrative construction. While conducting our initial analysis we noted prominent themes and vignettes, emotional salience, active and passive characterizations, and expressions of powerfulness or powerlessness. A procedure of content logging and thematic tagging helped us account for the breadth of the interviews and see how certain themes reappeared and developed over the course of an interview or multiple interviews.

Early in the analytic process, we identified three prominent themes in Emilia's narratives for more focused analysis. These themes represented recurring stories that were not only analytically separable by us as researchers but that showed evidence of being salient and identifiable themes to Emilia herself. In order to identify boundaries of specific narratives, we relied on linguistic markers such as use of hedges and changes in pace of talking to mark a digression, thematic repetition, or emotional response. Our first marker of a theme boundary was structure; Emilia would often shift into a storytelling mode as an explanation/illustration of a central point that she stated at the outset. In addition, her transition to storytelling would often be marked by a hedging word (e.g. "well-- so") signifying a digression or aside, and finally coming back to her main point at the conclusion of the story. This aligns with a common narrative structure noted by Labov (1997, p. 13): abstract (a central point), orientation (elaboration of setting), complicating action, evaluation, resolution, and coda (restatement of central point). Our second marker is repetition, that helped in determining the themes most salient to Emilia; the particular narrative themes we identified came up several times during the interviews. Sometimes Emilia referred to stories already told as a shorthand reference, but often she would retell the entire story in a slightly altered form. At one point she became self-conscious of her repetitions ("You're going to be sick of hearing me talk after this") but proceeded to retell the story for the sake of continuing in her current line of thought. The third marker was indications of emotional salience for Emilia, often exhibited in a raised voice, quicker speech, and higher animation when expressing anger, or in a lowered voice, slowed speech, and lower animation when expressing sadness.

Having identified three central narratives, we grouped the interview content by narrative and interview date, to track how early formulations of the narratives shifted over time, particularly with respect to agency and theorizing. For short, we have named the three narratives which are examined in this paper: Vulnerability and Strength Regarding Math, Women in STEM: Conflicting Feminisms and Self-determination, and The Nature of Engineering: Authoring Disciplinary Narratives. Although we present the narratives separately, we (and evidence suggests, Emilia) see the narratives as intertwined rather than isolated and as central components of the overall narrative that Emilia is communicating. Within each of these three narratives, we identify substructures to her stories: Emilia names culturally-dominant memes—a popular idea present in society, in a family/parental conversation or interaction, in an interaction with a person with institutional power—all of which have the effect of marginalizing Emilia; and embeds them within stories that challenge or provide alternatives to the memes. These acts of naming as well as resisting, to us, represent acts of theorizing as liberatory practice.

Within each of Emilia's stories, the narrative elements which we are mapping to culturally-dominant themes are richer than simply a regurgitation of a popular cultural meme such as "girls are worse than boys at math," and include experiences, emotions, and circumstances unique to Emilia's life. Likewise we do not suggest that the culturally-dominant meme represents the whole of how Emilia experiences it in her interactions with individuals and institutions. Instead, we have tried to capture the rich tapestry of

Emilia's experiences as best as we can given the limitations of length and of the paper medium. We also do not see a wide divide in how Emilia experiences the culturally-dominant narrative in her interactions with others and the counter-explanations she constructs to find her own agency; these, we feel, are strongly intertwined for Emilia, embodying both vulnerability and strength, threats and opportunities as she experiences them. The reason we divide our story-telling of Emilia in this manner is for ease of presenting the argument and analysis.

### ***Assessing Claims***

This paper intends to make two central claims: 1) that Emilia's narrative work constitutes bell hooks' theorizing, and 2) that the process of theorizing has value for the individual experiencing oppression.  Towards the claim that Emilia is theorizing, we present examples from interviews that give a holistic sense of theorizing.  Rather than claiming that we can identify theorizing and coding and counting it throughout our interviews, we think it will be more useful and compelling if we present a lot of potential examples and ask the reader to determine the plausibility of our interpretation.

Towards the claim about theorizing being valuable, we note that other researchers might choose to measure the value of an intervention in other dimensions: persistence in a program, success in a class, or increase in self-efficacy.  Not only would our research design allow no such analysis, our intuitions suggest that these may not represent the same sort of value that theorizing can bring.  As such, we sought a way to address student comfort, understanding, and agency within the scope of a small case study.

After a member check with Emilia revealed resonances with her views and grew into lengthy conversations, we included Emilia as a co-author of the implications section to reflect on impact to her of these conversations. We have worked with Emilia to revoice some interpretations for this paper presentation but have checked that they still represent her thoughts and interpretations. The participant's member check (how these conversations and thoughts have played out in her own life) become another significant data point in the analysis of agency and the importance of theorizing.

**Narrative Analysis**

In each of the three subsections below, corresponding to the three identified narratives, we interpret and discuss the data as we are presenting it.

***Vulnerability and Strength Regarding Math***

A prominent theme in Emilia's interviews is her vulnerability regarding math, sometimes coupled with a low opinion of her "technical" (coding, circuit-building, etc.) abilities more generally, and sometimes contrasted with higher science-specific self-efficacy. Some form of the "I suck at math" theme came up in all 3 interviews, usually with very similar wording, usually to help explain one of Emilia's actions. One form of this theme comes with a 2nd person wording, as a familial narrative, as illustrated by this quote from our 1st interview:

> And then when my dad asked me like why would you do that [apply to the University Engineering program] you suck at math like why would you apply. Why would you apply to-- Because I was out of state for University and there was a little bit of concern that I wouldn't get in just because of SAT scores and, my SAT scores, they weren't bad it's just I got a 670 but it wasn't like 700 range. And so my dad was like your math, your math grade wasn't very good, you didn't take calculus…

1st interview

Here we see Emilia narrate how her vulnerability with respect to math is being constructed in dialog with her father around career choices. Thus the theme emerges as something salient to Emilia but not simply an internal property: Emilia is naming how actors in her life play a role in shaping her relation to math and to career choices. At other moments Emilia expresses this same theme as an internalized first person narrative, “I have to admit that sometimes when I'm like I can't believe I suck at math, like why?” (1st interview), “I guess career-wise maybe so I'm not very strong at math” (2nd interview), and the following passage from the 3rd interview (labeled “E” for Emilia and “S” for Stephen):

> E: I realized, like, one: I sucked at (ooh… gosh...). Um, you're probably gonna be sick of hearing me talk after this!...
>
> S: No no...
>
> E: 1- I suck at math.
>
> S: Ok...
>
> E: I don't suck, I was, was pretty weak at math. I didn't have natural. My sister has a lot more aptitude for learning math.
>
> 3rd interview

The repetition of this theme, in both 1st and 2nd person speech, suggests the entanglement of individual self-perceptions and familial relations for Emilia’s STEM experiences. Thus the narrative extends beyond a narrow academic self and her relationship to math reflexively structures (in part) her relationship with family. The somewhat agitated affect and precision of the 1st and 3rd interview quotes underline the emotional salience of this theme for Emilia, and the repetition across interviews shows its stickiness and influence in Emilia's thinking. The theme, in reference to career choices and participation in engineering, is not only connected to her past experiences but also to her present and potential futures. The narrative Emilia is constructing here echoes a broader popular cultural meme about engineering as being heavily mathematical and engineers as needing to be good at math (National Academies Press, 2008). Its alignment with this cultural meme may give "I suck at math" part of its emotional weight, and make it dangerous to admit.

Our analysis highlights the action of expressing vulnerability towards math, rather than seeing these quotations as a readout of low self-efficacy as an internal state of Emilia. The action of expressing vulnerability opens up the possibility for acknowledging and standing apart from emotionally charged thoughts and for constructing logical and narrative critiques. Emilia's parents are influencing her to choose STEM fields: Emilia feels she must choose STEM as the only "academically credible" option regardless of what is "fun" for her (Interview 3). Thus, in this narrative we see both marginalization (in Emilia being told she isn't suited for engineering) and a restriction of Emilia's agency (in Emilia feeling pressured to major in a STEM field other than engineering). However, we still see Emilia as exercising her agency in the narrative she constructs. In the context of her family's views and her own vulnerability about her mathematical and technical abilities, Emilia's application to engineering and her framing of it as going against her family's wishes and her own fears can be seen as an element of resistance to an otherwise oppressive position of highly restricted agency. Here our 1$^{st}$

interview picks up after the quote from above where her dad questions her application to the engineering major:

> …and then I got in as a chemE major and I still sometimes wonder well I guess they must have seen something, because I know my essays were really good. My past wasn't that good but somehow I was like ok I really really want to do this and I really liked taking physics in high school. So um...
>
> 1st interview

Having named her vulnerability (voiced through her father's words in this case), Emilia questions it by invoking her own cultural capital (resources valued by STEM culture, in this case her strong writing skills) and her reasons for persisting in STEM. As Emilia transitions from talking about her father to reflecting on her own resources, her affect shifts to being fairly cautious and more subdued than usual; perhaps she is tentative or slightly embarrassed to be building a positive story for herself and resisting her parents' story. Emilia's narrative work disrupts her parents' more limiting story for her presence and persistence in the engineering major. Emilia's agency in this case involves both real world action, applying to the engineering major against her father's advice, and resisting the implications of an embodied cultural meme that success in engineering is impossible without being good at math.

Further, Emilia theorizes about the cultural and circumstantial underpinnings of her relationship with math, problematizing her math performance as an inherent trait that she or others can apply to her. Continuing in the 1st interview, Emilia tells a story of how her high school preparation and experience contributed to her being inadequately prepared in math. This included early instructional deficiencies ("going back to middle school I had really weak algebra training"), structural disadvantages (at her private all-girls' school in her home state, even good students rarely took calculus), and cultural/familial particularities (asking to take a summer math class but always needing to visit family in Indonesia instead). Although her math self-efficacy intersects with her worries that the common belief about boys being innately better than girls at math may come true, she resists this form of stereotype threat with a logical counter-argument:

> I have to admit that sometimes when I'm like I can't believe I suck at math, like why. And I know it's not because I'm a girl it's because I never had that proper preparation starting from my freshman year of algebra to not taking calculus.
> 1st interview

For Emilia, a cultural explanation of gender differences appears more empowering than a biological gendered explanation; if sucking at math is biological then there is nothing she can do, but if it is based on prior schooling she can work hard to fix it[22]. Thus, in her complex "I suck at math" narrative we see Emilia threading elements of internalized low self-efficacy and gendered biological differences with sub-storylines about resistance through action and theorizing cultural and situational explanations. There remain points of insecurity for Emilia with respect to math, as we might expect. But the localized logical refutation shows what may be an internal conversation Emilia has with herself, which has been rehearsed and reinforced over time due to its productive empowerment.

A final way Emilia resists her math vulnerability is through active work to the counter the cultural meme that math is crucial for engineering work. Emilia reframes the nature of engineering by developing a sense of a bigger "real world" out there that rarely

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[22] Her explanation of her deficiencies resonates with scholarship that a growth view of intelligence is more productive than a fixed view (Dweck, 2008).

gets represented in her STEM classes, a sense that engineering jobs rely more on soft skills and cultural understandings and less on math. While naming and reframing a narrative around math in engineering is a potentially liberatory act, Emilia has also actively sought evidence in the "real world" to confirm her theorizing. She attended networking events to make contact with real world engineers. At these events, she asked several professional engineer alumni "What was the most useful class you ever took?" (a common answer was Engineering Leadership), and the importance of Calculus and math calculation skills on the job. She particularly wanted to clarify the importance of Calculus, after she received a disappointing "C" in her first semester. One of the engineer's answers in particular reinforces her sense that real-world engineering has a place, and a prominent place, for Emilia:

> And he's like, let me tell you-- on a really bad day I have to square something. Like I have to like make the cosine of Pi/3. And I was like oh really? He's like yeah… like… I don't, like, and he was saying like, you can always be an analyst engineer, like punch numbers, crunch them. But they keep you in the basement. If you actually want to be someone who does things that they put on brochures. You have to be able to know all of this [gestures towards humanities side on concept map she made]. And I could tell all those people I talked to, these successful alumni who clearly were in positions of great like-- they they had this [humanities side]. They had you know all of this stuff.
>
> 3rd interview

Here we see a powerful mix of resistance through theorizing and direct action in support of Emilia's taking agency. Expressing vulnerability and fear that she might struggle with math forever and eventually succumb to the fact that she cannot survive in engineering helped open it up to reframing, and for others to offer resources towards that reframing. Her narrative around math is now buoyed by the idea that she might struggle with math for now but one day she'll be the one on the brochures. Emilia's reframing work underlines how theorizing is not merely a pep talk or individual coping mechanism, but constitutes active work of the participant and the interactive contributions of many others.[23]

Thus, in what can be seen as one continuing process of theorizing, Emilia is naming a core source of vulnerability in her relationship to math, describing forms of active resistance, developing alternative explanations which alleviate a biologically limiting view, and seeking out and drawing on alternative perspectives on the relationship of math to an engineering career.

**Women in STEM: Conflicting Feminisms and Self-determination**

Another prominent and marginalizing theme for Emilia connects to a cultural meme of women as a minority in STEM fields: Emilia tells a story of herself as "fighting the statistics," fighting sometimes intangible forces, in her attempts to persist in engineering. There is a feedback relationship between cultural memes, women's self-perception, women's outcomes in STEM, and research / media reporting. We can see Emilia's construction of her own story in the context of this milieu.

The clearest marker of this Women in STEM cultural meme is in Emilia's repeated mention of representation and retention "statistics." For example, while

[23] Emilia's networking and narrative construction could also be viewed as navigational cultural capital (Stevens et al., 2008; Yosso, 2005).

explaining why women choose lower-prestige roles on their design teams in the Introduction to Engineering Design class, she says:

> I definitely know that in the back of our heads that none of us want to let ourselves down or each other down. Like, we just don't. And I'm not-- And I don't know why the *statistics* like work out that way.
>
> 1st interview, (emphasis ours)

As she said this, Emilia's expressions, register, and volume, indicated lowered affect, suggesting sadness or resignation. The "I don't know" also seems to represent a moment of confusion, of not yet having come up with a satisfactory explanation for why women are a minority in STEM. Although retention statistics clearly contribute to this meme, Emilia also folds into her narrative experiences with other women in STEM, from her all-girls' school and a seminar concerning women in engineering which she attends:

> Um, again maybe because again going to an all-girls school for 4 years of my life we were always told just do what you want and you shouldn't like blah blah blah bullshit, everyone will tell you what to do, blah blah, because you're a girl, blah blah, and you can buck the *statistics* blah blah blah.
>
> 1st interview, (emphasis ours)

In Emilia's narrative, the dominant statistical storyline from these popular and institutional sources is coupled tightly with certain actions required of girls in order to succeed:

> So to me the fact that like um I don't know I guess sometimes throughout-- yeah I went to an all-girl's school so I've been hearing this for like 4 years of my life.

> ‘You guys should definitely be more technical, be-- improve your math skills and blah blah blah’
>
> 1st interview
>
> and in our seminar they'd be like ‘Oh girls don't let them be like only do the organizational stuff’
>
> 1st interview, (with respect to introductory design class project team roles)

In the above quotes, “blah blah” is likely a marker of having heard the same well-known narrative many times and having grown tired and/or reacted negatively to it in the first place. We note the following markers of a lack of agency in Emilia’s rephrasing of the memes and exhortations given to her: “oh girls” (likely patronizing), “don’t let them” (imperatives on her actions rather than leaving the choice of action up to her), “everyone will tell you what to do” (framing impending gendered actions with a removal of agency), and “we were always told” (blanket advice regardless of circumstance). There is an underlying message to these narratives that because Emilia is a woman she should feel compelled to “buck statistics” and resist being relegated to “girl” roles. Through this segment, the choice of words suggests that, tacitly, Emilia may also be conveying a sense of being talked at, rather than with. By naming these memes and identifying them as tiresome and limiting, Emilia creates a separation between herself and the meanings and imperatives they bestow upon her identity in STEM.

Emilia resists and works to deconstruct this dominant cultural and institutionally-embedded meme for Women in STEM via weaving together multiple counter-explanations, arguments, and resistances. At one point, she has a strong emotional reaction to retention statistics and connects them to the “suck at math” narrative:

> I said it and I'll say it again, like I don't want to let the system down. I have to admit that sometimes when I'm like I can't believe I suck at math, like why. And I know it's not because I'm a girl it's because I never had that proper preparation starting from my freshman year of algebra to not taking calculus. It just so happens that I'm a girl! *And I'm like f*** this*—why does it just happen to be that way?
>
> Interview 1, (emphasis hers/ours)

In this narrative reframing—that she is a girl who happens to be behind in math as opposed to someone who is bad at math because she's a girl— Emilia builds into a heightened anger, showing resistance through emotion. As for the advice of the seminar leader regarding team roles, she finds it "ridiculous" and "completely unfair that the girls are expected to be a guy in engineering," with a sense of exasperation at the lack of acknowledgement of the hypocritically stacked playing field. She continues this deconstruction of the idea of stereotypically feminine team roles, pointing out the hypocrisy of blaming girls for doing what they are good at:

> If because you are a girl and just happen to be really good at organizing or planning or doing numbers or making nice spreadsheets, that should *not* be an indication that you are failing.
>
> 1st interview, (emphasis hers)

> If she's good at paperwork, *paperwork*! I mean again, no one wants to do it, yet why do people go to business school to become accountants? It's because it's important.
>
> 1st interview, (emphasis hers)

In her broader narrative, Emilia builds toward an implied message: Don't ask girls to change to be more valued by the Engineering system; ask the Engineering system to change to (re)value all students in more accurate and gender neutral ways. Rather than viewing team roles as inherently restrictive and gender enforcing, she develops an alternative framing for her stereotypically feminine strengths, skills, and weaknesses: "I am a girl and I am different from a guy in engineering and that is good. I think I help my team by being different." Over the first interview we saw many examples of Emilia describing her big picture insight, visualization, strategic thinking, oral and written communication, management, and delegation, skills that she feels are not high-status. For example "a lot of the boys in my group are very technical but whether or not they feel comfortable taking on my [management] role…" (i.e., she knows a lot of the boys could not comfortably take on her role, one teammate has told her this explicitly). Here again we see Emilia acquiring agency by raising questions and sometimes taking action to resist both the marginalizing cultural meme about "real" engineering as centered around stereotypically male roles and the standard coping strategies suggested by institutional programs ("don't get pushed out of those real engineering roles!"): She recasts her "soft-skills" role on her design team as important, hard to fill, and something she actively chose rather than is getting relegated to.

As another component of her narrative for Women in STEM, Emilia brings up a piece of advice from a seminar in the 3rd interview:

> There would be some effect on like my frivolity in terms of like my ability to do it like for example like for our like seminar thing um, you know she'd be like—you can definitely go with pants, like if it's wear a dress make sure it's not like too

> bright and too colorful for interview you know you want to look like, you know.
>
> 3rd interview

This advice from the seminar and outside sources may correspond to certain "coping strategies" to make the women's lives easier in male-dominated STEM departments (Ko et al., 2014). Emilia resists the seminar leader's fashion advice by examining the assumption that feminine norms of dress should adapt to masculine norms (continuing on from prior quote):

> And all of the other girls in my class were like, but if it's cute it's cute! Like, you know, if it's still professional it's professional, like if it's like you know a plain dress but it's like bright orange. I think that's acceptable you know and most women now would opt for like the pantsuit and blazer just so they can get past like that stereotype or conception so it's not just like aesthetics I think there are other things that are undeniably female that are completely ok and fine, that sometimes misses the mark and again like… I think my two students like A--- and J--- I think they might be too female for some people's definitions to ever consider STEM. Cause they're too loud and too passionate and um… they care about things that are considered frivolous and to the majority of people in this field they're you know logical, practical, pragmatic, traditional.
>
> 3rd interview

To many, the seminar leader's suggestions might seem well-intentioned and at most mildly restrictive. Their intention was surely to pass on relevant tips and tricks, rather than to reify gender norms. And yet, to Emilia, this advice arouses a passionate response, indicating the extent to which the advice feels excessively restrictive, denying her the agency to interpret and decide her best course of action. Although such advice is clearly well-intentioned and has undoubtedly proven helpful to many women, it seems assimilationist and oppressive to Emilia when she is engaged in liberatory theorizing about how engineering culture can and should adjust to gender diversity.

We note here that Emilia casts her stereotypically feminine strengths and preferences as an assertion of her femininity (e.g., “I am a girl and I am different from a guy in engineering and...I help my team by being different”) while also resisting the view that her stereotypically feminine weaknesses such as math skills are connected to her gender (e.g., “I know it's not because I'm a girl it's because I never had that proper preparation...It just so happens that I'm a girl!”). In this way, Emilia’s “suck at math” and Women in STEM narratives both draw on and resist gender essentialism, the idea that men and women are essentially and inherently different. In light of this selective uptake of gender essentialism, it is not surprising that the culture of engineering and her institutional culture feels oppressive to Emilia, in failing to value her stereotypically feminine “soft skills” and performance, whereas she does *not* see as oppressive the broader cultural norms about how women should dress (“if it’s cute, it’s cute”) and perform (emphasizing “soft skills”).

There remains an interesting disconnect between the seminar leader’s intentions to empower and offer coping strategies, and how much of the advice comes across to Emilia as itself oppressive. Inden’s (1990) definition of agency may be helpful in understanding this disconnect: the seminar leader in some moments treats Emilia like a helpless *patient* and like an *instrument* of a feminist initiative, rather than empowering her to come to her own interpretation and appropriate response as an *agent*, or to take up the feminist cause via her own logic. There are other possibilities at play here. Perhaps the seminar leaders are enacting a “2nd generation feminism” formed under shared experiences of women surviving in the workplace in the 80s and 90s, whereas Emilia’s millennial peers do not have an appreciation of where these strategies and interpretations came from, and feel coerced (Vaccaro, 2009). Perhaps teacher-student power relations are at work, and classroom norms prevented Emilia and her friends from raising these objections during the seminar. Or perhaps they only come to these conclusions together after class in the dorm. Whatever the circumstances of the disconnect, we see an increase in personal agency for Emilia in reframing her teamwork and fashion choices as a form of resistance; Emilia decides she has good judgment and can make up her own mind rather than just follow the seminar leader’s rules. In another interesting intersection between rethinking things and taking real-world action, Emilia dresses subversively on several noted occasions (e.g. people say she dresses “like an art major”) and (half-jokingly) suggests that she stays in engineering partly to “help people dress better along the way” (3rd interview).

In summary, within the Women in STEM narrative, Emilia names, resists, and reinterprets several cultural memes and particular experiences from society at large, her engineering department, the seminar, and her all-girls high school. The theorized narrative she forms interweaving these elements in part subverts dominant norms for skills, demeanor, and dress, and in this she finds a liberatory practice which subverts prescribed norms in personally authentic ways.

***The Nature of Engineering: Authoring Disciplinary Narratives***

As a student in her first year of college, Emilia is in transition between the high school and university worlds. At such transitions, students are likely to seek to understand the new cultural context and their senses of self. For engineering students, especially those from marginalized groups, there may be an especially urgent need to define engineering and themselves as engineers. Seymour and Hewit (2000) and Margolis and Fisher (2003) have noted this sort of additional identity work required of marginalized non-dominant groups entering undergraduate STEM and computer science majors respectively. During this intellectually and emotionally charged transition from high school to college, messages sent by course content, textbooks, professors, and peers about what constitutes engineering might be particularly important. For this reason, we were not surprised that Emilia was strongly attuned to the messages she was receiving about what counts as engineering, and engineers. In short, the dominant institutional message Emilia perceives about engineering is that it is monolithic, heavily technical, and uncreative: a narrative which coincides with a broader cultural meme (National Academies Press, 2008). She expresses frustration with several elements of her first semester: the pace of lecture, lack of real-world application, and lack of meaning. For instance, when asked what she learned about design from Introduction to Engineering Design, she replies:

> E: Nothing.
>
> S: Ok
>
> E: Um, I learned more designing things probably playing with Legos and play dough when I was a kid.
>
> …

> It's that you're following the textbook steps on how to build it, But in fact what you're really, I think the whole what I learned was trial and error and planning.
>
> S: Mmhmm
>
> E: Not design. Design to me involves innovation and concept and there's supposed to be a message across like you're supposed to design something for purpose.
>
> (1st Interview)

Implicitly, the class (a group project to design a robotic hovercraft) has attempted to teach her its conception of design, and she is already resisting the class's definition, calling what the class does "trial and error and planning" rather than design—a fairly subversive act considering her lack of formal training in engineering and design. And yet, she does have an intuition for what the word means to her, and refuses to relinquish the meaning to the course structure. Likewise when speaking more broadly about engineering:

> S: What is it like having that be your first semester in engineering, make you think about engineering. Like has it--
>
> E: Typical.
>
> S: What do you mean?
>
> E: Like what everybody says it is. Just power through and not fail and get your degree. Um, it wasn't like a surprise to me that it was kind of like that. I was excited for the class. But what I saw that really what I was spending my time on was just trial and error and making things work. If we had time to like pull apart the fan and be like oh look there's the gear that actually makes the Q run. Or like

there's the point that like sends the signal, um. I don't. It doesn't give me any negative connotation on engineering whatsoever.

S: You just don't think that this represents

E: Engineering

S: (Laughs)

E: No. No.

S: You just think

E: To me it's just kind of one of those classes like everyone was saying you just have to take it. And we all hate it…

(1st Interview)

The lack of inspiring engineering content fit into a common narrative she had received—generated and propagated within the engineering *student* culture— that a "typical" engineering major's path means "power through and not fail and get your degree." She resists allowing the class to create (or allowing the interviewer to infer?) a negative connotation with engineering in general, because she rejects her experience in the class as the only definition of engineering. This is the picture we get in the first interview. It is not a fully fleshed-out polemic on the nature of engineering, but it hints at a willingness to resist having "engineering" defined by others in ways she does not like and that marginalize her.

At other points in the first interview, however, emphasis on technical content in her courses, which contrasts with her own skills in communication, teamwork, and strategic planning, causes her to question her position in Engineering:

> I do doubt like am I really fit for engineering? Like what am I supposed to do with like all this art and science, like all this English and science stuff and English literature stuff? Like so far I can definitely manage the team, I know what's going on, I can talk to the instructor, I communicate really well. I can build the hovercraft if you tell me what to do. But if you ask me to design the circuit schematic I wouldn't be able to…
>
> (1st Interview)

The dominant institutional (and broader cultural) meme that engineering centers around technical skills, is marginalizing and disconcerting to Emilia. If her experiences in Introduction to Engineering Design represented what engineering is really like, Emilia's position and future in engineering would come into question.

As mentioned previously, in the spring term, Emilia enrolls in an English class with a focus on pedagogical theory and a service learning component where she tutors/mentors students at a local high school. Possibly by instructor design, Emilia is mentoring racial minority female students who have interests in STEM careers, causing Emilia to reflect heavily on her own development and experiences. The second interview with Emilia is centered around concepts and experiences in her English class. Emilia appeared to be feeling excited and empowered by the new educational theories and eager to map them onto her engineering experiences. This may be why she requested a second interview; she seems to have wanted to connect these ideas to the prior conversation and to make sense of a lot of synergistic ideas around the same topics.

Among other new concepts and theories, Emilia uses the central concept of *plurality* to help map out and sharpen her new proposed critique of engineering (and

STEM). Plurality means many interconnected things for Emilia, including diversity of perspectives and backgrounds, interdisciplinary work, and taking into account multiple dimensions of design problems or engineering work. Considering engineering curriculum, Emilia (as she did with “demoting” Calculus) draws on role models and contacts from the “real world” of engineering/business to support her arguments, this time for plurality as important in engineering. From Emilia’s perspective: in the real world, everything is interdisciplinary and intertwined, and cultural nuances are important; while in the engineering classroom all of that is excluded. She sees her role models (Bill Gates, Steve Jobs, Jack Welch) as the exception, not as having learned plurality from their engineering courses/degrees:

> But that's again this is very few people who out of their own volition will encourage that and therefore. If society doesn't encourage that the departments won't ever encourage that. Because academia is a part of society. And therefore the professors, the professors I think have plurality themselves but they see that: Oh these kids are going to go into technical jobs they're going to work for Boeing or design some cool stuff. They're never going to have to worry about what the product actually does, they're never going to have to worry about ok like who's actually making the metal. Where is it coming from?
>
> …
>
> But the fact that like the cultural demand or the societal demand on engineering school is producing these really genius people who are just technically brilliant. Doesn't ever-- they don't ever need to change or adapt the department.
>
> (2nd Interview)

Emilia connects academic engineering culture to broader culture. By her account, professors do understand the broader social and interdisciplinary context in which engineering happens, but do not pass this understanding along to their students because the culturally expected role of engineers is not to worry about complex and interdisciplinary elements of their designs. Emilia extends this argument in the 3rd interview, viewing her university as responding to social forces for the preparation of "boring process engineers," whereas elite universities are creating CEOs, game-changers. By continuing to develop critical cultural deconstructions of the university's engineering department, she seems to be reducing its power over her.

Her theorizing about the staunchly non-plural academic engineering culture in which she is immersed does not seem to constrict or depress Emilia; rather she uses the construct of plurality to help give extra meaning and value to her own background and skills. So, for her, the theorizing is liberatory, not marginalizing. For example, Emilia talks herself through her frustrations with her technical preparation by reversing the traditional narrative of the importance of technical versus "pluralistic" content:

> And then now I'm in the engineering school and I'm like why, and I could the thing is when I thought about this more I was like-- maybe I'm just being really really stupid and I'm just considering plurality is like this really bad idea and I'm just being super biased because I learned in high school. And I'm like I should have come in with more technical skills-- cause the first I think half like the last half of my semester when I was on winter break I was really angry that I just didn't come in with the technical preparation that everyone else did. I was so angry I was really mad I was like oh man and you know I just need to put I just--

> who cares about all this other stuff it's all pointless I can't believe I cared about English and whatever it was.
>
> …
>
> So, when I thought about it more and I was like I could always improve my technical skills I could always get better grades in my technical classes because I have to study.  On the other hand you can't always develop your sense of cultural plurality or your sense of your transfer studies or your ability to model and connect relationship between your technical skills and your application.

In this noteworthy narrative reframing, Emilia's lack of technical skills is positioned as fixable or relatively easy to acquire later, thus giving her agency and strengthening her position for persisting in Engineering.

In general, when discussing the nature of engineering, Emilia's narrative shifts from the first interview to the second.  In interview 1, Emilia is resistant and frustrated with the way engineering is being presented, but her critiques focus mostly on specific classroom practices and her struggles cause her to question her engineering trajectory.  In the second interview she moves to a much more actively critical position, where she connects many of her prior complaints to newfound pedagogical theories and impressions of the real-world value of plurality in all its senses.  This is a good example of bell hooks' liberatory theorizing at work, empowering members of marginalized groups in the process of making meaning of their oppression.  We see agency both in how she theorizes about her educational environment and in the options opened up to her by her revised vision of the nature of engineering and her place within it.

**Implications and Conclusions**

Our narrative inquiry into Emilia's theorizing follows its development along three prominent themes, and analyzes them over time in order to track the parallel development of critique and personal agency. Within each of the main themes of Vulnerability and Strength Regarding Math, Women in STEM: Conflicting Feminisms and Self-determination, and The Nature of Engineering: Authoring Disciplinary Narratives, we see Emilia construct a narrative weaving together named culturally dominant memes, which tend to marginalize her within the engineering field, and narrative resistance which can combine logic, action, affect, and the power to retell the story in a way which empowers and liberates.

We note the following implications and contributions of our research.

***For Participant: Post Hoc Participant Commentary***

Following hooks' notion of theorizing, we want to recognize the power of students' sensemaking of their own situations, of marginalization and of agency and liberation as "democratic" theorizing. When students question the taken for granted axioms of the system embedded in sexism, patriarchy, capitalism, and technocracy we see a form of oral theorizing that opens up the possibility of imagining futures not held hostage to the past. The first and primary implications of this work then are for the participant themselves.

As part of an in depth member check, the conference paper version and argument was presented and discussed with Emilia, including opportunities to correct and edit interpretations and findings. Finding that the paper resonated, Stephen asked Emilia if she would participate in the writing by discussing the role of these sorts of conversations in her educational experiences and persistence. This participant commentary was assembled from several smaller written reflections. It was co-edited by Stephen and Emilia to accurately reflect Emilia's perspective, presented here in Emilia's voice:

> When Stephen brought up the idea of writing a response on the impact of these sorts of "theorizing" activities for my life in engineering, it brought up a lot of existential "engineering identity" questions for me. His paper sees my survival, persistence, and thriving in engineering as a success story, but in the day to day of my life it can be hard to see that and to *know* it. It is hard to feel like a success story when I still question whether my ability to be a *better* engineering student has improved, i.e. my technical abilities. I still consider myself a fairly average student, A's, B's, and C's. I'm not sure if I qualify my undergraduate engineering career as a success story of persistence, when it feels like sometimes I have not persisted enough.
>
> My biggest battle with any experiences of oppression or marginalization is not believing in the validity of my own experiences. I was in constant doubt about my feelings and the validity of my ranting. I had to carefully think about who I chose to engage with about them, and how. After completing three and a half years of engineering, it seems I've had many of these conversations in a variety of places: with a supportive advisor (head of the Women-in-Engineering program), Stephen, an upperclassmen mentor, my roommates. In each of these cases, the biggest value was the intrinsic sense of validation I received from someone else "qualified" or more qualified than me to have an opinion on the same fishbowl in which I am swimming. It was the nodding of their heads, their agreement of shared sentiments, which encouraged me to persist and theorize.

Drawing on this support, I believe that I have been able to persist and better navigate this "engineering" world with more confidence and purpose due to having the space and time to process my reactions and growth. Specifically, I believe I am able to carve out a space within my engineering world, which allowed me to persist in the classroom. I've realized many of my activities at roles at the engineering school involve outreach and recruitment. I was a program assistant in the engineering school for a college preparatory program as an SAT tutor and general mentor for geographically local underrepresented students. Perhaps, I am redeeming my not-so-easy path of persistence by sharing my story, all the bits and pieces I've put together, for others to now succeed at by looking at my "big" picture.  Just recently, I felt a major motivation to help my sister study for her first college Calculus class, perhaps trying to prevent for her the same feelings of inadequacy I felt during my first semester of college math.  I also recently tried to confront TAs about some damaging classroom dynamics where quieter students get overlooked by more aggressive and confident students who always ask questions first.

I think all of these examples, illustrate how I actually choose to "succeed" in engineering. I found situations and opportunities for engagements that I chose and defined.  Places where I could actually affect a situation or someone. I found "reinforcement" for my weird observations about curricula, professors, and higher education systems. Strangely, most of these experiences happened outside the classroom.  I'm grateful that I have managed to piece together outlets from outside the classroom to sustain me inside the classroom. From various

> internships, to my English class, to conversations with professionals, to the Women-in-Engineering department, to reading non-engineering literature, I have been able to become more confident in my engineering work.

From our shared perspective then, Emilia's theorizing work was consequential for her persistence and thriving in the engineering department. It potentially helped her cope with difficult experiences and led her to take on leadership and activist roles. Emilia has trouble putting her finger on what exactly this process afforded for her. This may be in part because Emilia is such a "natural theorizer" (hooks, 1992) that this orientation to the world is inseparable from her identity and trajectory; and in part because persistence and identity are always in process and uncertain. Nevertheless, we submit that Emilia (aided by Stephen) engaged in a dialogue consistent with hooks' theorizing and that it had a liberatory value in the participants' life. The "reinforcement" Emilia felt may have been simply in having agency and resources to tell her own story.

***For Scholarship on Marginalization in STEM: Theorizing as a Form of Agency***

Agency of marginalized groups within STEM departments has primarily been conceptualized as coping mechanisms and navigational strategies, whereas the concept of agency through critical theorizing and the shaping of one's own narrative is relatively novel. In this study, Emilia rejects the coping strategies presented to her with the aim of helping her persist as a woman in engineering. She perceives these strategies as pushing her to find agency by being more like a male engineer rather than valuing her own strengths. Instead she argues in support of her natural skills of organization, management, and writing as being central to engineering practice and wants them to be recognized as such. Emilia finds agency in creating a narrative that challenges perspectives that tend to maintain the status quo of technical knowledge and male-ness in engineering culture. Her post hoc commentary reveals she marshals these counter-narratives to take specific actions of resistance in response to marginalizing experiences. Emilia's post-hoc commentary tentatively suggests Emilia's "theorizing" approach was fostered by other prominent mentors and shared by some of her closest friends. In a further reflection, she also notes at least two other distinct approaches amongst her peers:

> Recently I've noticed how different students seemed to approach this same struggle. My female friends in engineering tend to fall into one of three categories: 1) those who buy into, power through, and succeed within the system as defined, i.e., by the masculine-dominated institution, 2) those who stick in the system by socializing and finding identity outside of engineering, and 3) students, like her, who stay in the system while wrestling with and "theorizing" about the experiences (as Stephen says I did in this paper). I sometimes try to shift students from one of these groups into engaging with me in effectively "theorizing." I find that although all of my friends in the three categories steadfastly supported me, they all usually chose to default to inflicting the blame of struggling within engineering on their personal failure rather than theorizing about the larger educational, social, and cultural systems they were immersed it. Although I see the value in their strategies I found that it was personally harder for me connect to those who rejected the system as part of their identity (approach #2) or chose to succeed in the system as defined (approach #1); often as a result of theorizing, I felt empowered to try and change the system and test her ideas/beliefs with others.

> There are resources (mentors, professors, advisors, other students) at the engineering school and university overall who are able to support students who persist through all three strategies if one looks for them. Unfortunately, I think students usually do not have the processing space to recognize and value their version of persistence, perhaps because of a lack of connection with the right mentor, or simply a lack of time.

Interestingly, these approaches seem to connect to some of the current literature on underrepresented groups in STEM: the first group, which buys into the system and powers through, has resonances with those who note the power of personal drive (Ong et al., 2011, pp. 188–189). The second group, which pursues activities and identities outside of STEM, sounds like students employing an agentic mechanism of "getting out to stay in STEM" (Ko et al., 2014). If so, Emilia may represent a third sort of student, one who stays in a hybrid "third space" (Barton & Tan, 2009), in between buying in and getting out.

***For Qualitative STEM Education Researchers: Liberatory Potential of Narrative***

Our basic research methods were fairly consistent with standard qualitative research, in fact, the study initially developed out of graduate education class designed to give students a first experience of conducting qualitative interviews. In fairly standard procedure, a semi-structured interview protocol was developed, and then abandoned as the conversation scope expanded over the course of a longitudinal study, which at times was requested and driven by Emilia. As the study progressed, the interviewer only attempted to be responsive to the participant in what she was sharing, looking for ways to reflect back an understood meaning or push for a further connection.

As conventional as the research methods were, the study had an emotional and practical impact on the student participant. We come back again to the scholars who have noted the political and voice dimensions of research (Hutchinson-Green et al., 2008; Pawley & Slaton, 2015; Vossoughi & Escudé, 2016). We think many of the qualitative researchers in STEM education are engaged in work which has power for student participants, yet few write about it. As an example from two of the co-authors, we reflect back on a similar research experience from a few years ago. Danielak, Gupta, and Elby (2010) longitudinally followed "Michael" over several years, documenting how his identity as a sense-maker about natural phenomena (electric circuits, radiation, etc.) lived in tension with what he took to be the intellectual norms of his engineering major—largely rote problem-solving rather than deep understanding. The paper, trying to inform the improvement of undergraduate engineering programs, discussed how Michael felt isolated, unable to talk about these identity issues with most of his fellow students. However, the paper did not even mention Michael's comment that his interviews with Danielak were like "therapy," a rare space in which he could vent his frustration and discuss how he thought systemic factors rather than ill-intentioned individuals sustained the intellectual climate with which he dis-identified. In other words, the research itself helped create opportunities for the participant to engage in theorizing, as was the case with Emilia; but the researchers did not write about this aspect of the research.

***For Diversity Support Work: Bearing Witness to Student's Pain***

Finally, we note a tentative practical implication. Narrative theorizing appears to be a source of agency for Emilia and a potential resource for her persistence in engineering. On the basis of this exploratory study, we propose that faculty and student advisors, who have a vested interest in supporting students through marginalization, should pay attention to and support processes of theorizing by students.

At this point we can only conjecture what sort of instruction or support this would look like, and ask questions that might be answered by further study. Emilia's "theorizing" emerged in interaction with her classmates, from the interview context, and from mentors in positions within the engineering institution. These were smaller, more focused settings than the official seminars and programming designed to support her. Sometimes the narratives presented in the official seminars struck Emilia as marginalizing themselves, although they were probably intended to advise and empower her. For Emilia, "theorizing" was a constant process, for other students the process of simultaneously deconstructing the very curriculum they are being taught might be disconcerting. There is research to suggest this tension in revealing and processing marginalization can be pushed too far and too early (Han, Sax, & Kim, 2007), but also literature that suggests at some point an acknowledgement of marginalization becomes its own form of resource (Erickson, 2012). The complications of differentiated support multiply when the individual nuanced needs are embodied by dozens of individual students with disparate experiences.

While we take these potential complications seriously, we also note the potential power in investigating and understanding them. We think that many practitioners in diversity support are striving (hooks, 1994) to offer students "healing words, healing strategies." We think there is great power in envisioning a diversity support program which can "speak directly to the pain" of marginalization, and can "be a witness" to students developing their own "healing theory."

**Additional Commentary on How to Support Theorizing**

My conversations with Emilia began in a fairly typical qualitative research scenario, but developed in some unique directions as I have demonstrated above. In addition to explaining how methodologically I approached the work, it seems worthwhile to try to account for why in particular it reached the places it did. It may be hard to create a "how to" guide or to label a definitive "secret sauce" of our interaction; this entire reflection may smack of myopic navel gazing. I am cautious about overstating my own abilities in the matter, versus what I should attribute to randomness and idiosyncracies. It seems quite likely that there are many things which influenced our conversations about which I was not aware. Nevertheless, as I try to position this work with respect to future diversity support efforts, it seems worthwhile to attempt to account for what appeared to help create this study.

*Individual Aspects of Emilia and Stephen*

It is true that the three other interviewees I met did not all equally blossom into 4-year liberatory friendship-research partnerships. Some amount of personality quirks may have led to the study taking off. Emilia seems prone to probing conversations about culture and experience-- she is not shy about it, and she was not shy about initially suggesting to me to talk more.  On the other hand, I've now learned that Emilia doesn't actually open up to everyone about everything all the time, so there are probably ways about the way things unfolded that led her to trust and open up to me and enjoy the process. Emilia and I probably share some of the same opinions on which topics are interesting to discuss, and which typical aspects of engineering are problematic.

Our institutional positions and identities were also salient. Emilia pointed out that the fact that I had a position of some authority in the engineering department helped our conversations be validating for her experience, and I definitely had a baseline understanding for knowing what she was talking about. But it was also probably important that I was never in a position to grade or evaluate her.

*Abandoning Structure and Time Constraints*

It took a very long time to unpack Emilia's experience, more time than we could ever really afford. During the first interview, I had only allotted 50 minutes before the next interviewee was coming in, and it felt like I had to end things abruptly. After that, I usually tried to schedule them as open-ended as possible so I didn't have to cut it off. We usually tired ourselves out of talking, or she had to run to another event but sometimes after over two hours.

I had to throw out my initial interview protocol which was pursuing questions unpacking ENES 100 experiences, team roles, understanding of design, and engineering identity. During the first interview I felt some tension that Emilia didn't seem to stick to those questions very well, so I didn't analyze her interview during the PhD class because of how far afield we went from the interview protocol. But I likewise didn't feel like the originally conceived interview was getting at the most important things being said, so I was happy to shift to whatever Emilia was bringing up. Although ineffective for the original purposes, I think abandoning the preconceived structure for our gatherings added to the overall meaningfulness of the study.

*Listening and Talk Moves*

There were rare moments when I came with an idea of what to talk about (e.g., I suggested an activity of making a concept map of her life for Interview 3), but many more times the interview unfolded out of a sort of extended stream of consciousness venting session about several of the latest goings on. I would sort of listen and eventually steer towards topics I thought were meaty and worthy of further unpacking. Although it sounds obvious, I would emphasize the act of actively listening and finding a genuine human response as key to the whole process.

As for facilitating talk moves, there were probably many that just probed for further connections, "why do you think that is?," while others were more helping co-construct a line of reasoning Emilia was developing that seemed fruitful. Honestly though, Emilia talked on these topics a lot, and she enjoyed the task of trying to explore and come to grand theories about engineering, culture, and the world. So the talk moves were much more like steering a kayak than pedaling a rowboat—I just tried to stay in the moment and see where the conversation went.

*Expressing Solidarity, Sharing, and Giving Back*

One difference with other qualitative interviews, where an interviewer might try to cultivate neutral responses (e.g., does "can you say more?" sounds more neutral from "ok, yeah…"), I often felt like I usually had to go the other direction. Perhaps because I was a white man and I wanted to establish some trust that I "got" what she was talking about and was safe to share more, perhaps because of the emotional power of many things she shared, I felt like I needed to break some interviewer norms and declare solidarity at times. I would make clear expressions of my opinions (e.g., "Wow, that's messed up"), and take opportunities to share a more extended set of opinions on related issues.

A lot of this solidarity ended up happening on longer time scales and grain sizes than could be shared in the narrative excerpts of this paper. I would listen to her talk about the lack of valuing humanities and plurality in engineering classes, and then would share a paper on humanistic engineering, or a book on design thinking. I would listen to her talk about being accused of "dressing like an art major" and end up sharing an extended parallel story—I had hung out in the Physics department basement for a bit before she showed up, and walking around in a yellow polo shirt I felt a bit out of place with all the folks in bland hoodies pushing nitrogen tanks. We would reference these shared stories later (Emilia encouraged me to keep wearing the yellow polo as she left that day), and this contributed to a sense of almost conspiratorial solidarity.

I was very conscious of the fact that I wasn't compensating Emilia for her time, this was all done outside of the typical grant compensation or course extra credit systems. Sometimes I bought her an iced tea as a small friendly ritual to thank her for coming. But I think elements of solidarity and sharing were also part of me thinking of the interview as a space that should be more bi-directional than an ordinary interview, where I would think about gleaning information from her. Conveniently, I didn't actually need any particular information from her (because of no hierarchical funding purpose), the interesting thing to me was that she was apparently getting something out of the process of interviewing. I wanted to keep doing whatever that was and keep exploring it. So I consistently thought about a responsibility that she should be getting something out of the interview, and not just giving me information, which I think led me to more acts of sharing and solidarity.

*Outside influences*

Finally, Emilia mentioned how influential several other players were throughout the engineering school, her peers, her other course experiences were. These are aspects I don't actually know much about, and wouldn't have had particularly good access or IRB permission to investigate further. But it seems Emilia's participation in conversations similar to ours and the fodder for theorizing about cultural influence (e.g., her English class that injecting the topic of plurality into our interviews) was quite influential. This makes sense—since her and my conversations were only 1-2 times a term, her access to other sources for these conversations and ideas may have been much more influential in her day-to-day life. This may speak to an importance of humanities courses, or humanities-like courses for Engineers, where they are challenged in their thinking and conversations around broader social, cultural, historical, and political systems to which their own experiences connect.

# Chapter 6: Contributions to New Directions in Diversity Work

## Recovering the Obscured Influences on Diversity in Engineering

> *"Some things you miss because they're so tiny you overlook them. But some things you don't see because they're so huge. We were both looking at the same thing, seeing the same thing, talking about the same thing, thinking about the same thing, except he was looking, seeing, talking and thinking from a completely different dimension."*
>
> Robert M. Pirsig, Zen and the Art of Motorcycle Maintenance

I began the dissertation by thinking about the standard approaches we take towards diversity work in engineering education, and what aspect of the situation those approaches emphasize or obscure. When we very often focus on present day underrepresentation statistics, retention factors, and experiences of marginalized students, we obscure the influence of history, dominant group actions and interactions constructing student identities, and contestable cultural aspects of engineering, all of which can expand our thinking and open up new avenues for remediating and responding to educational problems on diversity. While the latter approaches are not unheard of in the diversity literature, they are comparatively rare and less prominent.

In sum, this dissertation provides an example of the value of a critical examination of history, culture, interactions, dominant groups, and the nature of engineering to our understanding of and support of diversity in engineering education.

Chapter 3 showed how engineering culture influenced the construction of the failure of a student. In the day-to-day, culture influenced classroom interactions, where dominant students often perpetuated micro-inequities of stealing attention, time, experience, or credit at the expense of non-dominant students. Chapter 4 pushed deeper into a cultural understanding of the competitive actions of dominant White male students, using a sociohistorical lens to situate the norms of the engineering classroom inside broader trends and contexts. Chapter 5 showed a student contesting normative forms of engineering culture, its fundamental nature, and the oppressive prescribed role apportioned to her within the culture. The study shows her taking agency in the act of constructing a complex narrative interweaving named oppression with resistance and critique.

Revealing the workings of culture, history, interactions, and disciplinarity required penetrating the small and seemingly unimportant moments of educational life. If on the surface we were investigating a student who lacks “a brain for” programming, a student who never got to feel like she “knows what [she’s] doing,” a student who took a non-technical team project role, or a few White men competing to answer questions first, the dissertation implicated far more than these individual educational problems. Grounded in these small events, the dissertation uncovered the hidden depths of complexity and power in local settings, and the impact of big and unseen forces rarely discussed. As Pirsig (whose The Zen and Art of Motorcycle Maintenance (1974) is a metaphor for focusing on and revealing lessons and meaning inside of seemingly mundane minutiae) might say: I was looking at the same things many have seen but overlooked because they are tiny, and revealing the things they don't see because they're so huge.

This chapter takes stock of and envisions next steps for the dissertation work. In the following sections I will examine the dissertation as a hybrid intellectual space between certain research dichotomies, assess the contribution to various engineering educational stakeholders, and propose implications for further progress in areas of associated research and practice.

## Seeing the Dissertation as Hybrid Intellectual Space

Having presented several smaller research studies, I want to use this first part of the conclusion to synthesize some themes of my current and future scholarship. One theme I see in my dissertation projects is a hybridity between dichotomies which are often assumed and embodied in education scholarship. In this section I discuss several of these dichotomies and discuss examples of where I see my ongoing research with respect to the dichotomies.

### *Theory versus Practice*

Theory and practice are often dichotomized in educational literature, and many engineering education researchers embody one side of the dichotomy (Felder & Hadgraft, 2013). A large body of purely pedagogical description work appears in the disciplinary journals and conference proceedings, where professors simply describe their assessment of their curriculum and class events. If practice-oriented paper or grant proposal authors feel compelled to have a theoretical framework section, the treatment of theory can be tangential or cosmetic. On the contrary, there is also a trend towards theory-building work without direct practical implications (e.g., developing theoretical insight into sociocultural learning processes or cognitive schema), or empirical applications (e.g., suggesting how one might think of the engineering curriculum as process management or as a complex system, or of engineering work as an act of empathy). Even if ideally robust research draws and builds theory through a pragmatic empiricism, a good deal of scholarship seems to dichotomize the activities and to embody one side of the dichotomy.

Rather than fitting into one side of this dichotomy, I would position this dissertation as both highly theoretical and highly practical. A particular contribution I see for my work is to bring new theoretical insight to well-covered territory in conversations about engineering diversity. But I diverge from other cultural approaches, e.g., some sociocultural theorists, for whom I think the ultimate goal may be a deeper understanding of the sociocultural world as an end to itself. Instead, I see the power of theory to change thinking and frames for seeing the world, not only in research, but in practical day-to-day circumstances. These new ways of thinking open up new insight for solving problems which often seem intractable. In Chapters 3 and 4, new theoretical visions grounded in culture and history recast the meanings of everyday circumstances and events. In Chapter 5, I argue that the power to create theory played a major practical role in Emilia's life. In comparison to the engineering educational world at least, I feel as though I do enjoy the role of the theorist, but a theorist who focuses on and impacts the practical educational circumstances of the day-to-day.

***Disciplinary versus Social Justice Work***

As I alluded to in the introduction, the overlap between the scholarly world of social justice (diversity work) and that of the engineering discipline is a small but important next frontier for engineering education research and practice. The disciplinary world I refer to here may be Discipline-Based Education Research more broadly or Engineering Education Research, specifically. It is required to have intellectual rigor steeped in the discipline of concern, to be credible with the disciplinary practitioners, and to be conversant with the discourse of the disciplinary community. The social justice world typically engages only those at the periphery of the discipline: disenfranchised students themselves, the workers who mentor and support them, or, perhaps, the upstart political activist. It pays attention to terminology to address the disenfranchised communities, to histories of power and oppression, to interactional microaggressions, and to culture.

In this dissertation and beyond, I intend to pursue research both disciplinary and progressing towards social justice in the senses I have laid them out above. I see the engineering discipline in particular as compatible with and requiring a greater attention towards social justice, and I see social justice work as needing to engage with the disciplinary content and conversation in order to be heard. Although it could have engaged the disciplinary content even further, Chapter 3 drew heavily on the particular programming content and in situ interactions of active learning in the setting, and this increased the power of its commentary. The longitudinal interviews in Chapter 5 consistently touched on specific pedagogical experiences and disciplinary norms, and the specificity of our conversations kept it ingrained in Emilia’s relevant experience in engineering. Thus, I see my work as both deeply informed by the discipline, and firmly oriented towards social justice.

### *Political Purpose versus Empiricism*

In a related way, I see a dichotomy set up where research either has an empirical purpose, collecting data to form knowledge about the world, or a political purpose, to sway an audience or enact change in favor of a new direction. These need not be mutually exclusive, of course, but generally critical theorists would place themselves on the side of politics, and, say, positivists and traditional ethnographers more on the side of empiricism (though it is an empiricism which ethnographers and positivists would define very differently from each other). Some focus on empiricism and see their only political project as swaying a debate with respect to an intellectual community. Others focus on politics, assuming an unfairly constructed world as a foregone conclusion and create research which is a plea to others to shift circumstances. In this landscape, I align more with critical theory and a political project to change hearts and minds, similar to the scholars who inspired me. I see myself as falling at a position on the spectrum which still heavily values empirical data to make a political claim.

I can see places where a political purpose took precedent, particularly in Chapters 3 and 5, where I felt an argument about social labels was important to make almost *because* of how unprovable yet impactful it was. I could not make a conclusive case that gender was "in the air" at all moments of the engineering classroom, or that Letters and Sciences was coming to organize the identities seen with respect to one another. I built up support for the argument up with available data, but argued that the far-reaching effects still went beyond the data I could observe. I felt this, based on the moments that everyone knew about but no one noticed Jillian in her lab section, the moments the professor spoke of underrepresented groups and those lacking programming background as a single group. These were hints at the organizing power of social labeling, but hard to pin down.

But, if I failed to mention the *strong* possibility that these social labels were influencing the construction of ability in the setting, I felt I missed something important and unspoken about how these identities were known and shared in the classroom. Perhaps one way of saying it is an alertness to intersections of localized and historical oppression formed a theoretical backdrop for understanding classroom hierarchies; or perhaps I wanted to make space for multiple political purposes in my account.

Likewise, in Chapter 5, although I have a deep sense that agency is the thing that mattered to Emilia, I struggled to make a firm claim about what agency was and how it was produced. Yet drawing attention to critical theorizing as agency seems like an important message to bring to potentially shift thinking in diversity support, for other scholars to then try on as a lens and see if it holds up. Finally, in Chapter 4, I acknowledge the theoretical focus around race, gender, and competition was partially motivated by political rather than empirical purposes. Particularly the emphasis to personally challenge myself and others around race represents a political rather than empirical necessity—as I have suggested, the data was not easily going to reveal race without my interrogating it.

Generally though, I tried to make a case which was well-grounded in the data, rather than a political polemic. I stayed close to the educational facts and interactions which occurred (Chapter 3), rather than delving into a symbolic interpretivism of a compelling framework around impression, as some critical theory work might be characterized as doing. I see the dissertation and my future work as politically-motivated empiricism, or empirically-grounded political activism towards the engineering education community.

***Individual Agency – Culture – Historical Structure***

A well-known *trichotomy* particular to cultural analysis comes in the form of the Structure – Culture – Agency triad (T. M. Brown & Rodriguez, 2009, pp. 223–224), where I would also align a focus on the Individual with Agency, and a focus on History with Structure. Although not all who use the words structure, culture, and agency are attempting to parse them as individual forces in a given social setting, I think many anthropologists and sociologists do attempt to separate out these three aspects as a precursor to their analysis, and they read this underlying framework into each other's work. Thus I have heard a critique (in Margaret Eisenhart discussant commentary at AERA session) that cultural analyses should pay a greater attention to structure, and I see certain *figured worlds* scholarship as particularly building on Cultural Production with a further theoretical understanding of the role of agency (D. Holland et al., 1998).

I think the dissertation differs from those who typically employ the S-C-A framework or figured worlds. I frequently employ some of the terms of the trichotomy, though I reject positioning certain aspects of the trichotomy as mutually exclusive. Structure and culture seem so deeply intertwined that I am not often tempted to differentiate them. Oppressive and inequitable power structures can often become so enmeshed that they are taken for granted, a part of the culture, if you will. Cultural norms (such as a PowerPoint text that uses jargon, Chapter 3) can almost only operate at the support of normatively available structures (PowerPoint projectors, desks, institutions). This differs from some S-C-A and figured worlds scholars, who look for and see a firm separation of structure and culture.

I also note a trend of the dissertation towards placing emphasis on certain elements of the trichotomy as intertwined with taking different respective purposes. When broadly speaking to those in power, I see a blended analysis of structure and culture as the primary focus, since questioning the status quo procedures, systems, and ideologies of those in power can be a valuable way to work towards change. When speaking to those primarily at the margins, an emphasis on agency provides more hope and emphasizes the individual's power to change things. This differs from some scholars who, seemingly out of a preference for accuracy or for the dignity of marginalized groups, prefer to emphasize agency in all cases (e.g., many figured worlds proponents).

I operate under the assumption that scholars and practitioners (not students) typically read journal articles or dissertations, and that I have a (political) purpose to shift classroom culture, rather than a more intellectual purpose to document all pieces of a theoretical trichotomy of the social world equally. So if I am writing to scholars and practitioners about a marginalizing culture in a classroom, I see little value to emphasizing the rare moments of productive agency. In the worst case, perhaps then the reading audience can let themselves off the hook about the marginalization in their own backyards since as they've seen hypothetically a superhero student could pull themselves up by their bootstraps. McDermott described the position of the student with respect to the "always already there" culture as one of very limited agency (McDermott & Varenne, 2006a, p. 9). The normative outcomes of oppressive culture always have the potential to "shift in the interactional winds" (McDermott, 1993, p. 290), but they usually do not. And even when successes come, such as the illiterate exterminators learning to read, McDermott sensed that the broader forces which created the test to justify a social hierarchy would soon redefine literacy to create new illiterate and disenfranchised exterminators. McDermott is also suspicious of identity and agency as points of fascination, as an overly individualized American cultural conception (Varenne & Mcdermott, 1999b, pp. 1–4), compared to cultures with a more collective emphasis.

On the other hand, hooks writes predominantly to and for individuals at the margins, and she emphasizes and bolsters their sense of power to respond to oppressive culture. Likewise, when speaking with marginalized students in interviews, I see fostering a view of agency in oppression as the most important activity, and so a critical discussion of culture becomes a key form of seeking agency (Chapter 5).

## Assessing the Contribution to Engineering Education Stakeholders

The overall contribution of this dissertation is well-summarized by the idea of progressing beyond diversity work as usual in engineering education, drawing on critical cultural approaches to marginalization to envision new ways of looking at, talking about, and responding to these educational problems. Thus the chapters in the dissertation each represent an example of a new paradigm shift with implications for many stakeholders in engineering education. Having already addressed these implications in each of the empirical chapters of the dissertation, I will conclude by collecting them and organizing them by contributions for each respective community in engineering education: students, instructors, the engineering canon, diversity practitioners, and researchers.

### *Contributions for Students*

Earlier in this chapter I mentioned that I do not expect my dissertation to be read by very many students experiencing marginalization, and I would in fact write differently if I saw students as my primary audience (e.g., emphasizing the possibilities for resistance rather than the inevitabilities of culture). Although in general I see my audience as those with power in engineering to shift circumstances affecting students, I do think there are possibilities for more direct impact on engineering students. In Chapter 5, my desire to understand and support marginalized students motivated a re-envisioning of the research interview as a site for constructing agency in resistance of oppressive engineering culture. If Chapter 5 is proof that engaging with and understanding marginalization may have power for students, Chapters 3 and 4 provide new understandings of their cultural circumstances which may add to this power. A marginalized student who reads this dissertation may resonate with experiences and find new tools to make sense of oppressive experiences in engineering departments. Dominant students may find a new level of insight for the consequences of their or their peers' actions, and may be activated to make changes in their departments. I have at least initial evidence through Chapter 5 member checks and through sharing prior versions of Chapter 3 with engineering Learning Assistants that the work resonates with or challenges students' ideas productively.

***Contributions for Instructors***

The methodological and analytical move of "turning away" prompts an ontological refocusing of the nature of educational problems towards the interactions and culture producing it. As noted in the conclusion of Chapter 3, this refocusing movement may be a productive pedagogical orientation for classroom instructors. Classrooms are overdetermined spaces, where students with fewer socialized resources to perform may also be the students in underrepresented demographic categories, may also be the students seen to be "meek" in classroom discourse, may also be the students falling behind on assignments or tests. It can be tempting for an instructor to construct a deficit or difference story, particularly if certain social labels are “in the air.” But Chapter 3 showed it is also less accurate and less useful to think in terms of student deficit or difference, it opens up fewer opportunities for addressing the problem in terms of classroom circumstances.

An example comes from my own teaching. In the Introduction to Design course here, a common gender pattern is seen in the roles students take on their 8-person design teams, with the 2-3 women on the team taking more team roles related to note-taking or group communication, and men more often taking technical roles such as computer programming and construction. In other iterations of the course I had seen, it seemed if anyone even noticed this as gender inequity or a problem, it was with a sort of stable orientation towards what women were or weren’t doing, and what role they did or did not have skills to perform on their team. There were different schools of thought about whether having 1-2 women on every team was better or worse than 4 on some teams and 0 in another. The Women-in-Engineering program provided supplemental instruction in masculine-socialized skills like soldering and machining. But there was little to no direct challenging of the broader stable pattern involving both men and women. In the semester in which I was full instructor, this persistent educational problem became a primary interest. The pattern bothered me on a couple of levels, 1) I knew from my research that this might be subtly communicating a non-technical non-engineering role for women that seemed counterproductive to identity development, and 2) I saw it as an often-observed wasted learning opportunity for a class with a great diaspora of things to learn, that the students who knew the most about a part of the project (e.g., programming, writing) ended up doing that on the project, thus learning incrementally more about an area of prior experience and little about any of the other areas.

In a thought process similar to “turning away,” I focused less on the differential preparation of the struggling students, and more on how the problem came to be. I figured the pressure cooker of the course competition and grade structure made students more conservative in their role selections, and they then relied on stereotypes (e.g., “the nerdy looking male student is probably the strongest programmer, and the well-dressed female student should give our presentations”) to assemble team roles rather than subverting them. I wanted to counteract this, but I didn’t want students to be overtly self-conscious about their gender, perhaps even stereotype threatened, if I told them how precisely to handle gender equity in team roles. Instead, I tried to shift the culture of the course by shifting the assessment emphasis of the course and asking them to think hard about team role selections. First I elicited areas of strength and areas of growth from the students on day 1, asking students to circle a skill in which they had expertise to their team, and something they did not know much about but were interested in learning. I noted that many students had circled programming as a learning goal, and privately I imagined how few of them would end up making substantial programming contributions if the term turned out as it typically did. Then I told them they should of course contribute to their team in an area of strength that they had prior expertise in, but in my course I also wanted them to set a learning goal and to try something new. And while the competition scores would still be a measurable part of their grade and it would be hard to fault those who did not make major progress on learning and personal growth, I still had teacher authority to recognize through participation grades whether or not students genuinely pushed themselves out of their comfort zones to try something new. From time to time, when the course competition and content pressures increased in the middle of the term, I would remind my students of their learning goals, particularly how many of them had wanted to learn programming and therefore shouldn't give up and let the others' on their team do it for them.

Although it is only an anecdotal comparison, my feeling was that my teams exhibited significantly less gender bifurcation around the technical/non-technical role divide. Out of my 6 female students, at least 5 were taking prominent technical roles on their project teams—e.g., programming and calibrating their team's distance sensor or servos—much higher than the normal rates of participation I was familiar with. This shows how turning away towards interactional and cultural forces on educational problems may open up new opportunities for instructors to ameliorate persistent educational problems.

***Contributions for the Engineering Canon***

There are certain key pieces of disciplinary knowledge or experiences we expect engineers to progress through (Stevens et al., 2008). These are not strictly policed but encouraged through ABET standards, co-op or professional experiences, or the accidental competencies developed through the happenstance circumstances of progressing through an engineering program (Walther & Radcliffe, 2014). Within the discussion about a canonical curriculum for the preparation of engineers, there are many who call for a greater emphasis placed on "softer" liberal arts subjects, such as the macro-ethical implications of the role of engineers in society (Gupta, 2015; D. Riley, 2003), human-centered design (Miller & Sochacka, 2017; Walther, 2016), and an increasing emphasis on social justice (Baillie, Pawley, & Riley, 2008; Slaton, 2015).

My dissertation aligns with these calls and makes tentative additions. Most of the above claims make a *moral* case for engineers' understanding of socially-oriented subjects, and Chapter 4 similarly attempts to lay out certain social histories of oppression in the engineering discipline which I believe engineers have a moral imperative to acknowledge and respond to. In addition however, I have suggested that an acknowledgement of history can shift our contextual understanding of the present day (e.g., historicizing diversity). Likewise, in Chapter 5 I have demonstrated that, at least for one student, the work of discussing and reframing experiences in oppressive culture was a source of agency. Tentatively, I am suggesting a *practical*, not just a moral, importance for discussing broader historical and cultural context in engineering. Further work developing an empirical case for liberal arts and social justice understandings could strengthen the calls for its place in the engineering canon, and could motivate professional development initiatives for practicing or academic engineers as well.

***Contributions for Mentors and Diversity Support Practitioners***

The world of diversity support was one I interacted with extensively during this dissertation work, though often as an outside observer rather than an insider program operator. I feel this was at least in part due to the in-group identity understanding of the standard diversity work in engineering education. For example, I sometimes requested and had difficulty securing a graduate assistant role with a diversity programming group around a minority identity. Thus my experiences with diversity support have come either in informal research settings (Chapter 5), through ethnographic research projects

(Geddes, Habbibah, & Secules, 2015), or through settings outside of engineering, not in an official role as an engineering education diversity practitioner.

The outsider positioning and informal setting in fact lent themselves towards work which is rarely present in a diversity literature focused on achieving retention results through support programming; it allowed me to draw on new theory to ask deeper questions about what it means to support marginalized students. My sense is that the critical theorizing illustrated in Chapter 5 is resonant with some portions of the work in diversity support programming, such as processing experiences of sexism or racism, and can be at odds with others, such as empowerment narratives or instructions for coping. Empowerment narratives and coping mechanisms are not all bad, but could be heard as prescriptive or victim-blaming if left without an accompanying cultural critique. Chapter 5 provides new tools for thinking about the different functions of these messages and perhaps will help diversity support practitioners construct new messages. If empowerment and coping mechanisms are useful but can ring hollow on their own, perhaps critical theorizing about the need for these messages would be a useful organizing principle to nest the conversations in.

### *Contributions for Researchers*

Although assessing the contributions of a dissertation to the research community is standard practice, I fear it may run the risk of spiraling into academic esoteria: *Why is this research important? It helps us do more research!* It may also be deceptively challenging to do—providing a new type of methodological approach does necessarily not mean that other researchers will have understood, or be able to replicate, or wish to pursue the approach. The academic silos referenced in Chapter 2 suggest that some of our methodological innovations do not even get substantially considered by our nearby scholarly peers, much less flourish into productive research for them. Nevertheless, I see the dissertation as making a few key contributions to the methodological and theoretical tools of engineering education research.

In Chapter 3, I take up and try to lay out the methodological approach of "turning away" from an individual student and their character traits or socialization, in order to orient towards the cultural construction of the educational problem. Demonstrating a new focus on interaction and culture (of classrooms and the broader discipline, rather than of individual student backgrounds), is novel for the engineering education research field which has a tendency towards representing student experiences of marginalization in interviews, which are to some extent structured by an underlying logic that marginalization is rooted in the culturally different experiences and backgrounds of the individual. Further, in applying McDermott's "turning away," I realize I have improvised on the original focus on classroom discourse to include the role of artifacts, curriculum, texts, and history. Although it was not an original inspiration for it, perhaps this approach merges activity theory (Bakhtin & Vygotsky, 1978; Roth & Lee, 2007) with cultural construction. Cultural historical activity theory has been marshaled to make similar arguments about the interactional construction of failure in engineering education (Roth, 2016), and in at least one case it has been blended with McDermott's cultural lens to include environmental artifacts and constraints as an actor in the work of cultural construction (Tsai, Kotys-Schwartz, & Knight, 2015). This may be a productive area for further exploration around extending the arguments of cultural construction.

In Chapter 4, I suggest historicizing present-day circumstances, facts (statistics), identities, and cultural norms as a productive methodological approach for engineering education research. Without conducting primary source historical research myself, I place the present day into relief among the historical contexts built by others, to elicit new understandings about the present day. If other education researchers feel similarly intimidated by conducting original historical research, a first step to doing this work may be simply un-siloing ourselves from respective academic communities, between those who focus on the present day and those who write history (e.g., Pawley, 2008; D. Riley et al., 2014). The mechanics of taking that step for me included having conversations about my work with people steeped in STS and historical anthropological communities. The blending of academic worlds in Chapter 4 and the re-presenting of history is meant to help foster additional conversation and to build a platform for additional historicized analysis.

In Chapter 5, I point to the potential unexamined impact of the qualitative research interview as powerful for student participants experiencing marginalization. This sort of observation is consistent with the intuitions of some prior research teams (Danielak et al., 2014). The initial tentative claim around methodological value for participants deserves additional investigation. When writing an IRB for qualitative research, we generally think of protecting privacy, doing no harm, and compensating the individual for their time. Yet I have had several students over the years of these studies mention how they get a good deal out of the interview themselves, and at least two students refused to ever accept money from me. If qualitative researchers knew more and talked more about this form of personal impact, it could shift our views of the work from that of uni-directional knowledge gathering towards a bi-directional and co-constructed knowledge aimed at student support.

**Further Work: An Agenda for Research and Practice**

It is standard practice to conclude education research with areas for further work. Here I take up this purpose across the scope of the dissertation and related experiences, and organize this into several ideas for future projects in areas of research or practice. These will take the form of a short proposal outlining the idea, with a goal to make progress towards making versions of them realities in my future career.

***Expanding Ethnography on the Cultural Construction of Marginalization***

This project direction would expand on and formalize the critical ethnography work in the Cultural Construction tradition (Chapter 3), looking across participants and institutions with a collaborative lens to shift classroom norms.

Rationale: Several ethnographies of the engineering classroom have shown the day-to-day interactions inside engineering classes to be consequential in perpetuating marginalization and contributing to the attrition of students (Danielak et al., 2014; Foor et al., 2007; O’Connor et al., 2015; Secules, Gupta, & Elby, 2016; Tonso, 1996). While many ethnographies of classroom marginalization implicate broad cultural norms much more than specific instructor mistakes, certain features of this work limit our understanding of and ability to improve engineering culture. These ethnographies differ from each other in methodology, focus, theoretical lens, so that each individual account provides a window into what may be a broader pattern, rather than making a firm case for that broader pattern. Because of the sensitivity of the subject matter and the need to protect privacy, the publications about the research subject institutions are typically unidentified. Thus, it is often unclear whether after such careful work understanding how marginalizing culture operates, whether the researchers then intervened to try to shift culture or to see it operating differently. Although this is consistent with a view of ethnography and research as performing careful observation rather than designing interventions, it leaves the system it criticizes intact. In short, ethnographies of engineering education often point towards a broad cultural problem without ascertaining it, locating it in a specific context, or marshaling tools to shift it.

In order to make progress on attrition and marginalization related to underrepresented minorities and non-dominant groups, ethnographers of engineering education should expand on their current and often ad hoc research design (investigating the sites and topics which emerge) towards a more systematic and far-reaching documentation of marginalization in engineering culture. Likewise, in order to shift engineering classroom practices, ethnographers of engineering education should take up participatory design research methodologies which involve the instructor as a collaborative researcher, in order to publish stories of shifts in classroom practice.

Research Questions: What are the cultural and interactional roots of marginalization and educational problems in engineering education? How can we shift these towards less marginalizing norms and interactions?

Institutional and Participant Selection: The research design would ideally engage Co-PI led research teams across multiple institutions, in order to make a more robust commentary on engineering culture. Participating instructors would be selected for an interest in working on equity in their classes, but holding a range of familiarity and expertise with equity.

Methodology: The project would employ ethnography and discourse analysis (McDermott & Varenne, 2006b; O'Connor et al., 2015; Secules, Gupta, & Elby, 2016; Varenne & Mcdermott, 1999a) on the one hand, and critical participatory design research on the other (Barab, Thomas, Dodge, Squire, & Newell, 2004). In-classroom ethnographers would take fieldnotes, collect classroom artifacts, videorecord interactions, and interview student participants. Sessions for feedback and brainstorming with participating instructors would be structured at regular intervals in order to let the classroom proceed "naturally" while providing an avenue for feedback and change.

Dissemination: When publishing findings related to marginalizing engineering culture, co-authors from multiple institutions and working with multiple participants would provide additional cover to be able to speak honestly about the sensitive topic of marginalizing class norms, for instance, by combining "true" details of multiple participants in order to obscure their details. Publications would emphasize major findings related to cultural patterns of marginalization, as well as document specific efforts which shifted classroom practices.

*Intellectual Merit*

This work will expand our understanding of how marginalizing engineering educational culture is enacted in classroom interactions, by focusing across multiple institutions and participants with consistent methodologies. It will also expand understanding of how to resist and repurpose marginalizing engineering culture by documenting a collaborative design process to reform the participant classes.

*Broader Impact*

The tackling of marginalization in engineering educational culture has high potential to impact the experiences of underrepresented minority and non-dominant students in classes, which would have positive consequences for student identity and retention. In addition to the shifts produced in local classrooms, this study would produce a contextual understanding for shifting marginalizing engineering culture which would have high potential to be adapted in wider settings.

***Making the Empirical Case for the Value of Critical Historical Theorizing about Engineering Culture***

This project builds on the initial finding in Chapter 5 of a practical value of theorizing for students. It would document a holistic sense of the "value" for students learning about and engaging in discussions of engineering culture, including an understanding of the history of the discipline.

Rationale: The engineering curriculum has been noted to be heavily technical, leaving little room for "soft skills" or understanding identity, society, social justice, empathy or culture (Miller & Sochacka, 2017; D. Riley, 2003; Slaton, 2015). Many have made a moral case that these humanistic areas of ethics are important for engineers (Gupta, 2015), and a few have made a practical case for empathy and humanistic understandings as being useful to engineers (Fila & Hess, 2014; Hynes & Swenson, 2013; Miller & Sochacka, 2017; Walther, 2016). Still other work suggests that understanding and processing engineering culture could be an important form of agency for marginalized students (Secules et al., 2015).

When noting value for students, the case for including humanities and understandings of culture and history is usually made on the basis of a theoretical, moral, or small empirical study. This limits the power of the argument to shift conversations in Engineering departments about the need for space to be made for humanistic content in the engineering curriculum. Thus there is a need to determine the empirical "value" (broadly defined) for engineering students to have experiences of learning about and processing an understanding of engineering culture, history, and its broader relation to society.

Research Questions: What is the value for student learners of a discussion-based pedagogy focused on understanding the place of engineers in society, and the role of culture and history in structuring the enterprise?

Research Design: The project personnel would include an instructor and a research documentation side. The research team would employ multiple ethnographic data streams to improve the curriculum while holistically assessing value for the student. Possible forms of value include affect, identity, shifts in understanding of marginalization, connection to the discipline, or new activist orientations. Research team will also carefully assess any negative impacts in order to be fair arbiters, including potential increased tension among identity groups, a negative association with engineering, an increased self-consciousness among marginalized students, or a desire to leave the major.

Dissemination: Reporting will emphasize curriculum development from a design research perspective, as well as document the empirical case for value of the curriculum for students.

Intellectual Merit: The project will expand knowledge of how to make a curriculum focused on culture and history with relevance for engineers, as well as ascertaining the value of this work for students.

Broader Impact: The project has a high impact for producing engineers in the local setting who are more well-rounded, engaged, responsible, and empathetic, and who understand their relationship to historical oppression and have a new imperative for their actions to resist it. Likewise, the empirical findings coupled with a contextual understanding of the curriculum design have the potential to make an empirical case for expanding the humanistic education of engineers more broadly.

***Analyzing the Impact of History on the Present Day with Masculinity and Whiteness Lenses***

This research strand grows out of and continues the work of Chapter 4, applying critical historical, masculinity, and whiteness lenses to an ethnographic view of engineering classrooms. As more of a research proposal than an ambitious institutional grant, it may be more appropriate to a funding body like Spencer Foundation than NSF, or it may represent future analytical work requiring little funding, but time and access to a dataset.

Rationale: Engineering education has noted the presence of a marginalizing oppressive culture which creates difficult experiences for women, racial minorities, and other non-dominant groups (Foor et al., 2007; Secules, Gupta, & Elby, 2016; Tonso, 1996, 2006a, 2006b). The social history of the engineering discipline has reveals a professional formation rooted in racial, class, and gender domination, and perpetuated through certain cultural norms and social exclusion (Oldenziel, 1999; Slaton, 2010b;

Wajcman, 1991). There have been calls and initial progress to connect historical context to the present day (Wisnioski, 2015). For instance, the role of masculine culture in perpetuating disciplinary boundaries which exclude women's work has been connected to present day boundary formation in narratives around what is and is not engineering, and what is masculine or feminine (Pawley, 2008). The role of masculine dominant culture has been noted as a historical force in engineering (Wajcman, 1991), as well as a potential homosocial norm which perpetuates masculinity in associated social spheres (Bird, 2016). The case may be made that White masculinity is perpetuating particular cultural norms in the engineering classroom, yet comparably little research has interrogated the actions, interactions, norms, perspectives, and culture of White men in engineering education. A historically contextualized critical whiteness and masculinity study of the engineering classroom can provide valuable insight into the forces perpetuating racial and gender norms and oppression in engineering education.

Research Questions: What do we gain by taking a critical cultural, critical whiteness, and critical masculinity lens in engineering education interactional settings? What are the sites and moments of whiteness and masculinity which perpetuate marginalization in engineering?

Research Design: The ideal research settings for the study would be interactive and naturally occurring settings in engineering, particularly those which involve sustained participant interaction, and those which are seen as consequential or challenging moments for the identity development of non-dominant students.

Methodology: The study would employ interaction analysis and ethnography, incorporating critical whiteness and critical masculinity lenses. A large classroom dataset of ethnographic fieldnotes and classroom video would be assembled and assessed for analysis. Participant interviews would investigate cultural norms in the engineering classrooms in order to reflect back and understand the meanings of interaction data more fully.

Intellectual Merit: The study would provide new insight into the workings of engineering culture, whiteness, and masculinity in present day engineering settings. It would also make progress in connecting the social histories of the engineering discipline to present day engineering classrooms, by connecting to broader observed sociological patterns perpetuating White masculinity in culture.

Broader Impact: The primary impact would be in fostering awareness, conversation, and critique of marginalizing engineering culture, in order to shift it in the future. Since engineering culture has a strong impact on underrepresented minority and non-dominant groups in engineering, the findings from the study would provide critical insight to make progress on the undergraduate engineering portion of the educational pipeline for diverse students.

***A Professional Development Effort Encouraging "Turning Away" as Pedagogical Orientation***

This project expands on and formalizes investigation of the idea that "turning away" could be a pedagogical orientation (Chapter 3), by conducting equity-focused design research with participant instructors who participate in a pedagogical development community group.

Rationale: A consistent educational problem in engineering classrooms is the production of students who feel as though are failing or unable to do the work. Although students create these scenarios for one another, the views professors hold of their students also contribute to the way they structure and foster classroom culture, their attitude towards students, and which approaches they take in responding to the educational problem. Many have noted that a focus on skill and talent deficits are unproductive for instructors to hold towards marginalized, minoritized, or non-dominant students (K. Lewis, 2014; McLoughlin, 2005). Although some pursue efforts to alert instructors to the productive "assets" of such students instead (Samuelson & Litzler, 2016; Svihla, 2016), efforts which are essentially rooted in finding a socialized difference among minority students to explain marginalization can also be patronizing, inaccurate, and lead to few solutions to the problem (McDermott & Varenne, 1995). Instead a methodological approach of "turning away" (Varenne & McDermott, 1999) from a focus on individuals to a focus on interactions in a culture has been suggested as a productive pedagogical orientation (Secules, Gupta, & Elby, 2016). Although it has some overlap with features of culturally responsive pedagogy (e.g., reducing classroom hierarchies C. D. Lee, 2001), the full implications of "turning away" have generally not been investigated as a pedagogical approach. This project investigates whether instructors can use the orientation of "turning away" to remind themselves to look at interactional and cultural constraints constructing the student as struggling, and what the consequences of this orientation are for their classroom practice.

Research Questions: How do instructors interested in equity progress with new lenses for looking at equity and culture in their classrooms? How does this impact their pedagogy?

Participants: Participants will be recruited to join a new professional development group around equity. The project team personnel will include an instructional side and a research / evaluation side.

Methodology: All class discussions will be videorecorded. The research team will follow certain instructors from the group who elect participation, collecting classroom video, artifacts, fieldnotes, and participant interviews as pertinent to documenting equity. The researcher will then bring artifacts, videos, and presentations of analysis back for learning and discussion in the professional development group. The group will watch video together or present mini analysis from the research team. This will give an opportunity to discuss what turning away looks like, and keep working on growth towards more equitable and less marginalizing classrooms. The continuity of the regularly meeting group will allow for gaining comfort having uncomfortable discussions, and provide possibilities for growth and learning by professors engaging over the course of the study.

Intellectual Merit: Rather than viewing professors as simply caring about equity or not, this project investigates whether and how instructors learn about equity and marginalization and how this effects their classrooms.

Broader Impact: The instructors engaged on the project will have new tools for approaching equity which extend beyond the end of the work, as well as a community of informed and equity-focused practitioners to continue to discuss issues with in the future. After dissemination, the research and evaluation process of documenting curriculum design and instructor progress will help other instructors and institutions make progress towards equity.

***Intersectional Praxis as Diversity Support***

This project grows out of a wide array of projects on and experiences with diversity support, from the dissertation and the past four years. In this final essay/proposal, I outline the limitations of our standard practices and envision opportunities for novel forms of diversity support.

Rationale: Engineering education research and practice has a goal of supporting several underrepresented minorities, including racial and ethnic minorities, women, LGBT populations, students of low socioeconomic status, first generation college students, students with disabilities, and other populations (Cech & Waidzunas, 2011; Seymour & Hewitt, 2000; J. M. Smith & Lucena, 2016). Programmatic diversity efforts represent an important source of support for students experiencing forms of gender, racial, and other marginalization. Efforts such as co-curricular support programs, engineering student support centers, and living-learning programs have been shown to have positive impact on the retention of underrepresented minority groups (Inkelas & Soldner, 2011; Seymour & Hewitt, 2000).

A key feature of these groups is that they form around a quorum of students experiencing a common source of marginalization, for instance Women-in-Engineering programs for sexism, Minority in Engineering programs for racism, and Out-in-STEM groups for homophobia and transphobia. While the in-group supportive conversations these groups offer are a critical force for their students, the groups are limited by their structure and function in a few key ways:

1. In that they operate on the basis of having a quorum of shared-identity students in a department, they cannot serve students who are in so

severely underrepresented a group that they cannot form a quorum. This might be the case for students with out gay students at campuses with comparatively little LGBT visibility, for students-with-disabilities perhaps at a department where only one or two students in this category, or for Native Americans in a state without a sizable Native American population.

2. In that they organize around a primary identity (e.g., women, racial minorities), current diversity support groups are not particularly arranged around the identities of students who experience multiple intersections of oppression. Black women engineers will have the opportunity to attend the women-in-engineering groups (e.g., Society of Women Engineers) and/or the minorities in engineering group (National Society of Black Engineers), and neither may spend very long discussing the reality of being a Black woman. In the women's group the discussion of being a female engineering student and future career professional may normatively structure around the experience of White women. In the racial minority group, the discussion of being a racial minority engineer may normatively structure around the experience of Black men. Although a group focused on women or racial minorities can engage intersectional experiences, this is a programming challenge and not an inevitable or easy accomplishment of the group. The typical assumption of the diversity support group is that members of the group share an identity and therefore share an experience and are a 'safe space' for one another. The

reality, however, is that intersectionality is always at play and structuring differences among a group of people, and that 'safety' is only achieved through careful community work, not through intrinsic sameness (Arao & Clemens, 2013).

3. In that the groups are organized around in-group identities, they limit potentially valuable conversation which occur across identity groups. If there are issues of sexism or challenging experiences related to gender on campus, women are the only ones talking about it. Even men who may care, potential "allies" to the feminist cause, are not being structured with a space to participate in a conversation about it. If there are issues of racism or homophobia on campus, racial minorities and LGBT-identified students are typically the only groups discussing them, respectively. The value of intergroup identity conversation has been argued for and demonstrated in practice, primarily in non-engineering settings (Nagda & Maxwell, 2011). Although some in-group conversations are critical, there is a missed opportunity for constructing positive dialogues across identity categories in engineering education.
4. Finally, the conception of single identity spaces emphasizes the student participants as a marginalized group, rather than noting the many elements of privilege and oppression which intersect each of them. Students with dominant identities (straight White men), as well as students with one marginal and other dominant identities (White women, Black men, gay White men) can gain valuable insight by processing their

> relationship to multiple forms of oppression. In a group formed around single identities, these conversations are possible, but less likely to take place.

Another key feature of these groups is their approach to providing support to student participants. Typically, diversity support groups take up empowerment narratives, encouraging and motivating students to succeed in the challenging engineering department. Additionally, they focus on improving student academic skills and preparation, by offering tutoring and supplemental instruction on professional skills. While empowerment and improvement are critical efforts for diversity support programs, they can come across as patronizing or prescriptive to students when the narratives are decoupled from a critique of the marginalizing forces which have contributed to their position (Secules et al., 2015). Praxis (Freire, 1968) and critical cultural theorizing about their experiences in marginalization (hooks, 1992) represent two possible framings for diversity support narratives and activities which engage students in acts of resistance and agency.

Prior Work: In initial ethnographic work with a Women-in-Engineering support seminar and community (Geddes et al., 2015), I and my collaborators looked at the resources and challenges encountered by the program. In one conclusion of the paper we found that it may become more difficult (or at least, no easier) to support those with multiple marginalized identities in a model built around a single shared identity category. For instance, although program organizers had scheduled discussions of racism and sexism for different semesters, a student made connections between affirmative action for women and racial minorities during a class discussion of the book *Lean In*, intended to be around students' experience of sexism. The comparison of sexism and racism (made by a White female student) created a minor awkward moment in the seminar, but more broadly it highlighted how the planned separation in programming may not accord with students' lived experiences. Drawing on these observations, I have come to question the ways in which institutional diversity support around women, racial and ethnic minorities, and (recently) LGBT identities may create several unintended consequences for students' awareness of intersections of oppression.

In addition, I conducted exploratory research suggesting that students' critical "theorizing" (hooks, 1992, 1994) about their experiences of marginalization can be agentic and empowering (Secules et al., 2015). A female student participant I interviewed (6 times over 3 years) wrestled with several received and marginalizing cultural messages (e.g., "Women are at risk in engineering, and their strengths and styles are not valued"). By naming and repurposing these marginalizing messages, the student seemed to gain agency in her continuing in engineering education. Reflecting on this collaborative research, both the student participant and I have noted resonances between our one-on-one work and the work of the diversity support programming she engaged with (she was also a member of the Women-in-Engineering program we evaluated and mentioned above). However, at times the work of critically processing marginalization was subsumed by the group's support efforts aimed at institutional goals such as retention and high performance, by boosting academic skills and supplementing cultural capital. When supplemental support and advice (e.g., about appropriate professional dress in a conservative masculine department) was decoupled from a critique of oppressive cultural norms and forces, it could be heard as patronizing and less than empowering. Drawing on these observations, I see a potential for diversity programming to center its work more strongly around supporting students to "theorize" across identities of marginalization, as well as privilege.

Project Focus: This project will conduct design research to develop a new form of diversity support drawing on an inter-group and intersectional view towards participants, and with praxis and theorizing as a guiding lens to the programming.

Participants: The selection of an institutional partner would be on the basis of alignment with or openness to the goal to shift towards intersectionality and praxis. Seeing this effort as in line with, rather than competing with, traditional programs, I could choose to work within existing support structures if the leadership is open to it, or I could partner with a school who has an underserved population (e.g., no support structures for LGBT, disability, or low socioeconomic status students), or I could enlist student allies from dominant identity groups.

Methodology: The methodology for the project would be ethnographically-informed participant design research. The project would use ethnographic methods to document participant sessions, utilizing a media form (post hoc fieldnoting, audiotapes) that is practical for the researcher and comfortable for and consented to by participants. The researcher/instructor would document reflections and observations as the group progresses, in order to aid in telling a progression story to a wider audience. In addition, the researcher would incorporate written reflection and select participant one-on-one interviews to help assess the value of the effort in the lives of the students.

Intellectual Merit: The project will enhance understanding of program creation and new forms of diversity support, which form a productive addition to, not a replacement of, current forms of diversity support.

Broader Impact: The project stands to have a transformative impact on diversity support efforts in engineering, by reaching students outside identity boxes, engaging dominant identity groups in conversations on marginalization, and assembling a critical mass towards transforming an engineering department.

**Closing Commentary and Intellectual Progression and Purpose**

Contrary to the appearance of order and intention present in grant proposals, I acknowledge that many of the most innovative aspects of this dissertation have developed through happy coincidences. I was placed in certain research contexts (e.g., a grant aligned well enough with my interests, a course project which asked me to interview students) which soon revealed certain interesting dilemmas worthy of understanding further. I was exposed to certain theories (e.g., McDermott, bell hooks) which helped guide my thinking about the contexts. Certain logistical difficulties with accessing diversity practice have led to thinking about how my research observations outside of these domains intersects them in new and interesting ways. Certain logistical difficulties with a dissertation entirely based on cultural construction in classrooms have led to this final dissertation form as a fruitful blending of multiple approaches.

So I will not be surprised if these proposed project plans shift and if circumstance and surprising inspiration still play a pivotal role in the way my future work plays out. On the other hand, perhaps the development towards intentionality parallels a series of personal intellectual progression: from exploratory to political, from intellectual to concrete, from sideline commentary to frontline engagement. In Chapter 2, I posed certain questions to myself about how to pursue work focused on marginalization in education in light of a complex interplay of factors affecting my researcher positionality and identity. In this final section, I will attempt to answer these and chart an intentionality around my own scholarship and praxis.

***Identity and Purpose in Diversity Worlds***

> *Anthropological work must begin with, but not stop with, a celebration of their resistance. For their resistance to what they cannot ignore also reveals the hegemony of all the institutions that originally constructed their problems.*
>
> Ray McDermott and Hervé Varenne, in Culture "as" Disability (1995)

Previously, I raised the possibility that rather than a simple intellectual choice of framework, the way we approach scholarship on marginalization in education may be a complex interplay between factors such as researcher voice, epistemological stance, ontologies of culture, research context, purpose in relation to a current literature conversation, research traditions and lineages, and social identity. It may be that in some cases we are conscious of the alignments and commitments we are making in our work, and in other cases they blend together. Perhaps a particular writer resonates with a reader and he goes down a rabbit hole exploring their work, only to later think about the overlaps in purpose and ontology which helped support the resonance (e.g., me and McDermott's work). Perhaps a set of close colleagues works in a certain tradition and carry the set of purpose and intellectual commitments which are associated with this scholarship (e.g., a group of STEM Education scholars in Cultural Production).

My roles in this dissertation primarily took up Cultural Construction and Liberatory Pedagogy approaches[24]. The quintessential Cultural Construction ethnographer is a relatively high-status but critical insider to a setting. It is a role which requires an understanding of the ins and outs of the system and culture, of the logic and language of insiders, as well as a fluidity with language and meaning to be able to resituate it in new ways. I noted that it seemed important that Ray McDermott was at Stanford, a White man, and clearly had a fluid grasp of academic content and language. His critique with Learning Disability was not that he didn't understand it or felt personally affected, it was cultural and functional. I opined that if bell hooks had written the same content, particularly a few decades ago, it might have been read as the ravings of a Black feminist. White men with academic authority may be granted extra permission to make pronouncements about what is and is not culture, what is and is not working with the system in place.

If that is a role I have taken up, as an insider to the engineering discipline who has enough fluidity with language to be able to attempt a McDermott-style critique, I should be wary of how I take up that role. It is a role I think has value and (cynically) may only be heard through certain identities and statuses and writing styles. An 2016 AAA conference attendee interrupted my poster presentation detailing the white, masculine, and competitive histories of engineering to ask if I was an engineer myself, and admitted this helps her trust the research more. I silently acknowledged the irony of needing to be a White male engineer to be making a valid cultural critique about engineering. A few

[24] I also see definite potential for a blending with Cultural Production approaches, such as the idea of wondering how historical cultural context influences interactions in a classroom (Chapter 4), or how culture shapes the consequential interactions of people in power (O'Connor et al., 2016; Varenne & Koyama, 2016).

words of caution, to myself, as I pursue this line of work: I want to make room for other voices which may be grounded in other positionalities and purposes, even when I see critical ethnography as providing unique and intellectually rich insight. I want to engage identity in my analysis, something which other scholars enraptured with a critique of meritocracy have sometimes faltered in doing. I want to balance the critical ethnographic work with political work which applies and engages in resistance.

My second line of work has been inspired by Liberatory Pedagogy, seemingly a fitting antidote to the potential to be an armchair critic who gains accolades for making pithy commentary but puts no skin in the game. I see myself expanding in this role as I gain access to carving my own roles, rather than accepting the received roles of specific assistantships and projects. As with critical ethnography, I think this work has value and requires certain strengths, not all of which I am confident at this point that I possess: an ability to politically organize, and a writing style which embodies the political purpose. I drew on a smaller form of Liberatory Pedagogy, only requiring one-on-one responsiveness, but hope to develop further activist and leadership tools as areas of growth. I have a few notes of caution to myself, pursuing this work: As a White man in a field which is heavily racialized and gendered, I may not always be a natural fit for this role. There may be a perception by others, or even a reality, that solidarity with marginalized participants is not easy or possible. I will continue to draw heavily on empathy and listening, and to find times to state my positions of solidarity so that participants are aware of them. I may need to forge alliances with research partners who are women and people of color and other disenfranchised groups, particularly if I am hoping to have impact on current diversity support practices which are based on in-group identity membership. In this role, I want to be sure to respect the concerns and intuitions of marginalized participants for what they need, and not to divert them in the favor of more theoretically attractive models. I will need to embrace hybridity and humility in order to make progress which stays meaningful and authentic to the positionalities of marginalized participants.

I believe I have found a voice related to the parallel projects of Cultural Construction, as emergent critical ethnography blended with an analysis of historical contexts of power, and Liberatory Pedagogy, as a political orientation of solidarity in oppression. These ways of approaching marginalization will continue to be the overall orientations suffusing my future work. As I bear witness to students' pain and celebrate their resistance, I will nevertheless work to expose and critique the hegemonic culture and institutions that originally constructed their problems.

## Appendix A: Constructing McDermott's Cultural Analytic Framework

Having addressed something of the breadth of ways research and institutional programming have tried to address the problem of struggling students in STEM, I now more substantially introduce McDermott's cultural construction framework, drawing on text from a comprehensive exam I wrote on that subject. One aspect of applying McDermott's cultural analytic framework is seeing it represented across multiple paper versions, and more importantly, across his life's work. McDermott's powerful case study of Adam began in the 1970's as part of his dissertation research, and then got reinterpreted and reformulated over the course of 3 decades, sometimes in more practical or more theoretical, more research-oriented or more pedagogical terms. Thus his cultural construction framework can be seen as a theoretical view of reality, as a methodological approach, as an analytical tool to dissect any existing data set, or as a persuasive framework to explain results to others. Here I try to account for the history and breadth of the framework's development before summarizing the final iteration which I will draw on.

McDermott's study of Adam's classroom came out of McDermott's PhD thesis in 1977 studying the ways classrooms operate. Out of a research trend in ethnographies of the "concerted efforts" in typical classrooms (H. Mehan, 1979), McDermott investigated what cues students and teachers take for granted and use to communicate to each other what they are doing in order to stabilize an educational interaction, and he particularly focused on student success and failure (McDermott, 1977). McDermott also did work within a contemporary research strand in cognitive ethnography (Jean Lave, 1988), particularly concerned with discussing ecological validity of cognitive psychology (Cole, Hood, & McDermott, reprinted 1997). He wanted to ask (and contest) whether cognitive psychology experiments are in fact "valid" for describing mental task performance in the real world. This work sought to disrupt psychology experiments on the grounds of ecological invalidity: if the psychological experiment context is more restrictive and controlled than the real world, is it telling us anything useful about the way people actually think in every day life? Thus his work in this era was operating along the logic of the psychology experiment to try to disrupt it, and to show that the real world had different intellectual affordances.

McDermott also has a long history of being a methodologist, of considering which aspects of the real world should be brought into a given lens and how to explore them. He has written establishing methodological criteria for ethnographic descriptions of "concerted events" (McDermott, 1978) such as those examined in his thesis. In another 1978 paper (McDermott & Roth, 1978), the authors present a review of research on methods assuming a "person's behavior is best described in terms of the behavior of those immediately about that person, those with whom the person is doing interactional work in the construction of recognizable social scenes or events" (McDermott & Roth, 1978, p. 321). This paper sought research lenses that went "beyond micro and macro" (1978, p. 322) for instance because "The specifics of such socially pervasive facts as gender, ethnicity, status, and role are…'reanimated or creatively affirmed' from one moment to the next by members constraining each other to appropriate ways of proceeding given the environments they have reflexively generated for each other" (1978, p. 323). This gives a clue for how McDermott consistently wanted to understand social forces as locally enacted, rather than the "social" as somehow other and above and beyond the individual. "A careful analysis of people in interaction shows how the smallest and least talked-about strips of behavior can help to constitute and reveal a great deal about a social order" (McDermott & Roth, 1978, p. 324), in other words local interactions are the mechanism for constituting the social (and cultural) order. The paper goes on to highlight a dialogue between a White guidance counselor and a Black student in which miscommunication serves to limit the information provided, which the paper argues is a localized enactment of institutionalized racism, via cultural differences. Already in 1978, McDermott argued against a static conception of individual behavior in a context: context should not be treated as the independent variable and behavior the dependent variable, but behavior helps produce the context and vice versa reflexively.

In a paper which expanded on the methodology concerning interactions, Dore and McDermott (1982) explored what they termed the indeterminacy of speech events. Here the authors advocate for drawing more and more context into a discourse segment. They illustrate positioning and power in a student reading group to show how sometimes the literal words being said may be exactly opposite in meaning or effect in the interaction. Here McDermott's ideas of physical positioning are similar to the types of physical cues that have been used productively in physics education (Scherr & Hammer, 2009) to give clues to what frame students are in, or what they would say is the nature of the activity at the moment. In a critique of purely linguistic discourse analysis, he addressed the indeterminacy of any individually uttered speech event, because what it actually means—for participants, for observers—is continually being contested, checked, and built up in meaning through the course of the local interaction. Later on he comes to see the local interaction itself as also potentially indeterminate, unless one allows oneself to ask questions about and analyze possible broader cultural meanings present in the interaction.

McDermott says his interest in his case study subject Adam began organically out of the work on the ecological validity of the psych experiment in every day life. Since cognitive experiments take as their foundation that there are cognitive affordances and deficits amongst people, this was part of McDermott's initial framing for the study. In the initial formulation (Hood et al., 1980), the authors are conducting what they tentatively call a "person-environment interaction," looking at the particular ways Adam's cognitive abilities interact with arbitrary environmental constraints to produce his troubles. Over a decade later McDermott revisits the Adam case study, this time indeed pushing the analysis beyond the 1980 analysis, and showcasing the multiple layers of analysis he could take (McDermott, 1993). In this paper he treats Learning, Context, Language, and Culture as on approximately equal footing, a prioritization he will shift in later versions to having culture undergird everything. He goes on to suggest a rope and fiber analogy to understand the approach to how to think about Adam: you can only build the rope by looking at the fibers, but looking at individual fibers will not necessarily give you a sense of it being a continuous thread, unless you also keep in mind its broader function (1993, pp. 274–276). He proposes analyzing fibers (individuals, interactional moments) while keeping in mind the continuity of the rope (the context and culture surrounding them). He shows Adam's relative performance in cooking class, school, psychological evaluation, and every day life could be conceptualized on a few different continua:

1) A continuum of task difficulty and cognitive deficit, takes context to be a static variable with which to apply one's cognitive abilities. Adam simply performs worse in contexts that challenge him more.

2) A continuum of arbitrary demands and left out participants (essentially the approach it becomes clear he sees his own analysis as having taken in 1980), additionally takes into account the interactional work of trying harder not to fail at meeting the arbitrary demands, and therefore of disabling oneself further. McDermott notes a previously unexamined detail which explains the slippery slope here—he makes a choice to reveal late in the paper that Adam is actually a White male from a "good" background, and others performing "better" than him on the more arbitrary school tasks are poor and African American. If anyone would be expected to have a cultural alignment with school it might be Adam. We would be left only with Adam's brain for plausible explanation for his failure. When the rubber hits the road, looking to justify performance with differences in background will eventually mean someone somewhere is failing "all on their own."

3) A continuum of degradation and labeled children, where the local context is seen as well organized to produce problems in children. Hypothetically context (social order) can shift in the interactional winds via individual agency, but it usually doesn't, because in fact everyone works hard to organize the social order around ability roughly the same as it started (i.e. via concerted effort). He considers the power of a context to make disability visible. The visibility of the LD is less about the difficulty of the material in a certain context (since every

> context is difficult/complex in its own ways), and more about School's focus on finding disabilities, the concern Adam has not to be found out as incapable, and the concern of other players to find him not capable, or alternatively to ignore it. Language and culture are not neutral media but come loaded with a power structure and define what it is to have and to lack.

At this point in McDermott's intellectual history, he goes on to his most theoretical and celebrated versions of his framework. In his powerful book with Varenne about American School culture, *Successful Failure* (1999), he includes as first chapter titled Adam, Adam, Adam, and Adam (1999a) a reformulation of the 1993 paper on acquisition of a child by a learning disability. It also includes a chapter called Disability as Cultural Fact which borrows from a 1995 paper called Culture *as* Disability (1995). Finally in a 2006 book chapter on educational ethnography, McDermott makes a generalization about the prior cultural analyses to include understanding school failure, inequities of race and gender, and other educational problems as culturally constructed (2006a). Each of these versions presents the cultural construction framework in ways powerful, compelling, poetic, and philosophical. In these works, McDermott advocates culture as the analytical focus of any work on education. The most important move beyond the 1993 version is the primacy of culture, as a theoretical underpinning affecting all aspects of the classroom. It is not just that culture is a part of the mix of classroom stuff that contributes to disability, but that American School culture demands disability, and it finds it via classroom contexts, interactions, and language.

While the structure of the framework I will draw on aligns most with the final (2006) version, I note that the process of retracing McDermott's trajectory is useful for a few reasons. McDermott's later papers are making a persuasive argument for a paradigm shift, rather than outlining a study. Nevertheless the type of setting, data, methods, and methodological choices made during the Adam study are part and parcel of the framework itself. In order to understand the practical application of the framework to an Adamx4 style project, one needs to return to the original sources and to his accompanying papers addressing methodology in detail. McDermott's early papers (1970s-1980s) are a window into some underlying aspects of doing McDermott-style work—including its basis in ethnographic and interaction/discourse analysis traditions. Likewise, if one needs a clear picture of what the progression of cultural analysis looks like, seeing the contrast within McDermott's own work as it progressed from examining cultural differences to treating culture as the unit of analysis clarifies the form and power of the final framework beyond rhetoric.

In this final (2006) iteration of the cultural analytic framework, McDermott emphasizes that all educational problems are cultural problems. The production of the educational problem involves many actors; those who ask and those who answer the question in academic literature, those who in practice recognize and those who are recognized as having the problem, and the many more who support the common cultural understanding of the phenomenon as a problem. In this paper, McDermott proposes a three-stage framework to take different levels of any educational problem into account. In Stage 1, an individual has problems completely on their own; any problems identified are simple evidence of the individual's own intellectual, moral, cultural, etc lacks. In

Stage 2, an individual experiences problems on the basis of social structures much larger than them; and any problems identified can be explained as the natural result of having been socialized to occupy that position in society. Finally in Stage 3, the problem is created only via the concerted effort of many actors in a culture which imbues meaning on the problem; any problems which are able to be discussed must have been noticed, measured, compared to a norm, reported, discussed, and accorded a shared meaning and importance.

## Appendix B: Preliminary Interview Protocol for Chapter 3 study

***First Block: Intro/Attitudes/General scoping*** *The purpose here is to get to know the student a little bit. Get at their background in coding and how they relate to those past experiences. And getting at their motivations and expectations for the intro-programming course. And a quick check on how they relate to the programming course in terms of their career. We cycle back to this later.*

*Could you say a little bit about why you joined the course?*

*What previous coding classes or other experiences have you had?*

*Follow up: What do you (what else do you) expect to get out of the course? How do you expect what you get out of it to be the same and/or different from what you'd get out of ENEE140 (only for ENEE148 interviewees)?*

*How do you think the course is relevant your future (career choice, major, etc)?*

*How is the course going for you?*

*--Follow-up. What do you think makes this course hard? (For you personally, or for others.) Confidence level as coder?*

*Anything you are enjoying (or not)?*

*- Follow up: If in any of the previous questions ENES100 comes up, pursue what connections they see or not with the programming-course experience.*

Decision: Pursue self-efficacy as needed/relevant.

***Second Block: programming epistemology***

How do you decide if a code you have written is correct?

If something is not quite right, how do you proceed to troubleshoot?

How important is it for you to know the C-syntax by heart?

How important is memorizing C syntax.

How do you start out writing a code, for say, a HW assignment?

*If two students both write correct code, could one of them be "better" than the other? What makes code "good," besides working?*

**Decision: make a call for going to third block or fourth block here.** *If there is only enough time to pursue coding (say around 20-25 minutes left) or if you feel that the student is itching to show some coding chops, or if it just naturally leads there, then first skip to block 4 and then come back to block 3.*

***Third Block: More Epistemology + Identity***

How does the problem-solving experience in the programming class compare with problem solving experience in other classes (*If this comes up naturally in the first batch of intro questions, then probe that there; if not, then come back to this after the programming-specific prompts)*

Follow-up: Something about the group-work aspect. What do they get out of collaborating?

*Follow-up:* Specifically probe comparison with ENES100 or engineering project experience.

Do you think that knowing how to code is important for your major? Follow up: for a professional engineer?

Do you feel part of an engineering community? Follow up: does this class (or experiences in this class) contribute to that sense?

Would you consider what you're doing in this course to be 'engineering'? In what ways yes, in what ways no?

***Fourth Block: Actual Coding***

Would you be willing to try your hand at coding something right now? (if "no," explore the hesitation: could you tell me more, what makes you hesitant?)

If "yes" --

1. Write a code segment to program the thermostat at home at 68-degrees.

Alternative Statement: You want to keep a room's temperature between 75 and 80 degrees. You have a fan, heater, temperature sensor, and a programmable microprocessor (like an Arduino or Raspberry PI or MIT handyboard). Write a program to maintain the room's temperature within the desired range?

2. Write a code segment to program the cruise control system in your car

3. Imagine two arrays of positive (non-zero) integers. Each array is terminated by a 0 (zero). Write a program to concatenate those integers into a single array of positive integers (with the single array terminated by a 0).

Write a code segment to program the cruise control system in your car

Write a code segment to program the thermostat at home at 68-degrees

# Appendix C: Long Form Cultural Construction Analysis

**Who is here?: Deconstructing Social Labels**

Yes, the broader socialization patterns in the US filter into the classroom reproducing inequities. Women and non-Asian racial minorities aren't found as often in engineering, particularly not electrical and programming (Margolis & Fisher). But these aren't static qualities of individuals indicating a predestined way of acting; they are culturally defined and socially enacted. More so, we could say each individual who enters the engineering classroom has a race, a gender, a religion, a political inclination. All of this information could be noticed and made salient at any time. Yet in this engineering class there were a few dimensions of individuals in particular that seem to come up immediately and repeatedly, as McDermott observed, they are "in the air."

There was yet another localized demographic category that had a significant impact on the educational experience in this class: students with or without programming background. At first glance, this might sound counterintuitive: shouldn't students in an introduction to programming course by definition not know how to program yet? In fact, students arrived with a wide spectrum of programming experience. A few students are [1] here with no programming experience, but most having some degree of exposure to programming. Some have learned another programming language before (Java and Arduino are common), others have already taken a C++ programming course but without the required AP Computer Science or State University placement test score to pass out. Some of these students with prior experience perhaps could have satisfied their degree requirements without having to register for our focal course, but did not try or did not know that was a valid option. If you're a student who already knows how to program and if grade performance matters (to you, to your department, to everyone around you), why not play it safe and give yourself an easy A this semester?[2] With privilege comes the agency to choose between good and even better options.

Becca has "no programming background" (and was not even sure what the word programming meant when she enrolled). Although hypothetically this label is not a problem in this "introduction" to programming, and hypothetically she is the ideal candidate for making great learning strides, in practice the lack of a programming background quickly became a deficit background of the individual, in comparison to a majority of the class who seems to already have at least some programming background. But "no programming background" is not a trait of Becca; she cannot be "no programming background" on her own. The effective label and material reality of "no programming background" is a cultural construction in McDermott's sense: requiring an economic system which values programming as an important skill for engineers and a time period wherein programming has achieved partial normativity in the educational preparation of incoming American undergraduate students. In addition, its power depends on the socialized differentiation of programming ability amongst lines of privilege associated with gender, race, and socioeconomic status. It is almost inconceivable to worry about a systematic socialized deficit of rich White and Asian men to do a valued engineering skill (although there is plenty they do not typically do as well as other groups that may be valuable in engineering), they are 'by definition' culturally prepared for STEM careers. Finally, "no programming background" only makes sense in this and other similar educational settings; it requires a set of particular students on whom these differentiations have become locally inscribed, and a local classroom setting where the label has salience, meaning, and value (you cannot, under normal circumstances, be "no programming background" in a grocery store). For all of these reasons and more: "(no) programming background" is a cultural construction, requiring many actors in a system to produce it, and requiring a culture to inscribe its meaning and value solely to an individual in the system, while masking the role of the multitude of other actors involved.

There is another major category of students at play in shaping this classroom: engineering majors versus Letters and Sciences (LTSC). This class is an introduction to C++ programming course for electrical engineers, and a special course offering (this course is offered as an alternative to a more traditional introduction to programming lecture course), incorporating new technology, Raspberry Pis, for learning programming in the context of micro-computer controlled circuits. It has attracted several students because of this new technology, who are already on the upper end of the programming experience spectrum. It also attracts students who are institutionally marginalized, with the institutional label of Letters and Sciences (L&S). Mostly L&S students consist of undecided majors or students who were admitted to the university but not the limited enrollment engineering department. L&S students, depending on their grades in first year classes, have options for joining specific majors in year 2. L&S students have difficulty registering for classes given certain institutional policies, thus the fact that this special course offering was lesser known meant that it still had seats open at the last minute. Thus two very different forces were pulling students into the classroom. One group came because of their interest in the technology of the class, the other because it was one of the only doors left open by an institutional gatekeeper.

Letters and Sciences could also be seen as based on individual merit (admissibility, SAT scores, GPA, prior education), but is again not owned or produced by the individual, it is fundamentally a cultural construction, which perhaps more accurately "acquires" (as per McDermott, 1993) a certain subset of the incoming undergraduate population. It is primarily a label and an induced material reality (of restricted access at the university), which resides at the clash between a large institution of public education with continued policy demands of enrolling more STEM majors, and the limited resources of a department which finds it needs to be more selective than the institution. The engineering department exists within an engineering discipline which perhaps also has a legitimate concern with remaining selective and elitist to some extent: if everyone became an engineer then its status as a discipline would decrease, along with the desirability and job security of its graduates, etc. Likewise the engineering education enterprise exists within the milieu of dominant meritocratic and individualistic cultural values of American School (Varenne & McDermott, 1999), the metrics and strict standards of admission to engineering departments can be seen as masking the systematic consolidations of power of those who are best positioned to be admitted.

Gender, race, programming background, L&S—these were major overlapping social categories, and in that they connect to forms of power, they are also systems of oppression which reinforce one another. They inscribe overlapping power relationships onto the individual identities of this classroom: all of the women in the class were enrolled due to L&S scheduling issues, two of the women had little to no programming background. Becca had three marginalized identities: a White woman, currently fighting her way into the department from L&S institutional status, and no programming background whatsoever. In comparison, Sam was a White male with one of the most substantial programming backgrounds in the class. He was also institutionally idiosyncratic, but in a way that aligned him with power in this class: he was a "special advanced student" returning for a second undergraduate degree after already finishing a degree in math.

As social constructions in a broad sense-- gender, race, programming background, institutional registration status-- one might argue that these are only theoretical categories imposed, say by the researcher. On the contrary, we saw that these categories were "already there" in the classroom before anyone took their seats or spoke about them out loud in the space. How do social labels become material that structures a view of the classroom? A professor concerned with promoting diversity was worried about these categories-- in this way the actors attuning the professor to these differences include even this research team and the well intentioned researchers in the literature review. Feminine names on the course roster (available in advance to the professor) and feminine bodies in class, can be (and are) quickly counted, in this case 3 out of 29. A roster letter code next to each name will give an indication of institutional status. Codes on a typical roster: ELEC if already an electrical engineering major, LS if not, and perhaps a CS (computer science) major taking the course as an elective-- in this case by day 1 of the class just a few non-ELEC codes including one LS. (Interestingly, the roster label and social category of LS did not correspond to all students who had arrived because of Letters and Sciences registration reasons. Many of the students had recently been accepted as full electrical engineering majors, so their registration difficulties over the summer which brought them into this class were not as public as they were for Becca, who still embodied the label.) And, in this case, all students in the classroom were White and asian. The fact that this renders race mundane as a dimension of students shows just how remarkably racialized engineering classrooms are.

We argue that these social labels, loaded with history and connotation, are elements of the interpersonal framework the professor (and to a lesser extent the students) had access to in framing their interactions. But far from taking these as predestination based on socialization, we now turn to examine the ways that these labels were embodied, acknowledged, performed, and thus, (re)constructed in classroom interactions, ultimately contributing to the production of educational facts about who is or isn't cut out for engineering.

**Bodies in Seats**

A State University engineering student upon first walking into the EE 135 programming lecture would have found little surprising in the setting. 40 old-fashioned wooden and metal desk chairs are arranged in 6 rows, leaving the 30 (soon to become 29) students left to arrange themselves with a few seats left over. Some sit in the last row, and presumably they know that this will communicate some subtle lack of interest or no need for instruction. Most fill in the front few rows with few gaps in between. Does a front row seat communicate an eagerness for the subject matter? A worry for keeping up? Even if the student selected the seat simply so they could see the writing on the board better, their seat selection can be an early building block in constructing a status in this classroom.

| Desk and Desktop |
| --- |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | Smartboard |
| | M | M | M | M | M | M |
| | M | M | F | M | M | M (Sam) |
| | F (Becca) | M | M | M | M | M |
| | M | F | M | M | M | M |
| | M | | | M | M | |
| | M | | | | | |
| | | | M | | | Researcher |
| Door | | | | | | |

Figure: Typical seating layout in EE 135

As noted, gender was the primary physically visible demographic category of salience in this setting, and insiders to State University engineering would quickly become aware that there are three women in the class-- and that they are all on the left side of the lecture classroom. Some take up the back and left-side seats closest to the door: they arrived after class started and didn't want to draw attention, or they only have 10 minutes to cross campus to get to a class afterwards and need to make a quick exit. A more accurate though less immediately visible demographic description of the classroom: in general the most experienced programmers (men, including Sam) sit on the front right side of the classroom near the smartboard and the less experienced programmers (women and men, including Becca) sit to the back and left sides near the door. Seating patterns began to map out and mark these dimensions of epistemic power, and they created the circumstances for differential experiences of the lecture content.

Although a small classroom, the physical distance from the closest to the furthest seat meant that screen text was orders of magnitude smaller for students in the rear left. This became particularly apparent in the switch from PowerPoint (which typically used font sizes appropriate for a class presentation) to code implementation (which used the default font sizes of a programming IDE). An unfortunate educational micro-inequity, since many students attest in interviews that the code implementation portion is the most useful and interesting part of lecture.

The professor, Phil, usually starts class on the left side of the classroom as he discusses course logistics at a desk with a desktop, but quickly gravitates to deliver most of the lecture content from the right side of the room next to the smartboard PowerPoint projection. The front and right side is the “center” of this classroom: from those seats, a student can mumble a reply or make a comment without raising their hand. When the professor checks informally whether students are following along and understanding things, he can literally only hear the few students nearest him and the smartboard. Students on the left side of the classroom are usually out of the loop, missing some of the mumbled content and requiring the more official and visible (thus, socially risky) hand-raising for all participation.

Does the professor gravitate to the right only because of the smartboard, or because, as the semester progresses, he enjoys talking with advanced students? Do the experienced and inexperienced students take their respective seats by coincidence, or are there subtle hierarchies at play in where a student feels entitled to sit and what conversations they can enter into? Or perhaps they are sitting in friend groups that coincide with power relationships? Perhaps less programming background correlated with a course schedule (for example, for L&S students) that necessitated a seat near the door to enable a quick exit right after this class was over to race across campus to another class? In any case—the seating arrangements organized around programming background took hold quickly and were not disrupted over the course of the term. The Power Point, the professor, and the effective center of the lecture classroom, pivoted around the programming-experienced students.

What we mean to illustrate through this discussion of the bodily arrangement of students in the classroom is how seemingly benign aspects of the classroom such as who sits where can reinforce narratives of student competence, and in little ways fuel mechanisms by which some students have greater access to the content on the board, the attention of the professor, and/or to displays of disciplinary proficiency. These little mechanisms, however, as we show in this paper, in conjunction with myriad other happenings play into the emergence of more stable inequities in who is seen and sees themselves as belonging in the classroom and cut out for the discipline.

**A "Crash Course" "introduction" to C programming: Lecture Content and Jargon**

With this setting of the classroom we come to the first set of lectures, a two-week 108-PowerPoint-slide "Crash Course in C Language." The content of these first two weeks is what it sounds like: a fast and comprehensive overview of the different functions and commands one might use in C language, sort of the toolbox they can use. That is, for the first two weeks of a course titled "Introduction to C Programming for

Electrical Engineers," the professor is giving a "Crash Course" in the same programming language. This is the pedagogical equivalent of starting one's first history class with a quick crash course in the entire historical period including lists of all vocabulary and events which will actually be covered later. What is a helpful overview to someone with a baseline understanding will inevitably be overwhelming to someone without one. These quotes from the first slide of the "Crash Course" provide the professor's rationale for this approach:

> We are going to take a quick look at C through a sequence of short (but increasingly complex) programs. This way, you will get a flavor for what is possible and quickly be able to write and run your own programs.
>
> In the chapters that follow, we will take a more exhaustive look at the main features introduced in the first chapter.

Again, I liken this "get a flavor" for full example programs approach to starting an introductory Spanish class (with some native Spanish speakers, some bilingual in a similar language, some who only speak English) by speaking in Spanish about parts of speech and idioms. For students who already know the language (Spanish, C++) this is a pleasant review, for students who already know another similar language this is perhaps a useful introduction to some specific nuances that are different from what they already know, and for students who know nothing about programming / speaking a foreign language it is mostly meaningless and overwhelming.

An example slide from the first week Crash Course shows that by only Slide 27 (covered on the first or second day), the second example features an entire program with fairly high level content:

Slide 27

```
/* example #02 electric field calculation
* Written by Phil
* Version 1.3 Last updated Sept 3, 2014 */
#include <stdio.h>
#define CHARGE -1.602e-19      /* new feature */
#define EPSILON_0 8.854e-12
#define PI 3.141592654
```

Slide 28

```
int main(void) {
  float e_field, radius=.0025;    /*new feature */
  e_field=CHARGE/(4.0*PI*EPSILON_0*radius*radius);
  printf("Electric field at a radius %f = %f\n",radius,e_field);
  /* this printf has more than one argument */
  return 0;
}
```

If some of the terms and format here seem like unexplained jargon to those of our readers less versed in programming syntax, so it is for the student without any programming background. The subsequent slides break out parts of this code and add vocabulary and conceptual lessons, for example:

Slide 29

```
#define CHARGE -1.602e-19      /* new feature */
#define EPSILON_0 8.854e-12
```

```
#define PI 3.141592654
```

Pre-processor directive “define” generates symbolic constants. Constants are replaced in code by numeric values before compilation.

No equal sign and no semicolon

Convention for constants: use all uppercase letters

Good programming practice: use symbolic constants often!

The order of getting a whole program first, and deconstructing and discussing it second is a pattern used throughout the “Crash Course”, and it favors students with a basic foundation in programming. Slide 27 is almost entirely meaningless for a student without a programming background. Slide 29 is intended to explain Slide 27, and breaks down 3 lines of the code with further explanation. Yet it continues to use so much jargon that it would be hard for even a somewhat experienced student to follow it: “pre-processor directive,” “generates symbolic constants”—what are hypothetically the explanations to the more opaque “define” terminology are in fact jargon-heavy ways to explain simple concepts. While the Crash Course ended after two weeks, this sort of jargon continued to dominate the PowerPoint slides and spoken lecture content. Again, we don’t mean to highlight these to critique the instruction; these slides would be pretty standard of introductory programming courses throughout the country. Our purpose here is to help the reader get a feel for what a student with less programming background might experience in such an “introductory” programming course at the university. In some sense, the lecture slides function to highlight for those those students their lack of background, when none was required as prerequisite; instead of increasing understanding, they potentially generate anxiety.

As expected, student interviews and survey free responses consistently reported that the first two weeks were the most stressful for students like Becca without much programming background. All students found lecture in general to not be a major space for learning but they did use the lecture PowerPoints as reference materials to study for exams. Looking at the level of jargon in these example slides, this use as a reference material looks extremely plausible—it would take a glossary and a bit of meditation around Slide 29 for it to become clear, particularly to the newcomer. Is this a lack of foresight? An unintended consequence? Or is it consistent with a course that is not designed to "introduce" someone to programming as it purports to? The intended (but unofficial) target audience for the class is students who have at least some programming background in another similar language.

While the Crash Course ended after two weeks, this sort of jargon continued to dominate the PowerPoint slides and spoken lecture content. Lectures that are above the level of some students in class are perhaps not uncommon in undergraduate engineering. It is a supposed meme of academia that professors have their head in the clouds, are thinking on levels "above" their students, and find it difficult to engage with student where they are with their initial understandings. Perhaps all the more so in technology-focused engineering lectures than in more discussion-based disciplines. It is not a coincidence that the way Phil understands this content is more closely aligned with students with more programming background / academic privilege. But what could otherwise be an isolated pedagogical emphasis can be seen as a further building block in establishing engineering ability, via inequitable access to the basic content of the class.

One additional dimension to consider about these lecture slides: in an impossibly "ideal" classroom management scenario, if 100% of class time was devoted to the professor delivering and students clarifying the lecture slides, they would still have to do so at a fairly fast clip: 108 (dense) slides of the Crash Course were scheduled to be covered in a maximum of 200 minutes (four 50-minute sessions) of lecture time in the first two weeks. The time spent on a lecture slide with a example code is another critical aspect of equity, as "experts" in a subject will tend to "chunk" the content in different and more efficient ways (Chi, Feltovich, & Glaser, 1981), they can see structure and purpose in code in ways that "novices" will not (for example, why does it make sense to break off the first three lines of the code as a chunk?). Although Phil the professor produced the lecture slides in this content-packed manner, it was not necessarily due to personal whim. Phil is also highly constrained by his position in a system: as a special course offering this class had to contend with the expectations for what students would learn from the typical introductory programming course, while offering its new content in addition. Engineering departments are often conservative in this way, as perhaps many educational institutions are—new content on cutting edge technology is welcome and encouraged, but not at the expense of any of the previously held fundamentals, particularly not ones built into the traditional course progression. The result, it seems, is stressed teachers delivering overstuffed syllabi content in under-allotted class time to overwhelmed students. More is not always more.

In reality, the lecture was typically not used to maximize the time for delivery of these lengthy and dense PowerPoints. Next we turn to the lecture as a social interaction, including how class time usage became the next building block in the cultural construction of ability.

**Lecture games: "That's way beyond the scope of the class"**

Next we turn to the lecture as a social interaction, including how class time usage became the next building block in the cultural construction of ability. What we find is that the lecture was typically not used to maximize the time for delivery of these lengthy and dense PowerPoints. We start with an example day to illustrate some aspects of the classroom interactions and present interview excerpts to triangulate our interpretations of those events.

So how did Phil, the instructor, use his class time? It might be more accurate to ask how students and the instructor jointly construct their class time. There are 29 of them and one of Phil. Although Phil has some authority and power in this space, he also has limited control. If the students wanted to do something different than Phil did in the class, he would at least have to spend some amount of time responding and redirecting them. The classroom is a social space, and as such no individual has full agency, no one should get full responsibility or blame for any event, and every individual has some agency to affect the space. We intend to look at a sociology and anthropology of this classroom, to see what happens and who and what has helped shape those happenings.

One day mid-semester, students are engaging Phil the professor in a time-honored mid-semester tradition: asking what material will be covered on the midterm examination. Phil says, "Good question: Chapter 5, or the notes from today." Instead of the Chapter 5 content that he alludes to, for 45 minutes out of 50 Phil primarily discusses and fields questions on 1) course logistics: lab materials he has been working on, quiz feedback, midterm approach, sample tests on ELMS, office hours reminder, curve, traditional programming course pace comparison, and 2) lab content delivery in preparation for a servo lab: PWM, duty cycles, magnetic sensors, clocks, servos, stepper motors. He loses track of time for presentation of the final content which will be on the midterm, until the last 5 minutes of class. We know these things happen in real and non-idealized classrooms, but how and why do they happen in this case, and what is the effect? While much of Phil's first set of question topics were driven by a variety of worried students coordinating pre-exam logistics with their instructor, the latter set of topics were primarily driven by responding to advanced students asking questions on technical items related to the servo lab.

Phil is introducing servos and duty cycles for the upcoming lab. He draws a stepwise function on the board, and asks a follow up question: "What's the name of the duty cycle length, for those with experience?" A student with programming experience takes the cue to volunteer and supplies the correct answer—"Period." Perhaps the cue for experienced students to volunteer prompts another advanced student to interject with a seemingly related question, which is actually a diversion from the lab content discussion: "How does the clock work?" Phil responds with a winking admonition of the student:

> "My god, take another class. 244, 120-- I'm not sure what is taught in each of those depending on the lab. There are different ways. But it's way beyond the scope of the class. Basically there are certain types of crystals that are unstable so they go up and down and you can connect them to create a high and low switching state forever…"

Phil is conscious of not wanting to waste class time, and in his joking exasperation he acknowledges this has become a pattern of student questions that end up having a time-wasting effect. He admonishes the students in a way that contains no teeth of actual disapproval, in fact joining in the game of wasting class time by revealing what he knows on these subjects. His admonishments also contain subtle praise and reminders of the students' ability to ask advanced questions. For instance after several minutes and additional advanced questions, he cuts off the conversation by saying "That's as far as I go on a good question but outside the scope of the class. No more questions outside the scope of the class today." Several students laugh, at the professor's play disciplining.

As I would find out, at least some of these students were consciously playing this game. One student, Brad, commented in a private interview on how it was fun seeing how far they could get the professor to go astray from the day's lesson. From his point of view, the game involved finding an advanced word or concept or "crazy questions" you think probably relates to the day's content, and then finding a way to "weave it into the discussion." From my point of view, playing this game was exclusively available to students with a programming background prior to the course, those who knew of words and concepts beyond the current or previous topics in the course. So the rules of the game were not just stacked in one group's favor, but also the playing field was located in the physical space and social rapport shared by the programming-experienced right side of the classroom students with Phil. These were students for whom time on ordinary content learning was less vital and more boring. Playing this game was more fun than lecture, winning at this game had the added benefit of projecting one's own ability to ask an advanced question.

Sam was good at playing these sorts of games (whether he was actively trying to or not). On the first day I observed in the lecture, there were some dense equations written on the White board from the class that met in that room before this class. While the professor was erasing them, the students and professor were discussing how difficult they looked, how they weren't even sure what they meant or what subject they were. Sam interjected casually, "It's 380," a much more advanced engineering course number. How did this student know what all the other students and professor were wondering about? Did he simply know that the course which came in before theirs was 380? The implication was that he had somehow deciphered and was familiar with the equations, he knew what they meant, he knew where they were located intellectually and who would be writing them. It was a prominent early moment in making ability visible. Sam showed himself to be consistently able to perform this ability. And he could do so in a most effective way, casually and confidently; he didn't always need to raise his hand if he knew his question was good or his answer was right.

Other students noticed who was winning at the classroom games. Peter, a White male, who felt mid-range on the class's ability hierarchy, described to me in an interview how he saw ability in the room:

> The professor will ask a certain question and someone will have their hand up and they'll answer it and give them-- or ask a very in depth question that shows not only do they have the grasp of the knowledge but they are very far ahead. Um, also there's certain attitudes that I think a lot of people put on-- like-- it's the way they sit-- there are certain people in the class who are leaning forward with their pencil and looking at their board, cause they want to know everything that's

> going on they're hanging on the professor's every word; and there are certain students who are kind of laid back and will just call shots.

Peter is acutely aware of how in his view a student constructs ability in this classroom. Peter sees, with an ethnographer's keen eye: some questions aren't really questions, some questions are statements of the ability to ask a question. Some answers aren't students answering questions they think they might know the answer to, they are ways to sneak in vocabulary words and talk in depth on a subject that is more than a student in this class is expected to know. There are students who "lean in" and students who lean back and "call shots."

Some students don't lean in or lean back: during these advanced question and answer displays Becca often puts her head down instead. She tells me in interviews how she actively avoids the advanced topics so she doesn't get herself more confused. But her confusion isn't because she can't understand programming lectures, it is a natural by-product of students playing this sort of advanced-question-and-answer game, it is designed to steer class time to stuff just out of her reach. Mixed into that game is a signal for who can play and who can't, and those who can't play don't just lose out on some understanding of primary or tertiary technical content, they receive an embodied reminder for just how uneven this educational playing field can be.

In the end, Phil runs out of time for Chapter 5. Maybe he didn't need to test Chapter 5 on this midterm anyway. He was being responsive to student questions, and his class that day was engaging and fun for many of the students. But which students, exactly? When does an advanced question rob another student of a basic explanation? What does equity in this classroom mean? When do students have equitable access to ask a question? When is the localized social hierarchy giving certain students access to decide how classroom time is used? Are all questions equally valuable in a time-compressed lecture? What space should be made for “How does a servo clock work?” versus “What will be on the midterm?” versus “Could you go back one slide?” versus “I really just don’t understand *if* statements yet.” What does an instructor do to intervene in or co-create these classroom norms? Further, what sort of culture produces the classroom game Brad described? Or perhaps, what makes it fun? Is it just a waste of time, or are there more serious stakes behind the game for Sam and Brad and Peter, stakes that prompt Peter to become such a good study of its rules? What blinds the student players (conscious participants or not) to empathy for the students they know in the class might really need to hear the lecture content in the time allotted, the students who can’t play and wouldn’t find this game fun? What are the consequences for those students who can be seen not playing? In that both advanced students and the professor enjoy the game, it creates a visible insider group that marks the students with academic status. From the students’ perspective, it is a fun distraction; from the professor’s it is a fairly harmless waste of time and indulging a healthy curiosity in the subject. From our particular sociological and anthropological lens, the outcomes of the game are to make visible an ability hierarchy based on programming background, one that may have major consequences for student positioning and trajectories in engineering.

**Engineering abilities constructed and coopted in individual lab work**

Lecture classes with these sorts of dense PowerPoints and advanced question games—these are the mundane everyday contributors to ability in engineering classrooms. In my view, they are common in more or less recognizable forms across

State University, across the country. Many students have had similar experiences in high school, in other college classes, some of them will have them again in graduate school. Typical programming classes are instructed primarily through lectures of this sort. The "learning by doing" of programming is through homeworks and projects. A TA-led discussion section is often scheduled for extra help, but the primary focus is on what the student figures out for themselves, in their dorm rooms on their laptops. This is the way programming has "always been done," if that is even a useful description in a field so young. Lectures more or less like these are the primary educational material throughout most programming classes in undergraduate engineering departments.

The purpose of this class however, and the reason I was even present in the setting, was to explore a new pedagogical option—a lab-based project-based class would use Raspberry Pi microprocessors to teach programming. Programming would be embedded in "real world" engineering tasks. Instead of programming a black jack game or a webpage, students would light up LEDs, detect magnetic fields, and navigate mazes using distance sensors. The novelty of this pedagogical component is what funded the research that brought me into contact with it.

Rather than alone or with friends in their dorm rooms, students learned to program in three 10-person lab sections, for three hours each week. Student desks were arranged around the perimeter of the room facing the walls. In general, lab was a public space. Students are packed in close to each other, each student has a lab partner right next to each other, and even a student with their back to another student can basically see everyone else's progress if they want to—who is walking up to get the materials for the next step in the lab, who has finished early and left already. Familiar patterns of which students finished first could be observed, patterns which mapped once again primarily onto students' prior programming background. You can choose not to look around and compare with your neighbors, but you can't particularly choose what you hear. If the room is quiet, the mere sounds of people troubleshooting and celebrating successes will inevitably send messages of where other students are on their assignments. Alongside the unique pedagogical affordances of the space, in this setting everyone ends up knowing how everyone else is doing. In a public and collaborative learning space comes the public display of ability.

Becca is in a lab section with one other woman, Diana. On the first day of Becca's lab section, the TA chose to have all students name their programming background. Becca, Diana, and one other male student raised their hand. This moment became salient to Becca, and the professor once she shared it with him. Several in the class came to believe that 3 was the accurate number of students without programming background, although my own observations have uncovered that other students in the class had the same or less programming background than Diana, who had learned Arduino in a prior class. If nothing else, this is the clear interactional construction of a perceived programming background into a form delineating something other than actual programming backgrounds. And once programming background became public, particularly in the lab section and to a lesser extent in the whole class, it increases its potential to map deficit and explain the educational fact of engineering performance.

Diana and Becca were conducting an individual lab next to one another. Two male teammates were on their left and right sides respectively, Albert was next to Diana and Neeraj next to Becca. Sam was behind them and facing a wall perpendicular to their row, paired with other students. Students are setting up their circuits and trying to get them working. Typically students are checking several details of their circuits as they go, to try to avoid making mistakes. There are few conceptual conversations going on. Becca checks with Diana if V-out should go to the resistor; the resistor should go to ground. The direction of questions and the direction of advice are flowing in predictable orders: in general, Diana advises Becca, Becca checks understanding and next steps with Diana. There isn't much discussion here of why do we need a resistor here, how did you figure that out? It is product focused, it is working-product focused, and the primary measure of success is apparently for each student to produce identically working circuits. I don't think this is a pedagogical failure of this class, I think this is a common approach in engineering, probably what a lot of engineering debugging in classrooms looks like if we put a video camera on it. Engineering disciplinary culture is justified in being product focused, it is a discipline that needs to design and create and implement. Without blaming students or TAs for this approach, it could leave us to raise questions around both learning—is asking basic implementation questions to reproduce identical circuits really the thing we want to have learned in lab moments—and equity—if advanced students are only sharing products of their own thinking with less experienced students we are almost guaranteeing the less experienced students do not have access to the deeper conceptual understandings of advanced students.

There is a problem in the lab today, and several students around the room are independently verifying that there must be a software problem, a problem with the code. Students are all a bit stuck, they are walking around and checking over the shoulders of other students whether anyone has figured out this piece. The TA appears a bit stressed and flustered. While trying to fix a hardware element he thinks could be contributing to the problem and simultaneously explaining his actions to the students, he trails off mid sentence and never returns to the explanation. Individual lab days are hard on the TA, and it is a threatening social position to try to remain in authority while quickly racking your brain to find the source of the problem before your students intellectually mutiny.

Inside this mini social pressure cooker, the student who makes some progress will end up with a moment of increased status. Diana makes headway at two distinct moments. First she does a simple proof that her LED is not broken and her electronics are connected correctly by constructing a circuit that accomplishes the same LED lighting goal, but by bypassing the Raspberry Pi. At her moment of breakthrough, she smiles, she leans back in relief, she calls out in celebration to those around her. Becca and Albert ask "What did you do?" She explains what she did, she laughs a little bit—perhaps out of embarrassment because it was a simple trick that is being made a big moment out of, perhaps out of excitement, perhaps a slight note of condescension. Albert and Becca adjust their circuits to follow Diana's example, and this step (even though it doesn't solve the entire problem) propagates around the classroom via word of mouth. Another student on the other side of Diana asks what she did, and she says "we cheated." Albert also uses "we" in describing what circuit they built. This was really Diana's idea, the fact that Albert has a similar circuit now is just because he wanted to try it too. Is the use of "we" simple mirroring of Diana's usage, a bid for camaraderie in lab, or a subtle coopting of Diana's achievement as something "we" both figured out?

Diana got another, even bigger success a few moments later. This time she found the key typo in the code—Pin 11 should have been Pin 15 in the code for the way they all constructed their circuits. She gets it working, she is initially skeptical that she has not once again cheated, since it is working backwards (the LED turns on at exactly the opposite times she would like it to). Albert is also a bit skeptical "Wait, what?" but Becca confirms "that's exactly what it's supposed to do." Diana calls George over, and soon the entire class congregates around Diana to see what she accomplished. George confirms it's right and that the backwards aspect isn't a problem. George applauds. George instructs "Ok everyone open up your code"—you can hear the TA and the student passing along this nugget of information.

This was Diana's biggest moment in lab this day, the biggest moment anyone got on this day due to the pressure cooker of the unresolved problem, and probably her biggest moment in the entire semester lab sessions. In a public learning environment with only 10 students, ability can be constructed by little successes like this—get one moment where you figure out something important before everyone else (or at least before someone else) and you will have a brief moment of status in lab. It's equal access to the top of the ability hierarchy.

Or is it? What gets recognized as a successful performance, and who recognizes who, and how does it need to be portrayed? Becca had a useful thought a few minutes before Diana resolved the whole issue. She is staring at the whiteboard with the TA's written instruction, and she says to herself or perhaps to Diana who she is simultaneously turned towards: "Shouldn't the code not have worked for the group before us too?" Diana, often seemingly consumed in her own thoughts, asks "Hm?" Becca repeats her question even more quietly this time, "Wasn't there like a lab before us?" It's actually a great question, from a perspective of solving a coding problem as a systems engineering problem, one could think of the fact that there are other humans who have been tasked this problem before. If the code was inherently irredeemably broken, they probably would have told the professor who might have canceled all of the day's labs by now. The fact that there was a lab before them and now they are doing the same task leads Becca to doubt the idea that the code is a fundamental problem. It may have led Diana later to think that there might be a minor not a major problem in the code, and to tinker with a few lines that seem like they might be important. Becca's focus on the people who code is often seemingly manifested in her looking around the classroom, in asking questions and reporting on what other people in the lab have figured out. Typically her approach may have the effect of making her appear not to be thinking for herself. But in this moment, a people-focused coding approach is uniquely valuable as a different sort of programming epistemology—it's probably precisely what led to her to seeing something different in the coding problem than all of the tech-focused coders in the room.

But instead of being Becca's shining moment, it seems almost 99.9% certain, that Sam eavesdrops on her from 5ft away. The room is extremely quiet while Becca says what she says, and in such conditions eavesdropping in this lab is indeed almost unavoidable. Within 5 seconds after Becca's original question, Sam says directly to the TA: "And also how come they didn't run into this problem earlier?" George responds, "That's a good question." Possibly George heard Becca's original question, possibly not. Sam seems to have, it would be an incredible coincidence for him to have arrived at the same question at the same time after several minutes of thought. So what was potentially Becca's big moment, something which could have been a small success moment like Diana's, was taken from her. Becca does not have many opportunities to be thinking of useful ideas faster than the other 9 students who have more programming background than her.

One could say that Becca's lack of confidence, her quiet speech, her inability to put herself forward are causing her own lack of recognition here. Perhaps another researcher might posit that she has low programming self-efficacy. But in this analysis, that would be like naming the problem with the problem. She has little programming experience and the lab environment has made this fact both public and salient. Why in this setting do we think she should she have high confidence? Becca started out quietly, and got even more quiet when asked to repeat herself. But Becca isn't shy, she doesn't have trouble expressing herself in the non-academic social moments of this lab, or in our interviews. Becca's quiet voice is much more a product of the high-pressure public venue for speaking about the content and having 9 students, 1 TA, and 1 researcher eavesdrop on her initial thoughts, as it is on her personal lack of confidence. It's a risky and threatening place to think out loud. In this social context, Becca simply doesn't share her immediate thoughts to the students or TA in positions of power, she shares them quietly to herself or to Diana—the friendliest and closest to Becca physically, socially, demographically, and in perceived ability. Becca has some agency but not full control over what can happen as a result of her speaking. Her quiet and even quieter approach may be to protect herself from the consequences of sharing her thoughts straight out into the lab audience for their judgment, thoughts which may have a risk of being wrong and used against her.

But Sam has agency here too. Sam knows Becca, they are friends. Sam could acknowledge Becca, or even just acknowledge that he eavesdropped and heard the comment from somewhere. Instead he takes the piece of knowledge, and speaks it directly to the TA. Sam's loud voice, confident voice, his casual and laid back "call the shots" voice if you will, is also a product of the room. If Sam felt out of his depths, Sam wouldn't be able to speak off the cuff to the TA as a peer. He wouldn't be able to hear something, decide it's worthwhile, and immediately turn it around to position his star even a little more brightly as a "good question asker." I can't say absolutely that Sam heard Becca or that George (the TA) did not. But for as much as Becca worries about who has found out which aspects of the code, and worries about giving credit to Diana during the moments of receiving help, Sam appears not to be thinking on these levels. He appears more focused on technical aspects, and less focused on issues of credit for ideas. Is this a tech-focused orientation versus Becca's people-focused orientation? Is it an aspect of academic privilege in the lab? For students lower on the totem pole, credit may be a more important aspect, lab may be a more threatening space requiring one to prove oneself. For Sam, is lab merely a place where he knows what's going on, he can treat any ideas as technical solutions for the problems at hand without worrying about him or others proving themselves? It's possible. But just because he may not have to engage consciously with these aspects of ability assignments does not mean he isn't party to them or complicit in them.

This was a fairly unique day. In general, Diana did not solve technical aspects of lab before all the other 9 students and the TA; in general, Becca doesn't have completely unique insights faster than all others, even ones that are overlooked. There are typical days where students are roughly completing steps and assignments in pecking order of their programming background. There's the day that Sam gets a debugging success and walks around the room with his hands raised like Rocky. These moments and days all add up to something, a stabilized impression of abilities that have consequences for the way students are treated in lab and the way they can see themselves as capable of engineering, or of not belonging. For Diana, a momentary success like the ones she had on this day can be a leg to stand on and a source of social capital, a building up of one's engineering ability to be on an even footing with her peers. For Becca, the momentary success never came, and the similarity and closeness of the two women in the lab might make Diana's successes all the more difficult for Becca. Becca's lived experience of the class was more one of being reconstructed as failing and not belonging in engineering, anew, in each day and each activity. Always being found slower, always being found asking what the next step was from someone who had already figured it out.

Here our cultural turn invites us to ponder—is there any other way? The way this classroom has constructed assignments and student success this seems like an intractable problem, there will always be a Becca in the class, if Becca were not here perhaps the pressure on the other two students without programming background would become even larger. But these aren't immutable facts of students, these are identities created in situ. Did there need to be a recognizably fastest and slowest student in this lab section? Diana had a momentary success, but she also possibly created a momentary failure for 9 other lab members and 1 TA (who perhaps should have been able to debug the code faster than her). If success is narrowly defined by speed and a functional product, potentially only one student can succeed each time. Is this the right approach for education? What if a successful student was one who was challenging themselves and making great strides in learning the things that were most appropriate for them at the time? What if students were rewarded for having their own and innovative approaches? Furthermore, do students always need to be working on the same end products in the same time constraints, inviting easy comparison of who is finishing first and last?

The product-oriented feel is not an accident in this engineering classroom, it is culture. The individual, competitive, timed, meritocratic feel to this classroom is also bigger than this classroom, and is probably far from an extreme example. The public displays of ability are an inherent accompaniment of this setting in a lab with the structural affordances, pedagogical choices, and cultural values of this setting. The tradeoff with a traditional course seems to play out in this reformed course's favor—these types of ability projections may only be bringing into the classroom view what happens more privately in hallways, dorm rooms, and study rooms already. Still, a cultural analysis of this building block towards differential ability allows us to ponder the cultural underpinnings that constrain the interaction, and to decide what our other possibilities would look like.

**Status and inequity in paired lab learning**

Individual lab assignments were the norm in the class, but paired and collaborative labs were an additional affordance for the lab space. After a pilot semester of the class, our research team gave the constructive feedback to try paired labs, where students complete one hardware / code implementation and write a joint lab report. We were guided by a rule of thumb educational value that collaboration opens up new opportunities for students to sense-make with one another and would be more disciplinarily authentic, (with a side benefit that it would make for more interesting video data for our education research). So in Becca's class, paired labs were being trialed out, intending for a 50-50 ratio individual to group labs. Group labs ended up being additionally beneficial in terms of TA time efficiency—less troubleshooting because partners could figure things out together; the TA was dealing with 5 pairs instead of 10 individuals. In the end, partnered labs ended up working so well that they comprised more than 50% of the labs. While for practical reasons and as an educational value partnered labs were an improvement, partnered labs simultaneously brought their own particular mix of conditions for constructing ability and inequity.

Becca's first lab partner was Neeraj. Neeraj was quiet, both in speaking volume and in number of words said, and he was never on video camera because he was never a central research subject for my study. As such, I don't have many fieldnotes on Becca and Neeraj—it's the louder and verbose students who stand out more. So in order to characterize her first lab partner experience I need to draw particularly on Becca's perspective on it. In asking how group labs went, she said Neeraj was "anti- let me touch anything" because he knew how to do it and wanted to do it himself. Becca found his preference not to seek help when stuck inefficient and infuriating. An extremely brief field note excerpt shows Neeraj using first person singular to wonder about a problem they have "Wait a minute I confused myself again" and Becca using first person plural to seek help "We're confused." Apparently his individual orientation to his work extended beyond the lab setting, Neeraj's idea of collaborating on lab reports was that he wrote the entire first one (and Becca felt shut out) and then asked Becca to write the entire second one (and Becca felt lost and helpless). Was Neeraj actively shutting Becca out? Or did a quietness and preference for individual work have that effect? In any case, Becca had a bad experience with her first partner. She complained to me, to others in the lab, to both of the female students in the larger class. Eventually word got back to George, the TA, via Sam, that Becca was frustrated and felt she wasn't learning anything. This prompted a realignment of partners.

Sam and Becca were paired together next. Becca and Sam were friends, and they were both very pleased with this pairing. But they were not friends because of similarities, say the way Becca and Diana were bonded together as the only two females in the lab section. They were friends primarily because of differences. One day walking into lecture, Becca called out to Sam on the other side of the room to ask what he got on a recent Physics test, the class which was Becca's primary struggle this term. He points out that he got a 95, and later makes clear that the highest grade in the class was a 95. "So you're the one who screwed us on the curve." Sam responds, "Thanks for telling the whole class." Becca and Sam make these jokes a lot of times, but they always go a certain direction. Sam has academic capital, Becca has social capital. Becca can tease Sam about being so smart, Sam can tease Becca about her choice of clothes (too fashionable or outlandish), Becca can tease Sam back about his choice of clothes (too nerdy). These are the typical dichotomies of Engineering—they map onto caricatures and memes the engineering community is familiar with and that's what makes them comfortable, easy jokes to construct. Sam can't tease Becca about her academic struggles this term, they are friends and Sam is not a jerk. They also can't necessarily form an effective camaraderie—one day in lab Sam and Becca are trying to commiserate about school pressures and Becca seems to get reminded of her own even worse position. Sam and Becca's friendship operates along certain dimensions of difference, one that appears to have practical advantages for both parties, including as lab partners.

My impression of their pairing, contrary to the students' impression, was a much greater concern for equity in learning. Sam typically has full control of the lab circuitry and the keyboard for programming. Becca takes on a spectator role, including the posture of an onlooker. Becca's computer monitor stays off, Sam stays at the center of all of the technical work. Sam typically explains all of the actions he is taking to complete the task and even explains the how and why of his thinking, as a teacher might think out loud about a strategy:

> We need to calibrate each axis. The way to do that is to get 3 points on each axis. Known z is like this. Mmhmm. Like this. So the axis is based on this. Right now z is pointed this way. Exactly. Exactly. So what we're going to do is start with 3 points.

Becca asks a follow up question after this explanation, and after Sam's answer she finishes with a good-natured compliment "You're good at that part." This is not a contested interactional positioning on either side—Becca does not take offense that Sam is taking such a teacher role towards her, and Sam does not protest that Becca should contribute or think more for herself. Both have stabilized the status positioning in this interaction, and one might argue it was for good local (who knows what to do in the lab today) and broader (who has status in the class and institution) reasons. Sam alternates between using "we," sounding like a teacher bringing along a class, and "I," sounding like a student doing a project on his own. There is little need for the pronoun "you" when Sam is paired with Becca—Becca is just about never making a physical contribution. This is the local construction of Becca's lack of programming background, and consequently, her inability to perform engineering tasks, and the simultaneous construction of Sam as a brilliant engineer. If the pedagogical affordance of this lab is learning by doing, Becca is not doing, Becca is largely not learning. If being an engineer today means building a circuit and/or writing a program, Becca is not being an engineer. The interactional construction of differential ability is one classmate doing all of a fellow classmate's work for them, and talking down to them in the process. Becca constructs Sam, Sam constructs Becca, and all in the public arena of the lab session.

Becca is usually following right along with Sam intellectually, in constructing pertinent questions and restatements of problems and actions: a testament both to Sam's think-aloud explications of his intellectual process and Becca's keeping up with the intellectual work. This could be what is meant by a "cognitive apprenticeship" yet it never transitions to Becca taking on a bigger role, in doing or deciding anything—that is never the end game. It appears instead, this disparity in intellectual work contribution is a byproduct of a product-focused orientation in a competitive and time-compressed educational setting. Becca doesn't trust herself to try on a bigger role compared to Sam's better skills and experience, and it's hard to see why she should. With Sam she gets the enhanced peace of mind of knowing their work will turn out well, and she gets to receive a pleasant friendly lecture in the process. The other students in the lab, actively working and completing their work, the assignment, the lab time limits, these are just as complicit in constructing Becca's inaction in lab today, by creating the forces against which Sam is the more worthy competitor. Becca is indeed learning some technical content through her peripheral participation, but in the reality of this classroom she is also destined to learn that she must remain peripheral to win this game.

Sometimes Sam and Becca seem to have a breakdown in their shared meaning, and Sam seeks help elsewhere, that result in Becca's exclusion from Sam's intellectual work:

> [Students are sitting in two pairs in a row, and in the following order respectively: Brad with Elliot, Becca with Sam.]
>
> Sam (pointing at screen): What is this doing?
>
> Becca: Reading the data.
>
> Sam: Yeah but what is this doing? 4 bits of data?
>
> Becca: Cause that's what he did before, somehow I remember in morse code.
>
> Sam: Like I think I need this thing for each channel. But I'm worried I'm overriding the data.
>
> Sam (past Becca to Elliott): Does data have to be an array now?
>
> Brad (to himself): Data is an array last time...
>
> Elliott (to Sam): I mean if you wanna take the average maybe?
>
> Sam (more to himself): Data is already an array…

Becca is engaging with Sam's troubleshooting. Her answers are likely accurate "Reading the data" and adding material that may again be useful from a programming-as-a-systems-engineering-problem orientation, she reminds him of some information gained in a prior lab about morse code. We saw Becca take the same orientation in our prior episode (where Sam eavesdropped). But Sam has a different question on his mind to solve his problem. He doesn't engage with the comment on morse code. Instead he continues speaking, somewhat opaquely, about channels and data arrays. This is the same level that Brad and Elliot (sitting next to Becca) are also thinking about their coding and they respond easily and quickly with a shared understanding to his question. Becca disengages from their subsequent exchange. How useful would Becca's idea have been in this case? I'm not sure. By being somewhat lost in his own stream of thought to solve a technical problem, Sam bypasses Becca's idea, doesn't engage with it or explain why it isn't the right strategy at this point. He also moves on past Becca into conversation with other students. Becca is found to be a student who can't participate in the conversations of her classmates, but not for want of trying to engage intellectually. Potentially she has good and different sorts of ideas to offer. Is it just a random coincidence that her ideas are overlooked? A shared epistemology or working-norm amongst the high programming-background students in the class? Is this another product of a product-oriented engineering culture? Are students who are lost in thought just less likely to listen to new ideas? Or would Becca's idea have been a welcome interruption to Sam's thinking, if she'd had higher academic status and was more expected to contribute important information to help solve his problem?

This pattern of work, the troubling inequity of their intellectual contributions, and the severe positioning as teacher and student, was never disrupted in the moment by the TA. We could ask ourselves, why is this hard, what would intervention look like? It does seem to have been more programmatically disrupted. After two weeks in this lab pairing, George suggests yet another lab pairing. This time Becca and Diana are paired together. Diana is probably one of the most evenly matched partners available for Becca in lab, plus they get along together. Instead of welcoming the change, when Becca finds out she was going to be paired with Diana for a second week in a row she is distraught, "me and

Diana don't know anything, and I know we're gonna die in lab." Diana on the other hand is excited.

At this point it would be easy for a reader or observer to decide that Becca is lazy and not putting in the effort to do the work of being an engineer. She asks for help on each step of lab instead of figuring things out for herself, and her favorite lab partners are the ones who do all the work for her. Leaving that easy interpretation on the table, let's unpack the educational fact a little more deeply, to look at what it is Becca seems to be doing, how she is responding to her surroundings. Becca is in survival mode this term. She has arrived a semester late at the institution due to a community college transfer, and then due to mis-processed math placement scores she could not start taking any engineering prerequisites until this term, effectively her sophomore year. She has ended up loading this semester with all math and science prerequisites for the engineering major, with a schedule of: Chemistry, Physics, Calculus, and Programming. She is seriously struggling in Physics and Chemistry, and as such she is at risk of being denied access to the electrical engineering major at the end of this term. She is told, institutionally, that grade performance at the end of her classes this semester is the sole determiner of her fate. She is told, instructionally, that functional circuitry and working code are the ways she will be evaluated. She is not told, at least not directly or often, that she should try out her own ideas and she will be evaluated on what she learns today.

Within the pressure cooker of an intense term, let us examine the plausibility that Becca is responding with various coping strategies, aimed at institutional survival. Perhaps asking students what they have found in order for her to reproduce it is a more efficient strategy than asking why they approached their work this way, or how she should think about approaching it herself. It seems pairing with Sam is about survival. Pairing with Diana is threatening because she knows they will be two of the least well-positioned students in the class to do the work—what is an opportunity for learning is also an opportunity for failure.

The sociological concept of schismogenesis seems useful here (Bateson, 1972; Tannen, 2007), the idea that when people, or groups of people, who have different socialization come in contact with another, sometimes their differences become larger. So if you're a person who has been socialized to speak loudly, when you come in contact with a person who speaks more quietly you might speak more loudly to compensate and encourage them to speak louder, which might prompt the other person to be alarmed and speak more quietly to encourage you to speak quieter (Tannen, 2007). Bateson himself seemed never to come to terms with what would cause some differences to get larger and other differences to get smaller. Still, the idea that something people do in response to each other might in effect create for others something very opposite to the intention, is a useful possibility to consider. Especially in examining why people end up recreating persistent problems. So perhaps, in a stressful term and a stressful class setting, Becca was taking on a coping strategy in order not to appear like she is failing, in order not to be determined "not an engineer," and she is taking a few steps towards self-preservation and survival; Sam is being a gracious friend and helping her by doing the work for her. In that these steps may look to others (this researcher, the TA, fellow students) like intellectual shortcuts, they essentially communicate the opposite of Becca's intent, in these moments Becca is a non-doer of programming, and a non-engineer. In this class a bulk of the learning happens in lab, and it lives in the "doing" for oneself, and trying out one's ideas and strategies with peers. Becca is largely not doing this "doing," and it seems she will either fall behind or have to play catch up later in some other form. The idea of schismogenesis is that it adds up and gets worse over time—perhaps the more she struggles against being positioned as "not cut out for engineering" the more she employs coping strategies that are counter to learning and reproduce the impression she intends to avoid.

But this is not just randomly misplaced energy peculiar to Becca and Sam. In all lab pairings, the more advanced student was almost always seen doing more of the physical and intellectual work. Becca and Sam were the most extreme example of it, but they were also the most extremely mismatched programming-background pairing. I would wager that more or less the same patterns exist in engineering pairings in classrooms across the country, and this is why we get the simplistic literature that tries to solve pairings as best practices. Is expert/novice better than expert/expert and novice/novice? We can see in this analysis, both are deeply problematic—in one pairing Becca learns very little, in the other she is unhappy and stressed. But does this classroom actually have to have experts and novices? Not—does this classroom have to have differences in programming background or performance, those have been instantiated here by institutional enrollment, and if we're realistic we know that there will always be *some* differences in programming background. But "experts" are people who know what they're doing, and "novices" are people who don't. Experts don't need to learn anymore, novices are almost hopelessly stuck. In real life, experts are almost by definition the person who should be doing the task on the engineering team. But are either of these healthy roles in a classroom? It seems to be a reasonably well-grounded cultural norm in a product-oriented engineering classroom, that those who know how to produce correct solutions are put forward as the "doer" in the project group. But this is also an educational space. Could we put our engineer identities on hold for long enough to ensure a modicum of student learning? What about a pairing norm focused around student learners? One student has an opportunity to learn by doing, so the student who already knows how to do that item takes a back seat and an encouraging/supporting role. Maybe they switch later so both of them get to try it out, or they switch when they encounter something the other student has more of a need to learn. This won't be a perfect solution either—teacher/student positionings may be even more jarring when students try to force them in ways that don't seem natural. Simple measures of positioning like mouse or keyboard control could mask deeper positionings in whose ideas get put forward (McDermott & Varenne, 2006). If engineering is a selective and esteemed discipline, and if engineering classrooms are still the playing fields to produce the winners and losers, an educational intervention towards learning and growth might instead publicize and institutionalize the identity of the losers.

In the end, paired labs are nearly as stressful as individual lab days for Becca. They invite public microaggression-laden conversations about how valuable another classmate is as a partner, they invite strategies for survival that reify inequity in learning. In a culture focused on products rather than people, and focused on winning and losing rather than learning, any vision of the right way to pair experts and novices will result in stressed students or pairs of students, missed opportunities for learning, and the further construction of students on a hierarchy of those who can do engineering, and those who cannot.

**Identity in the classroom: making status and otherness visible in the lab**

Initially I chose to conceptualize gender and Letters and Sciences as parallel systems of oppression to the more salient category which they overlap: programming background. Programming background then becomes the major force which constructs inequity and differential access in lecture content and social dynamics, and lab activities, all of which reify engineering ability. I did so explicitly, because I reject the sexist idea that biological sex is playing a central role in someone's inherent programming ability, and I reject the idea that Letters and Sciences constitute a "type of person" which Becca is, and that that is a type of person who cannot do programming. I choose to acknowledge and counteract these conceptions of ability, explicitly since they are still so prevalent in between the lines of research papers and behind the closed doors of faculty meetings. I now turn to the ways in which I believe that social constructs such as Letters and Sciences and gender are in fact salient in the classroom. They are not salient because Becca is a certain type of person well-predicted by womanhood and Letters and Sciences, they are salient because they are used as weapons in the classroom, as tools for constructing and reifying engineering ability.

Becca's Letters and Sciences status became visible in lab. I'm not sure when and how this happened, but I could see some of its effects. A student will ask her "So you wanna be an electrical engineer huh?," and ask no other student. This is an introductory class for electrical engineers. It is a question that only makes sense if the student knows, and can serve as a subtle reminder, that since Becca is institutionally marginalized, her wish to be an electrical engineer may still be disrupted.

At other times the conversations about Becca's plans take a different turn. Neeraj and Becca are working together in lab one day, George is making conversation in between helping students. George asks Becca what she's thinking about studying. Becca takes this to be a simple question, answers "Electrical engineering." Again, it would be a strange question for any student in this class, but perhaps not if you know that Becca is Letters and Sciences status and therefore not quite in the major yet. But George is asking a different question: "Yeah but what?" Becca slouches down and mumbles a reply, "…I don't understand any of this." George seemingly encourages her, "This is the fun stuff!" Neeraj chimes in too, "I tend to agree!" Becca slouches down even further. Becca's lab partner shares the same enthusiasm as her TA, and Becca is constructed as an outsider.

Becca does in fact have some electrical engineering career ambitions. She tells me she has a background in a vocational electrician program in high school and is pursuing an electrical engineering major out of success in that program and out of encouragement from her teacher. She would like to become a building electrical engineer who prepares drawings for electricians to install and communicates well with them. It's a pretty plausible career goal, a real job description. But this motivation carries a completely different set of assumptions than the majority of the electrical engineering students. Becca is here with practical, vocational career goals. The other students are here because they love electrical engineering and/or programming. Becca's practical orientation was admired in her high school (at least by her teacher), and were central to thinking about the marketable skills of a vocation. Most of her classmates were probably in AP classes at a public school or a private school; Becca's school didn't have AP classes or programming. Her classmate's schools rewarded intellectual curiosity, merit, and performance; Becca's valued practicality. These are completely different and valid values, but only one set of them coincide with the power structure of the university. In this moment, George is asking Becca a question about what particular aspect of electrical engineering gets her the most excited. Becca doesn't have an answer. She doesn't have a clear picture of electrical engineering, beyond her electrician's background. It's also perhaps just not the way she thinks about her major. Perhaps in fact this moment had more to do with socioeconomic status and high school-type than Letters and Sciences, but I again view these as overlapping systems of oppression. If being a female in electrical engineering is a rare and marginal position, being a female who came from a vocational high school program makes her a complete anomaly. Letters and Sciences is a category often occupied by students like Becca who have attended high schools with atypical preparation norms. Those high schools are preparing their students for different paths entirely, ones consistent with the different access to power we afford to those at the bottom of an American socioeconomic apartheid. And being a big fish in that pond is a completely different thing than swimming in the institutional ponds of the privileged classes.

Becca's electrician vocational background became public knowledge in lab at some point too, again I'm not sure exactly when and how. But one day while Becca is looking at the board, Neeraj asks her "Didn't you do this before? Weren't you like an electricians apprentice?" His tone here, and the conversation continuing afterwards, makes clear his implication: Haven't you done this stuff already? Why are you so bad at it? Becca replies, "Yeah but we don't do this stuff. We do that stuff." She gestures at the classroom walls. "Stuff that's in walls." Becca is defending her intelligence and background, but she is almost forced to agree with Neeraj's implication that she is unexpectedly bad at this work. Then Neeraj insists, "Yeah but it's still circuits." Becca, unfortunately finds herself further distancing herself from the content: "It's not like that though. And the schematics are really different" in order to defend and justify her intelligence and experience. Neeraj has constructed the educational fact that Becca is bad at not just programming, but circuits and electrical engineering. Neeraj is attempting to deny Becca even the space of blaming her preparation, shouldn't she be even better at circuits than the other students? Like the mirror of a scholarly argument between cultural difference and cultural deficit, Becca is trying to explain her unique background to come to her defense, but Neeraj would like to locate the problem actually in Becca's own deficiencies.

Finally, having mostly treated gender as a diversity and equity issue which motivates my concern, I consider what gender truly has to do with programming, with Becca's experiences in lab. Because while there are many moments that appear possibly gendered, it is harder to say that for sure any of it has to do with being a woman or a man in the classroom. What is meant by being a woman or a man anyway? A biological sex assigned at birth that is constraining our actions throughout life? A daily performance through dress, hair style, speech, mannerism for us to project our gender to the world? A way of sorting people and assigning resources to certain people? What would it mean for gender to matter in programming class?

As noted, gender in the context of programming, electrical engineering, and STEM university departments, connotes a marginal and minority status. Thus moments that sexualize female students, moments that make gender prominent, moments that sexualize lab space so that it feels like a locker room or frat house—I conceptualize these as reifying female students' marginal position on a status hierarchy in engineering. I don't expect students, teachers, or people to ever truly be "gender blind" but if gender and sexuality becomes particularly prominent in lab, I see these moments as reminders that the men are in control, both in numbers and authority.

My most prominent example of this came from the other lab section that Becca did not interact in. There is one female student in that lab, Jillian. One day several weeks into the term, male students spent a long time guessing at Jillian's name—Ivy, Jessica. They were joking but also serious, they did not know it. The way in which they seemed to put Jillian on display, to acquire her attention and time, to know precisely who she was through her essentialized identity as the only woman, without at all knowing her as a person—this struck me, and Jillian upon reflection, as somehow strangely gendered and constructing a weird power dynamic. On another day, Jillian left lab early—(she was often quick and pragmatic about her lab assignments and was often seen finishing first)—leaving 9 male students, their TA, and me (a White male researcher). Minutes after she left the room, and without needing to turn around to confirm that the female student was gone, the male students left slipped seamlessly into sexual jokes and innuendo. Their backs were turned to each other, they didn't need to turn around to find out if the one female student had truly left or if any authority figures in the room might have minded. My fieldnotes just became a popcorn of disembodied sexual comments, called out casually into the ether while multi-tasking with the programming in front of them:

Stabbed the wires so it was looser.

That's what she said.

That's what he said.

Either way someone said it.

...bowling pin…

Anything's a dildo if you're brave enough.

Several seconds later, after I missed some overlapping dialogue, it became clear that the male students still had their minds on sex and/or gender, and that it connected back to which bodies were in which of their university STEM classes:

I'm in a (Calculus?) section with all guys, no girls

Are you surprised?

All of these comments seem to have the effect of reifying the boys club that STEM can be, once the minority of female students leave the room, or maybe while they're still there, who knows—they're a minority anyway. Gender is "in the air" as McDermott might put it—it is on the tips of the tongues and fresh on the mind of the undergraduate engineers here. And when wielded it can connote status and power in engineering.

In more subtle and less sexist ways, gender was made prominent in the form of 'othering' the student from the norm. The norm for dress in this lab was a White male, probably wearing a 'uniform' of t-shirt and khaki pants with tennis shoes, maybe wearing flip-flops and shorts in the warmer months. Dress is a way to connote insider status, but women will effectively be an outsider either way. Engineering is basically a straight White male cisgender space. A woman who dresses in the White male 'uniform' above would be seen as violating parts of that norm, while a woman who dresses in a more feminine way will be violating other parts of it.

Becca's dress became the topic of conversation at various points during the lab. Sam called across the room at one point, while Becca was wearing grey and Black patterned spandex leggings, "You have an interesting choice in pants." It was a minor moment, Becca defended her fashion choices as normal and made fun of Sam in return, "You're probably the only person on campus wearing corduroy pants." It deals in the same logic as the hierarchical joking relationship I described before—Sam makes fun of Becca for clothes that don't fit into the lab uniform, Becca makes fun of Sam for more or less adhering to it. Both have some leverage here—Sam has academic and local social status and his comment can jokingly point out Becca's status as an outsider or other. Becca has more broad social status and capital at the university, and can defend herself on this ground. But in this lab space, social status and fashion sense can be a deficit—the more serious students have less of it.

There are other moments that seem to 'other' Becca in lab in sexual terms—a questionably appropriate conversation about a male student who drunk texted her, and another about her tattoo. I see them functioning as reminders to the lab participants of Becca's gender, and thus as conjuring up corresponding memes and ability hierarchies. Gender is already plainly visible at all moments in the lab, it is prominent material and it can be used or highlighted or ignored at any moments throughout our lives, most of which have nothing to do with constructing engineering ability. But there are probably moments where Becca is allowed to operate as and be seen as an "engineering student" rather than a "female engineering student" in this setting. In engineering contexts, the "female engineering student" is a known anomaly, a definitive outsider. In these moments, I see one final and subtle layer of engineering ability connoted onto Becca's position, and I posit it as a way that gender itself, when made prominent enough, may be a building block towards constructing ability.

## Appendix D: Preliminary Interview Protocol for Chapter 5 study

### Research Protocol

How is the course going for you?

What is your favorite part? Your least favorite part?

*Rationale: Comfort, allowing developing of ethnographic student narrative*

Is this course like anything you did before? Maybe in your high school, or maybe at a summer camp?

*Rationale: Comfort, probing student background*

How would you usually approach a challenging class you wanted to succeed in? Do you think you have had to work differently in this class?

Overall, what do you think this course is trying to teach you? Do you think that it's working?

*Rationale: Starting with challenging ethnographic questions to see if productive. May return to it throughout the interview if student has this level of self-awareness*

Now I want you to think back about [e.g. marshmallow activity]. Remember what that was about. How did you feel when you first were given the problem? How do you think your group handled it?

*Rationale: Probing for student experiences and affect with specific design activities. May ask the student to volunteer other examples of design activities and ask the same question. Marshmallow task was a long time ago, and I may not be aware of all class activities.*

Would you change anything about the way you completed the activity? What do you think were the most important elements of doing [marshmallow] design? (E.g. doing calculations, assigning group tasks, sketching the structure, planning, testing spaghetti materials, trying alternative structures, testing the structure with the marshmallow, etc)

*Rationale: Probing student learning and synthesis of course content. This reflection may not have taken place in the classroom. How has the course content been received?*

Are you excited about completing your hovercraft project? How are you approaching it? What activities do you think will be most important to success on the hovercraft? How is working with your project group?

*Rationale: Affect and lessons learned for further design work. Asking student to reflect and draw connections between design experiences.*

At this point in your engineering major, how would you define or describe engineering? What about engineering design? After your experience in the course, do you see yourself enjoying being an engineer someday?

*Rationale: How does this experience affect their identity of practice of engineering. How has the overall course message been received (e.g. broadly, "I have a lot of new ways I can develop and grow to become an engineer," or "I am not like the engineer they want, I may not be meant to be an engineer")*

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