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## The Vigor of Creative Materialism: Making the Hidden Stories of Underrepresented Engineering Students Visible

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# The Vigor of Creative Materialism: Making the Hidden Stories of Underrepresented Engineering Students Visible

## Abstract

Despite decades of initiatives, engineering education continues to lack diversity. The proportion of women, BIPOC, LGBTQA+, low-income, first-generation, and disabled students in engineering education remains below national population levels. The culture of engineering is a barrier to increasing participation in engineering for students from these communities. The purpose of this dissertation study was to explore the experiences of underrepresented engineering students as they are socialized into the culture of engineering. I theorized a novel conceptual framework called creative materialism that combines culturally responsive methodologies, new materialist theory, and arts-based research methods. Two research questions were used to guide the study. First, how do underrepresented students experience the culture of engineering? Second, how did the unique creative materialist framework function to answer the first question? In-depth subjective research was conducted at the Colorado School of Mines from 2022 through March 2023 with three female students with multiple underrepresented social identities like their race, sexuality, first-generation and low-income status, and physical and learning disabilities. The methods included unstructured interviews, personal diaries, and creative practices of poetry, photography, drawing, and painting. A theme of visibility on a continuum of invisible to hypervisible emerged in the findings about the culture. The participants' myriad social identities shaped their experiences in the culture and campus community, which also was influenced by how visible their various identities were to others. Importantly, the participants resisted the harmful impacts of the culture on their mental health and well-being by enacting self-care and sharing their struggles with peers. Surprise findings for the researcher and all three participants to the second research question about the creative materialism framework were new neurodivergent identities that were unknown before the study. A significant contribution of the study is providing a novel framework for uncovering the hidden stories of how underrepresented students experience the culture of engineering. These stories offer new perspectives to engineering educators and researchers to better understand how the culture must be transformed toward inclusivity and access if diversity is to be increased.

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Engineering Students Visible

A Dissertation

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In Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy

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by

Katherine A. Robert

June 2023

Advisor: Dr. Cecilia Orphan

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Title: The Vigor of Creative Materialism: Making the Hidden Stories of Underrepresented Engineering Students Visible

Advisor: Dr. Cecilia Orphan

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### **Abstract**

Despite decades of initiatives, engineering education continues to lack diversity. The proportion of women, BIPOC, LGBTQA+, low-income, first-generation, and disabled students in engineering education remains below national population levels. The culture of engineering is a barrier to increasing participation in engineering for students from these communities. The purpose of this dissertation study was to explore the experiences of underrepresented engineering students as they are socialized into the culture of engineering. I theorized a novel conceptual framework called creative materialism that combines culturally responsive methodologies, new materialist theory, and arts-based research methods. Two research questions were used to guide the study. First, how do underrepresented students experience the culture of engineering? Second, how did the unique creative materialist framework function to answer the first question? In-depth subjective research was conducted at the Colorado School of Mines from 2022 through March 2023 with three female students with multiple underrepresented social identities like their race, sexuality, first-generation and low-income status, and physical and learning disabilities. The methods included unstructured interviews, personal diaries, and creative practices of poetry, photography, drawing, and painting. A theme of visibility on a continuum of invisible to hypervisible emerged in the findings about the culture. The participants' myriad social identities shaped their experiences in the culture and campus community, which also was influenced by how visible their various identities

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## **Chapter 1: Introduction**

In 2001, to increase participation in the fields of science, mathematics, engineering, and technology, policymakers at the National Science Foundation (NSF) in the United States (U.S.) replaced the existing acronym of SMET with the now familiar STEM (Ossola, 2014; White, 2014). The NSF intended to make an easier-to-remember term of reference for the collection of disciplines in STEM education to aid national efforts to increase participation by students with social identities that are underrepresented in STEM fields in relation to their overall population in the U.S. (Ossola, 2014). These underrepresented communities include women, Black, Indigenous, and People of Color (BIPOC), Lesbian, Gay, Bisexual, Transgender, and Queer (LGBTQ), and disabled people (National Science Foundation [NSF], 2023). Ten years later, President Barack Obama was the first U.S. president to speak about the need to increase participation in STEM during his State of the Union Address (White, 2014), noting the ongoing importance of these fields to U.S. global economic competition and national security (Downey, 2007) and unfilled professional positions in the workforce (Ashcraft et al., 2012). Improved diversity, equity, and inclusion (DEI) in education, including in STEM, is also now recognized across sectors of the U.S. economy as important to economic competition and national security (Leydens & Lucena, 2018). Because engineering professionals often work across national borders, the engineering

education accreditation agency ABET (2022) set learning goals that include understanding and appreciating the diverse perspectives and the variety of lived experiences people have. The agency states that these skills are necessary for collaborating and communicating across the cultural differences that are often found in international engineering firms. For students with these underrepresented identities, greater diversity in STEM education and professions contributes to more equitable and inclusive workplaces and campuses but also provides financial upward mobility through prestigious well-paying jobs (NSF, 2023). A search of the internet today finds that there are hundreds of organizations in the U.S. aimed at increasing the participation of students from underrepresented identities in STEM education.

Despite all these efforts, the proportion of these underrepresented students has not significantly increased, particularly within specific STEM fields (Anderson et al., 2018; NSF, 2023). Engineering higher education (EHED) continues to lack students with diverse gender, racial, sexuality, and disabled identities and remains the least researched among the STEM disciplines of science, technology, engineering, and mathematics (Riley, 2008). Engineering higher education includes undergraduate and graduate level work and a range of fields including electrical, mechanical, civil, chemical, environmental, petroleum, mining, industrial, aerospace, and computer engineering to name a few. Research shows that the notoriously stressful and rigorous culture of engineering with its technical and mathematical focus keeps many potential students away (Kennedy et al., 2018). In addition, for the underrepresented students who do participate, the campus and classroom environments can be alienating and hostile to

women, BIPOC, LGBTQ, and disabled students (Riley, 2008). There are historical and ideological patterns in the culture of engineering that contribute to these discriminatory, racist, and sexist environments, and researchers argue that these patterns remain invisible, ignored, or rejected in engineering education and professions (Cech, 2014, 2022; Riley, 2008, 2017).

I identified three interrelated cultural traits in the engineering education literature as the most salient for collaborative research with underrepresented students: the fetishization of rigor as extreme difficulty and suffering, the epistemic hegemony of scientific positivism, and a resulting *socio-technical dualism*. The socio-technical dualism is theorized as a cultural belief in engineering that social and political issues, including the social justice issues of diversity, equity, and inclusion, are considered outside the purview of engineers and thus irrelevant to an engineer's education (Blosser, 2017; Cech, 2014; Faulkner, 2007; Godfrey & Parker, 2010; Godwin et al., 2016; Leydens & Lucena, 2018; Riley, 2008). The epistemic dominance of positivism, or Western scientific ways of knowing, in the professional culture of EHED has been identified (Baber, 2015; Cech, 2013, 2014; Frehill, 2004; Godfrey & Parker, 2010; Harper, 2012; Haverkamp et al., 2019; Leydens & Lucena, 2018; Seron et al., 2018) as exclusionary to people with other ways of knowing, like Indigenous people (Smith, 1997), women (Heybach & Pickup, 2017), and neurodivergent people (Berryman et al., 2015). There is a growing body of research that shows that the hegemony of positivism and the limited pedagogies used in EHED are also exclusionary for neurodivergent people with autism, ADHD, dyslexia, and other learning disabilities (Chrysochoou et al.,



2022; Cueller et al., 2022; Taylor et al., 2019). Positivism provides engineering educators with a belief that the perceived objectivity and universality associated with science and mathematics make EHED an ahistorical, apolitical, equal, and fair enterprise. This belief that EHED is a level playing field creates a meritocracy (Cech, 2013) that assumes those who succeed must be more qualified and deserving than those who do not while ignoring the systemic inequities that are unseen barriers for underrepresented students (Cech, 2022). Positivism also creates pedagogical beliefs in the efficacy of rigor that perpetuates the culture of extreme stress (Riley, 2008; 2017). Unquestioned assumptions about positivism and its effects on EHED culture and this embedded cultural sociotechnical dualism create a culture in which naming one's oppression – or the systems that create it – is not acceptable.

In the rest of this chapter, I explained the background of the problem of increasing diversity in engineering education by expanding on these historical, cultural, and epistemological factors that are often invisible in engineering education research. The purpose of my study was to contribute a different approach to this problem. Specifically, I theorized a new conceptual framework based on epistemic pluralism, collaboration, and power sharing that generated findings that elevated underrepresented student voices about their experience in the culture of engineering education. Together, the participants and I offer new vigorous (Riley, 2017) possibilities for an engineering culture that supports interdisciplinary student learning and mental and physical well-being. Through sharing their experiences in engineering education, the participants and I hope to transform the assumption that there is a universal student experience in higher education let alone in

engineering education. We believe that by disrupting the dominant culture of engineering education and research with new perspectives, changes can be enacted that create inclusive and accessible learning environments for all, including at the Colorado School of Mines (Mines) where this study took place. As a member of the Mines community, I hope that this dissertation in some way contributes to the school's ongoing mission to recruit and graduate a variety of students while also providing every community member with a sense of belonging on a safe and inclusive campus. Together, the participants and I offer our stories from our research collaboration as new contributions to the extensive Mines oral saga (Clark, 1972) and to the continuing efforts by community members to transform the culture toward inclusivity and respect for differences, care and support in learning, and greater appreciation for the interdisciplinary needs of engineering education and the professions.

## **Background on the Problem**

### **Statistical Information on Underrepresented Student Populations in the U.S.**

While educators and researchers have attempted to increase the number of students in engineering education from underrepresented communities, their participation has not substantially increased. In the latest statistical reports by the United States Census Bureau of 2022, women and BIPOC people were a significant portion of the U.S. population for the age group of 18–64-year-olds. Women of all races and ethnicities accounted for 50.5% of the U.S. population in 2022 (United States Quick Facts, 2022). When the U.S. population is examined through a lens of ethnicity and racial identities, Latinos/Hispanic people account for 18.9% of the U.S. population, Black/African

Americans are 13.6%, Asians 5.9%, American Indians and Native Alaskans are 1.3%, and Native Hawaiians and Pacific Islanders are 0.3% of the U.S. population. The proportion of the population that identifies as having a physical or cognitive disability in 2022 was 8.7%, however, definitions and measurements of disability are not consistent (United States Quick Facts, 2022). Similar problems exist with statistics about the percentage of the U.S. population who identify as part of the LGBTQA+ community. Starting in 2021, the U.S. Census Bureau included a question about sexuality and gender in their household surveys. The organization recorded that of their survey respondents, 9.6% of U.S. households reported having members who identify as LGBT (Anderson et al., 2022). The proportion of students in U.S. higher education with identities associated with these groups does not match their national population proportions when examined using higher education statistics of enrollment numbers and degree attainment. College enrollment rates in 2020 for females in the U.S. was 58% compared to 42% for males (U.S. Department of Education, 2022). In a 2018 study, gay, lesbian, bisexual, asexual, queer, or questioning undergraduate and graduate students were 17% of the 180,000 students surveyed, while 1.7% of students in the same survey identified as trans, nonbinary, or questioning (PNPI, 2020).

Within the field of engineering, females remain underrepresented despite more female students than male students in higher education overall; however, from 2011 to 2020 females earning a bachelor's degree in science and engineering increased by 34% (NSF, 2023). However, the percentage of females who earned an engineering bachelor's degree (24%) in 2020 was lower than those who earned a science degree (43%). BIPOC

students' attainment of bachelor's degrees in engineering in 2020 varied, with Latino/Hispanic students earning 14% of undergraduate engineering degrees, Black/African American students earning 4.6% of engineering degrees, and American Indian and Alaskan Native students earning 0.3% of college bachelor's degrees in engineering. However, in all these underrepresented groups, there were fewer bachelor's degrees in engineering than in science (NSF, 2023). Across all racial and ethnic categories, females continue to earn fewer bachelor's degrees in engineering compared to their male counterparts (National Science Board/NSF, 2019) (Table 1). Retention is also an ongoing problem with 32% of females dropping out of EHED, and of those who graduate, one-third leave the workplace (SWE, 2019).

Table 1: Percentage of Attainment of Engineering Bachelor's Degrees by Race/Ethnicity and Sex.

Race and Ethnicity	Sex	
	Female (%)	Male (%)
American Indian or Alaska Native	20	80
Asian or Pacific Islander	26.2	73.8
Black or African American	25.2	74.8
Hispanic or Latino	22.8	77.2
White	20.2	79.8
Other or unknown race and ethnicity	23.6	76.4

When the data about specific engineering fields are examined by race or sex, differences in participation become apparent (ASEE, 2022). The top five engineering fields for Latinx, Black/African American, and Native American and Alaskan Natives, regardless of gender, are Civil Engineering (21.6%), Civil/Environmental Engineering (20%), Engineering Management (19.7%), Electrical Engineering (19.5), and Petroleum Engineering (19.4%). When examined by sex without race or ethnicity, the top engineering fields for females are Environmental Engineering (57.8%), Biomedical Engineering (51.5%), Biological and Agricultural Engineering (39.1%), Chemical Engineering (38.5%), and Architectural Engineering (36%). Female students regardless of race or ethnicity are a small portion of Computer Engineers (15.4%), Aerospace Engineers (15.9%), Electrical Engineers (15.4%), Mechanical Engineering (17.3%), and Nuclear Engineering (16.9%) (ASEE, 2022). In summary, quantitative research data provides a window into the lack of diversity in engineering education, however, it does not explain why students with underrepresented identities are not participating in engineering in greater proportions closer to their overall U.S. populations.

### **The Benefits of Diversity**

Part of what continues to drive engineering education diversity efforts is the recognition that including a wider range of perspectives, experiences, ideas, and values in engineering practice is beneficial to society, organizations, and individuals. Diversity efforts in education and across industries arise from a variety of imperatives. Studies show that diversity in corporate management increases the value of businesses generally (Loop & DeNicola, 2019) but also increases the value of engineering teams (Kidwai,

2022). Diversity in engineering teams is more desirable for younger engineers and helps create more accessible and relatable products for a wider range of customers. Experts argue that diversity in STEM disciplines must increase for the U.S. to stay competitive and innovative in a globalized economy by retaining intellectual capital nationally and filling vacant jobs in the STEM sectors of the economy (Ouimet, 2018). Diversity in the workforce is also necessary for keeping up with the rapid technological changes for national security and population growth issues (ABET, 2022; Weinbaum et al., 2023; White, 2014), solving global crises like climate change and improving environmental sustainability (AASHE, 2010; National Academy of Engineering, 2005), increasing social, political, and economic equity (Karwat et al., 2014), and advancing the well-being of humans globally (Walker, 2015).

Industry leaders are also influenced by the need for greater appreciation for the diversity in engineering, which is evident in their setting EHED curricular requirements for accreditation agencies that emphasize learning the skills that are required to work in diverse workplaces. The 2022-2023 learning outcomes for engineering students as stated by the Accreditation Board of Engineering (ABET) recognized that engineers must design on multidisciplinary teams, effectively communicate across cultures, problem solve in specific economic, social, and environmental contexts, understand the contemporary issues around their work, and be able to learn throughout their careers as their disciplines rapidly change (ABET, 2022). Diversity benefits are also recognized in the national security sector. A 2023 Rand Corporation report argues that neurodivergent engineers, scientists, mathematicians, and other workers are necessary for national

security because of the unique attributes they bring. People with autism and ADHD often have exceptional abilities in pattern recognition, deep sustained focus, and visualization skills, to name a few (Weinbaum et al., 2023), which industry experts desire.

Members of underrepresented communities who earn STEM degrees gain benefits including the ability to address social justice issues in their communities (Oyana, et al., 2015) like the health inequalities that emerged during the pandemic (Pearl, 2020). Those with STEM degrees have increased wage potential compared to other graduates from their communities with different majors (Graf et al., 2018). There is also growing evidence that the lack of diversity in STEM directly affects health outcomes in different communities due to biases in technology and research (Mackie, 2022), making diversity a matter of life or death in some communities. Having a diverse group of engineers working on projects makes product designs more inclusive by having a range of users in the engineering design process who can create items that meet different racial, gender, and disability needs. An example of a detrimental outcome, when there is a lack of diversity and bias in the design and development process, is the hand dryer that could not detect dark skin (This 'Racist soap dispenser' at Facebook office does not work for black people, 2017). And importantly for members of these underrepresented communities, increasing their participation in engineering professions provides role models who look like the underrepresented students (Pietri et al., 2018; Sanchez et al., 2019) and who can provide support for students from these communities during their education and professional socialization. Increased diversity in engineering potentially may create cultural changes in EHED and engineering professions, thereby improving the inclusivity

of the environment for future students and engineers from these communities (Bang & Medin, 2010).

### **Cultivating Diversity Requires More than Marketing**

While there has been considerable effort to increase diversity in engineering, many of these initiatives have taken a limited approach to the problem by focusing on outreach rather than on how inclusive and accessible the culture is that underrepresented students experience on campus. Research (Baber, 2015; Riley, 2017) indicates that because of their disciplinary training in positivism, engineering education researchers and leaders often approach their lack of diversity as a quantitative problem with simple cause-and-effect solutions. Baber (2015) researched STEM education diversity programs and found that the financial resources allocated to programs for increasing diversity were often reduced when numerical targets for increasing the participation of underrepresented students were missed, thereby undermining their DEI efforts. Disciplinary assumptions about the validity of positivist methods and the universality of Western education, in general, create a belief among some EHED educators, leaders, and researchers that underrepresented students merely need to be informed through marketing and exposure programs that engineering is a field open to them, if they have the proper preparation in math and science (Heybach & Pickup, 2017). And to some extent, the research on the increased exposure and preparation to engineering disciplines among students in underrepresented communities shows these initiatives are important for increasing participation, retainment, and completion of EHED degrees (Lord & Camacho, 2013; Ma et al., 2017; Rice & Alfred, 2014; Taylor, 2011).



Part of the problem with these marketing-based outreach approaches is that they assume a universal culture of engineering that is accessible to all and place the problem of diversity on the students themselves. Research shows that often these exposure and marketing initiatives perpetuate stereotypes and essentialize the demographic group they are trying to reach, like young girls (Heybach & Pickup, 2017). For example, to increase girls' interest in STEM, in 2002, Rowan University invited seventh and eighth-grade girls to collaborative workshops to expose them to hands-on engineering practices and female engineers as role models (Hollar et al., 2002). The workshop included a hands-on module about how cosmetics are engineered that was intended to demonstrate that engineering is creative and connected to the everyday lives of teen girls (Hollar et al., 2002). Heybach and Pickup (2017) classify this approach as “painting pink” and argue using feminist, new materialist, and decolonizing theories that STEM is not a fixed entity nor a commodity to be marketed and that these types of approaches rely on cultural assumptions and essentialize all girls as the same. Rather, they argue that STEM is grounded in a masculine and colonial ontology, which requires reflective research that exposes the relationships between science, engineering, history, and power. Heybach and Pickup (2017) argue that the marketing and preparation literature used in these recruiting initiatives identifies girls as lacking abilities, as outsiders to STEM, and in crises and in need of help: Girls need STEM, but STEM does not need girls except to reach numerical diversity goals. In short, they argue the culture perceives girls as deficient in their preparation for entering an established STEM culture that is universally accessible (Heybach & Pickup, 2017). This deficiency-based approach also ignores the complexities

of experiences that emerge for girls in STEM because of the multiple social identities that girls may have, like race, economic class, disabilities, and sexuality.

A deficiency approach places the responsibility for success or failure on the student and their communities without critically examining how the historical structures of racism, sexism, ableism, heterosexualism, homophobia, classism, and other forms of oppression, which are embedded in higher education and EHED culture, are exclusionary and affects student retention and completion (Harper, 2010). Iverson's (2007) research of higher education campus and organizational diversity initiatives showed that DEI programs that are merely rhetorical and that do not directly examine the historical systemic and institutional roots of inequality in education may perpetuate deficiency-based approaches that focus on student agency as causes of low participation. Diversity programs that rely on rhetoric (Ahmed, 2012; McKenzie, 2020) and that avoid critically examining the factors that contribute to the hostile campus environments that impact underrepresented students ignore the barriers to their goals of increasing diversity (Cech, 2013; Haverkamp et al., 2019; Lord & Camacho, 2013; Ma et al., 2017; Mayes, 2014; Seron et al., 2018; Slaton, 2013).

### **A History of Exclusions in Engineering Education and Research**

There are a variety of historical, cultural, and interdisciplinary threads entangled with contemporary engineering culture, education, and research that if examined, expands our understanding of the continued lack of diversity in engineering today (Riley, 2008; 2017). It is important to note that this exclusionary history continues to affect the

experiences of students from underrepresented communities in higher education in the U.S. generally as well by creating a sense of not belonging through experiences of marginalization (Cohen & Kisker, 2010; Harper, 2012; Iverson, 2007; McKenzie, 2020; Misawa, 2010; Stein, 2017a; Tuck & Yang, 2012). However, the histories of science, math, and engineering in Western cultures are specifically woven with invisible ideologies about who had access to engineering education and professions based on race, sex, and perceptions of physical abilities, which are tied up with notions of progress and the universalism of science (Riley, 2008). These invisible histories of exclusion continue to influence how engineering educators and researchers think about and discuss the problem of increasing diversity in engineering education.

Educators often make assumptions that higher education in the U.S. is neutral and accessible to all, which makes detecting exclusionary racial, gender, and socio-economic class ideologies difficult (Ladson-Billings & Tate, 1995). Harper (2012) noted that often higher education DEI researchers avoid the use of the term “racism” and instead rely on more comfortable euphemisms to describe campus settings like “chilly”, “hostile”, and “unwelcoming”. DiAngelo (2018) named White fragility, or the discomfort White people feel when racial inequalities are made explicit, as a barrier to White people seeing systemic and institutional racism that has been part of higher education in the U.S. for generations (Anderson, 1993). There are similar forms of discrimination against people with physical disabilities and neurodivergence in the form of autism, ADHD, dyslexia, dyscalculia, mental health, and other so-called disorders (Chrysochoou et al., 2022). These exclusionary ideologies that purposively excluded communities of color and

females are deeply embedded in U.S. education and theories about how knowledge is created and requires researchers to cross disciplinary borders to understand the complexity of the problem more clearly (Medina, 2013). The undetected and ignored marginalizing dynamics in educational organizations must be uncovered and examined to understand how institutions contribute to the ongoing lack of diversity.

The racialization of higher education remains problematic and is often unseen by White people due to their beliefs about the universal accessibility of higher education that allows the experiences of people of color in academia to remain invisible (Ladson-Billings & Tate, 1995). This invisibility perpetuates ignorance among many White people of how academic spaces are experienced by people from communities of color. Sara Ahmed theorizes (2007) a phenomenology of whiteness in higher education institutions in which whiteness is not about skin color, but rather is an ideology that goes unnoticed by many White people and those comfortable in the culture of whiteness. Ahmed argues that whiteness is a habitual, spatial, and temporal orientation toward success in academia based on shared ancestry, likeness, and familiarity with the dominant culture in higher education. For those comfortable in these academic spaces, these orientations feel natural. However, Ahmed theorizes that when people of color, and especially women of color, enter these spaces they are often deemed as “out of place” by those who have inherited comfort in academia due to race, sex, socioeconomic class, and generational knowledge. According to Ahmed (2007), these new arrivals often experience disorientation, pressure, restrictions, and uncertainty, and are blocked in their movements. And research on the experiences of underrepresented students in EHED resonates with the patterns that

Ahmed describes (Allen, 2017; Cech & Waidzunus, 2011; Godfrey, 2007; Harper, 2010; Haverkamp et al., 2019; Kimmerer, 2013; Lee, 2020; Liptow et al., 2016; Lord & Camacho, 2013; Rice & Alfred, 2014; Riley, 2008, 2013; Seron et al., 2015, 2018; Slaton, 2013; Stonyer, 2002; Tate & Linn, 2005). Further research is needed to better understand the experiences of underrepresented students in engineering education specifically and how the history of exclusions impacts student experiences today.

Part of untangling the exclusionary undercurrents in EHED requires studying engineering education specifically as a STEM discipline while also showing its interdisciplinarity and historical entanglements with science and mathematics. Engineering is a relatively new academic discipline within the broader STEM acronym (Seeley, 1999). Historically, science was included as part of the European pre-modern liberal arts education that wealthy White men pursued, and science was considered appropriate knowledge for White women to study and learn (Oldenziel, 1999). The modern industrialization of the U.S. economy in the eighteenth and nineteenth centuries required the standardization of education (Cohen & Kisker, 2010) and the professions, like law, medicine, and engineering (Oldenziel, 1999). This standardization thereby solidified disciplinary borders in a framework of rational scientific and efficient management that was explicitly tied with a modern capitalist economy and national security (Seeley, 1999). During the eighteenth and nineteenth centuries, as the U.S. transitioned from a rural agrarian society to a modern industrial urban one, the importance of higher education increased (Cohen & Kisker, 2010). Up until the end of the nineteenth century, engineering as a profession did not require formal education as it

relied on training passed down through shop culture, field apprenticeships, and learning on the job (Bix, 2013). The increased industrialization and mass production of consumer goods in the early twentieth-century U.S. made technology more complicated, resulting in the emergence of formal EHED programs that were increasingly reliant on scientific and mathematical theories (Seeley, 1999). This change in the knowledge requirements meant that trained technical educators and accredited programs were necessary to feed the needs of industry, the government, and the military (Downey, 2007). After World War II and during the Cold War, formal EHED programs with training in science and mathematical theory generated prestige and funding for laboratories, equipment, and research (Seeley, 1999). These historical trends influence the culture of engineering today but remain unseen and unexamined by many in EHED who are comfortable with the current culture.

These collective stories about the historical relationships between engineers and industry, global economic competition, and national security generate a type of organizational saga (Clark, 1972) that creates a shared narrative and emotional bond between members of the professional engineering community, which perpetuates the culture. These bonds, according to Clark (1972), require loyalty from the members to keep the sense of uniqueness that emerged from telling and retelling stories about the accomplishments and struggles of the group. Many researchers in EHED have identified how these stories are reproduced in the culture of engineering and are used to marginalize, rank, and stigmatize differences among students but also between engineering disciplines (Blosser, 2017; Cech, 2013, 2014; Faulkner, 2007; Foor &

Walden, 2009; Godfrey & Parker, 2010; Riley, 2008; 2017; Stonyer, 2001). Donna Riley's 2017 critical essay on the role that extreme conceptualizations of rigor play culturally in engineering education and research described how the concept is used to maintain narrow pedagogies and to police disciplinary borders in research, all to maintain the historical exclusionary meritocracy in engineering.

### **A Hegemonic Engineering Culture**

I focused on the culture of engineering in my study as researchers have continuously identified that the culture is a barrier to increasing diversity through decades of investigations (Blosser, 2017; Cech, 2013, 2014; Faulkner, 2007; Foor & Walden, 2009; Godfrey & Parker, 2010; Heybach & Pickup, 2017; Riley, 2008, 2017; Seron et al., 2018; Stonyer, 2001). These researchers found that engineering professionals and educators expect engineering students to assimilate into the dominant culture during their education (Adams et al., 2011; Heybach & Pickup, 2017). This meritocratic culture perpetuates a mindset that all student bodies are the same, and that the embodied differences between students do not matter, including racial, gender, and cognitive differences (Seron et al, 2018). This meritocracy implies that speaking up about negative personal experiences of racism or sexism is labeled as whining and complaining (Cech, 2013; Riley, 2013). Research shows that some educators characterize accommodations for physical and learning disabilities as cheating and getting special treatment (Chyrsochoou et al, 2022; Cuellar, et al., 2022). The culture is embedded with traditions that are historically tied to the military that contribute to a belief that physical endurance

is part of the engineering educational rigor which is conceptualized as overcoming physical suffering through extremely hard work as students (Freehill, 2004; Riley, 2017).

Riley (2017) challenged this concept of rigor and offered a replacement: vigor. Riley characterizes a reformed engineering culture based on vigor as one that focuses on community and caring, is inclusive of all forms of differences as epistemological pluralism, and embraces interdisciplinarity in engineering education, research, and professional practice. An engineering culture of vigor would not denigrate or punish those who cross disciplinary borders while creating new knowledge and would celebrate the building of knowledge over instrumental learning to earn credentials. For Riley (2017), vigor includes a critical social justice component that examines power and the cultural rhetorical assumptions about egalitarianism and neutrality that perpetuate an exclusionary disciplinary hierarchy with engineering at the top.

Bringing social justice issues into EHED attempts to overcome what is often referred to as the *socio-technical dualism* in EHED, or a belief that engineering education is only about solving technical problems, but not the social, political, or economic problems that have equity implications for underrepresented students and their communities (Blosser, 2017; Cech, 2014; Faulkner, 2007; Godfrey & Parker, 2010; Godwin, 2016; Leydens & Lucena, 2018; Riley, 2008). The socio-technical dualism is an epistemological and ontological problem within the culture of professional engineering and EHED that limits the legitimate ways in which engineers come to identify and solve engineering problems (Faulkner, 2007).



## **Epistemological Pluralism: Equivalent but Different**

With my study, I offer a different approach to exploring how underrepresented students experience the historically exclusionary culture of engineering, which includes interdisciplinary and different ways of knowing, or epistemologies. EHED researchers argue that underrepresented engineering students confront a hegemonic positivist culture that is hostile to these underrepresented students' cultural ways of knowing, like women, Indigenous students, and neurodivergent students (Cech, 2014; Chrysochoou et al., 2022; Hess & Strobel, 2013; Heybach & Pickup, 2013; Riley, 2017). This research shows that engineering students are expected to replace their existing cultural and embodied ways of knowing (epistemology) and being (ontology) with a positivist epistemology if they are to become a qualified, legitimate, professional engineer (Cech, 2013, 2014; Hess & Strobel, 2013; Heybach & Pickup, 2017; Seron et al., 2018). Research shows that this stark choice can alienate engineering students with different neurological, ontological, and epistemological ways of being and knowing the world like autistic, female, and BIPOC students (Baber, 2015; Cech, 2014; Chrysochoou et al., 2022; Cuellar et al., 2022; Godfrey & Parker, 2013; Hess & Strobel, 2013; Heybach & Pickup, 2017). These scholars argue that students must be able to frame their engineering identity, problems, solutions, and practices in personal ways that include their own unique embodied experiences culturally, economically, and politically (cole & O'Riley, 2017; Kimmerer, 2013), which my approach used. Additionally, students who are neurodivergent face barriers in EHED due to its rigid pedagogical adherence to memorizing pieces of theory and mathematical equations and an overreliance on testing for accuracy over

comprehension (Chrysochoou et al., 2022; Cueller et al., 2022; Taylor et al., 2019). In my study, I used alternative methodologies to uncover the assumptions and habits embedded in EHED culture related to positivism.

Some scholars argue that praxis, in which theory and practice are combined, is necessary to open the culture of engineering to change (Karwat et al., 2014) and redefine how engineering problems are framed. These engineering problems include the need to incorporate social justice issues in EHED (Cech, 2013; Faulkner, 2007; Leydens & Lucena, 2018). But changes are also needed to address the large-scale problems that engineers work on, like climate change (Cech, 2013). Culturally responsive research methodologies, which enact power-sharing in research with participants and center cultural ways of knowing (Berryman et al., 2013a), are needed in research designs so that individual students can tell of their professional socialization experiences during their education in their own voices within a community of care and support.

However, previous engineering education research shows that there are both benefits but also difficulties with crossing disciplinary and epistemological borders in research. Beddoes, Montfort, and Brown (2017) identified benefits for engineering students when they were provided opportunities to investigate their own personal epistemologies. The benefits of this subjective exploration included helping the students understand their own profession and practices better while creating new topics and questions that allow students to shift how they perceive engineering. The authors attributed the high rates of attrition in EHED to the epistemological confusion that some

engineering students experience and argue that more research is needed from the student perspective (Beddoes et al., 2017). Other research shows that subjective reflection by engineering students reveals their assumptions about being an engineer and creates opportunities for personal growth (Moloney et al., 2018). Douglas and colleagues (2010) argued that the embrace of epistemic pluralism in EHED research and the professions would create an acceptance and sense of equity for collaboration with other disciplines and professions and sensitize engineer educators, researchers, and professionals to social justice issues. They also called for the creation of spaces for qualitative research methods that examine underrepresented student experiences without fears of being silenced in the EHED research community (Douglas et al., 2010). My approach to this study offered these opportunities for the participants to uncover their own subjective experiences, from which deeply personal new knowledge emerged that included new neurodivergent identities.

Baille and Armstrong (2013) identified epistemic conflicts in engineering students who were thrust into interdisciplinary collaborations while the hegemony of positivism remained unchallenged in their education, and my study revealed nuances about these experiences. The authors used threshold concept theory to identify the epistemological process of moving through liminal or transformative spaces of learning. This theory argues that epistemological confusion is potentially difficult, and students can get stuck in these liminal spaces and become disillusioned in their learning. They found that negotiating different disciplinary knowledge was troublesome for engineering students trained in positivism, which my findings also revealed. However, their research also

shows that experiencing other epistemologies, or ways of knowing, teaches self-reflexivity and allows EHED students to think critically about their own discipline. Baille and Armstrong (2013) argue that interdisciplinary liminal spaces that support student transformations and allow time for the students to move through the turbulence of coming to know differently are necessary to overcoming the objectivity myths of positivism in engineering culture, education, and the professions that are barriers to increasing diversity. The goal of my study was to provide participants with opportunities to explore their own experiences in the culture of engineering using a conceptual framework that anticipated these interdisciplinary difficulties and offered support to the participants.

### **The Purpose of this Study**

The purpose of my interdisciplinary, critical qualitative, and arts-based research study was to better understand the experiences of underrepresented students in the culture of engineering using a vigorous paradigm that shows the variety of student experiences in engineering education (Riley, 2017). I worked collaboratively with three underrepresented engineering students to uncover and show how they experienced the epistemological and pedagogical assumptions in EHED culture that were invisible and how these assumptions impacted their learning, well-being, and mental health. Our collaboration also revealed how these participants resisted these cultural assumptions and modified their attitudes and behaviors toward acts of self-preservation that promoted self-care and the creation of their own communities of support and care with their peers. Many of these deeply embedded cultural values the participants resisted have been

maintained in the engineering culture in conceptions of able-bodied masculinity (Frehill, 2004) and the ideological and epistemological beliefs about positivism, rigor, merit, and the socio-technical dualisms that perpetuate these very assumptions (Cech, 2013; Douglas et al., 2010; Lee et al., 2020; Riley, 2008; Seron et al., 2015; Whyte, 2016). I used my research to uncover, make visible, and explore how these assumptions are experienced by underrepresented students on one campus. I shared their stories so engineering educators can better understand how to create inclusive and equitable environments for the variety of different students whose participation is desired by these very same educational, research, and professional institutions. I designed my study to explore alternatives to the hegemony of positivism in EHED research by theorizing and using a unique subjective conceptual framework to guide the research, which was based on power-sharing, collaboration, relationship-building, self-reflection, and trust.

### **Theoretical and Conceptual Framework**

For my interdisciplinary qualitative study, I combined two theories to form my theoretical framework: *culturally responsive methodologies* (CRM) (Berryman, et al., 2013b) and Nail's (2021) kinetic new materialist *contemporary loop object* (CLO) theory. CRM and CLO theory are both part of my methodological contribution that filled the gap in the EHED research literature, which called for interdisciplinary (Adams et al., 2011; Baille & Armstrong, 2013; Cech, 2014; Karwat et al., 2014) and subjective (Moloney et al., 2018) research approaches to better understand student experiences. I used these two theories to support my use of arts-based research (ABR) methods (Leavy,

2015), which together, formed my unique conceptual framework I call *creative materialism*.

Culturally responsive methodologies (Berryman et al., 2013a) are frameworks that humanize research and address the historical marginalization and dehumanization of marginalized and colonized people and communities by Western researchers and educators. CRM elevates and prioritizes the culture and contributions of the community that is the focus of the study, which for my study included the larger engineering culture but also the individual cultures the participants and I brought with us. CRM are grounded in *critical theory* and *Kaupapa Māori*, which is an Indigenous Māori framework from New Zealand that identified the harm that colonizing forms of education had on Māori students and communities. In Kaupapa Māori new forms of education that allocated and shared power and control in the Māori community were theorized, which provided the community the ability to expand beyond the Western concepts of knowledge offered in the established White education system (Smith, 1997). The values that comprise CRM are vigorous (Riley, 2017) and include building relationships through dialogue and elevating community members' voices through sharing their narratives. Human dignity and epistemological pluralism are emphasized in CRM as is utilizing the cultural-political consciousness of the participants and their desire for change. The goal for participants is to transform and control their future while challenging and restructuring power structures that are hierarchal (Berryman, et al., 2013b). In CRM, being and knowing are not separate, but instead form what new materialist philosopher Karen Barad (2007) terms in her agential realism framework as an *onto-epistemology*. Barad's onto-epistemology

describes a material ethical component based on quantum field theory in which our *intra-actions* with other people leave marks on those people but also materially change us; we are not discrete and separate but deeply entangled relationally and materially according to Barad's framework (Barad, 2007).

I chose CRM for my creative materialist framework for several reasons, including the possibility of an Indigenous participant in the study. However, I was drawn to CRM for its approach to collaboration and its community-building capacities. CRM's purpose is to assist both the community of the participants in the research, and also me as the researcher, with my own academic research goals. I found value in the CRM-inclusive power-sharing focus that is based on epistemic pluralism for my interdisciplinary approach (Nodelman, 2013). In my study, according to CRM principles, I am a learner with the participants, not an outside expert there to study them objectively (Bloomfield, 2013). We were a collaborative research community of four nested in a larger culture of engineering that we explored in relation to our own identities and cultures. This relational power-sharing required that I continually conducted self-reflexive critical interrogations of my assumptions and my power as the researcher in relation to the participants, but also those grounded in my social identities like gender, race, age, disciplinary training, and ultimately, my neurodivergence.

The other component of creative materialism was Nail's (2021) kinetic new materialist contemporary loop object theory, which he grounds with Barad's (2007) new materialist agential realism. I used contemporary loop object theory (CLO) because it fits

well with CRM in several ways. Nail's theory offers a different approach that is not grounded in modern Western scientific assumptions about objectivity and knowledge production—the same assumptions that mask and hide the cultural features in EHED that can make students feel as if they do not belong (Cech, 2013; Douglas et al., 2010; Lee et al., 2020; Riley, 2008; Seron et al., 2015; Whyte, 2016). Nail (2021) updates the scientific method through his interpretation of the kinetic epistemological and ontological implications of quantum field theory, mathematical category theory, and chaos theory. Nail pushes those trained in Western scientific research methodologies, like me and the participants, to reassess their epistemological assumptions about positivism and related constructs like objectivity and representation. With Nail's theory, scientific labor and its motions are shown as the very process by which we come to know materially, relationally, and iteratively. Nail formalizes a process of knowing that makes the process of knowledge creation visible. Nail (2021) describes this kinetic epistemological process as *know-how*, which fits well with my choice of arts-based research methods (Leavy, 2015). The findings and interpretations of my study show how the new knowledge we generated emerged relationally and iteratively through the research process using creative materialism.

With CLO theory (Nail, 2021), I created a theoretical bridge to create a vigorous (Riley, 2017) interdisciplinary research space that was both subjective but also grounded in the most current scientific theories. I as a Western science-trained scholar used CLO to intra-act (Barad, 2007) using arts-based research methods (Leavy, 2015) with the three participants who were from different cultures and different disciplines than my own



(Berryman et al., 2013b). I combined the qualities and principles of CRM, CLO, and arts-based research methods to form my interdisciplinary conceptual framework of creative materialism.

I also drew on Nail's (2021) interpretation of chaos theory in CLO theory to conceptualize the liminal experience of coming to know, whether in research or while learning in a classroom, as epistemic turbulence. From a theoretical perspective, chaos theory describes the inability to mathematically predict and model chaotic systems like turbulence. I used the concept of turbulence to describe and analyze what the research literature (Baille & Armstrong, 2013) shows are the messy, difficult, and confusing interdisciplinary processes of socialization for engineering students, but also the process of coming to know through research (Douglas et al., 2010). Additionally, previous studies by dissertation researchers using CRM (Berryman et al., 2013b; Bloomfield, 2013; Nodelman, 2013; Valenzuela, 2013) described the unpredictable and even messy process of using these principles in research designs, which fits well with my theorization of epistemic turbulence in the research process. Together, CRM and CLO theory provided a strong framework for me to build a collaborative arts-based research design (Barone & Eisner, 2012) that explored how underrepresented engineering students experienced the culture of engineering.

### **Research Questions**

Because my theoretical framework offers a different approach than Western and EHED dominant positivist ways of knowing, I did not seek to prove a hypothesis or

determine one universal generalizable answer to my research questions as in positivist epistemologies (Bucciarelli, 2009). Instead, I conceived of my research questions as guides to my inquiry. I used my two research questions to mark the borders of my research project and I used them in my analysis and interpretive processes.

1. How do underrepresented engineering students experience socialization into the professional engineering culture during their education?
2. How did creative materialism function to answer the first research question?

The first question directly explores the culture of engineering but from the perspective and experience of underrepresented students in their own voices, as called for in the research literature (Blosser, 2017; Cech, 2013, 2014; Faulkner, 2007; Foor & Walden, 2009; Godfrey & Parker, 2010; Heybach & Pickup, 2017; Riley, 2008, 2017; Seron et al., 2018; Stonyer, 2001). I included the second question to explore how my unique creative materialist framework functioned to fill the needs identified in the research for a more vigorous approach that was subjective, inclusive, flexible, critical, and qualitative (Riley, 2017).

## **Methods**

I chose arts-based research methods (Leavy, 2017) for my interdisciplinary, critical, and culturally responsive qualitative study at an engineering school. I recruited three undergraduate engineering students who self-identified as having multiple underrepresented social identities that they wanted to explore in relation to their engineering education and future careers. Following CRM principles (Berryman et al.,

2013b), I worked with each student participant to design the data collection methods, and what is referred to in ABR as content generation (Leavy, 2015), of conversational interviews, self-reflective weekly journaling, and creative practices like writing poetry, drawing, painting, and photography, with each participant choosing which creative practices fit them best. As a form of cultural responsiveness (Berryman et al., 2013a), I provided flexibility in the design to accommodate the stressful workload (Coley & Jennings, 2019) that engineering students experience, which all three participants needed during the data collection period. I also produced my own content through critical qualitative methods like analytical memos and field notes, but also with my own creative materialist practices that use arts-based methods like poetry, photography, collage, drawing, and painting (Leavy, 2017). I invited the student participants to collaborate with me in the analysis and interpretative processes of this study in keeping with the power-sharing aspects of CRM (Cardno et al., 2017). All the participants read the final drafts of this dissertation and approved it without requesting revisions.

### **Significance and Contributions**

The primary significance of my study resides in how I used a vigorous (Riley, 2017) unique, interdisciplinary methodology that I theorized, creative materialism, to study the least researched STEM discipline, engineering. I provided a much-needed culturally responsive methodology instead of a deficit-based approach in which students are seen as deficient and solely responsible for their struggles. I intentionally theorized my study's design to fill the gaps in the engineering research literature calling for different methods that were subjective, participatory, and that elevated student voices

(Baille & Armstrong, 2013; Beddoes et al., 2017; Chrysochoou et al., 2022; cole & O'Riley, 2017; Cuellar et al., 2022; Douglas et al., 2015; Harper, 2010; Karwat et al., 2014; Kellam et al., 2015; Moloney et al., 2018; Taylor et al., 2019). The resulting conceptual framework of creative materialism is a significant contribution to not only the engineering education literature but also as an example of using culturally responsive methodologies (Berryman et al., 2013a; 2013b) and arts-based research methods (Leavy, 2017).

A unique contribution I made to culturally responsive methodology research was my adaptation of the framework principles and application outside of Indigenous communities by applying these principles to a small academic interdisciplinary research community made up of the three participants and me, who all hold underrepresented identities. Instead of one culture, we each brought our own set of identities and various cultures to our collaboration. Rather than starting with a shared culture between us as the focus of our study, I used CRM principles (Berryman et al., 2013b) as a guide to creating a new culture of trust and vulnerability between me and the participants to explore the larger dominant culture of engineering. This new culture of care emerged through the collaborative research process itself and our intra-actions, which is a unique contribution to CRM literature. Additionally, I contributed significantly to neurodivergent research with my creative materialism by providing a possible framework for research with and by neurodivergent people, though further research is needed to better understand these dynamics and relationships (Chrysochoou et al., 2022; Cuellar et al., 2022; Milton, 2014; Pesonen et al., 2020; Taylor et al., 2019; Woods et al., 2018). I theorized my framework

as a methodology for my neurodivergence, which I became aware of through this research process because of the trust I built with the participants using creative materialism. I utilized my strengths and because I built my framework with components that made sense to me—CRM, new materialisms, and arts-based research methods, I found the methods stimulating and comfortable. As a result of participating in the study and using the creative materialist framework, all three participants also became aware of their neurodivergence, which was not an anticipated outcome.

My study was also significant by providing narratives, both by me and the participants, that illustrate the emotional process of discovering one's own neurodivergent identity in the current culture of stigma and misinformation around autism (Chrysochoou et al., 2022; Cuellar et al., 2022; Milton, 2014; Pesonen et al., 2020; Taylor et al., 2019; Woods et al., 2018). Particularly, my study provides an example of a non-deficit-based approach to uncovering and coming to know neurodivergence in education and among adult women (Zener, 2019). My study also contributes to the growing body of research on student mental health in engineering education but specifically contributes more insights into the experiences of underrepresented engineering students and how the culture of engineering impacts their well-being (Jensen & Cross, 2021). It is important to note that my unique framework of creative materialism contributes a much-needed qualitative approach to examining student mental health in engineering education, which is significant.

My study also contributes to the research in higher education that uses arts-based research methods. A review (Flint & Toledo, 2021) of the use of ABR methods in higher education research over twenty years, from 2000-2020, showed that ABR methods are no longer on the fringe of research that examines the complexity and nuances of experiences but also are now commonly used as an intervention in neoliberalized postsecondary education. Specifically, my study makes several significant contributions. One is by incorporating a range of creative practices including poetic writing, painting, and drawing, both by me and the participants; Flint and Toledo's review (2021) showed that photography has been the primary method in most artful inquiry projects. Importantly, their review found no use of new materialist theory with most of the articles they reviewed using constructivist frameworks, critical theory, or no theory at all. My study is also specifically significant in how I utilized ABR methods across the entire study, from theorization of the conceptual framework of creative materialism to the creation of the proposal, to data/content generation by the participants and me, but also in the analysis and interpretation portions of the dissertation process; most studies used ABR methods for data collection (Flint & Toledo, 2021). Significantly, we shared the works that were created in this document, both poetic and visual, in contrast to the literature review that showed that most studies chose to describe the creative works with text (Flint & Toledo, 2021).

My research also contributes to the limited studies that use creative methods to explore the experiences of neurodivergent people and researchers (Douglas et al., 2021; Ridout, 2014). However, my use of arts-based research methods specifically contributes

new knowledge to better understand not only the higher education experiences of neurodivergent students but within engineering education, which these two previous studies did not. My collaborative research also significantly includes narratives (Cuellar et al., 2022) that show the complex reality in which neurodivergent students hold multiple identities that overlap and matter in different ways depending on the setting. That is, each neurodivergent person is unique neurologically and must be treated as such (Stenning & Rosqvist, 2021).

Theoretically, my research contributes to the application of new materialist theories in research in specific ways. I used Barad's agential realism (2008) and Nail's contemporary loop object theory (2021) to ground CRM (Berryman et al., 2013a) and ABR (Leavy, 2017) as emergent, embodied, relational, and material processes. The findings show the vigorous (Riley, 2017) process of how new knowledge emerged from our intra-actions (Barad, 2007) and how we were transformed and created a new culture through our sharing with vulnerability and trust (Berryman et al., 2013a) rather than relying on notions of distant objectivity. But I also contribute to new materialist theorization by showing how knowledge production in research moves and affects change in the world (Nail, 2021), motions that created new insights for us and others through our intra-actions. By incorporating Barad's ethical components of intra-action (2007) into the creative materialist conceptual framework along with CRM decolonizing principles of cultural responsiveness (Berryman et al., 2013a), my study offers a different lens that can potentially shift educators' perspectives on why inclusion and access matter beyond the development and maintenance of diversity programs (Ahmed, 2012).

I believe this ethical, theoretical, and methodological framework is especially important as praxis to potentially move diversity practitioners and their programs in higher education and engineering education beyond performative diversity programs that are quantitatively focused (Baber, 2015) and prestige seeking (Ahmed, 2012). Our study showed that programs like disability support services, however well-intentioned, have the potential to create invisible barriers to inclusion and accessibility. Diversity and inclusion programs leave marks on students' and other community members' bodies (Barad, 2007). My study shows that it is critical to remember that these marks have the potential to be affirming and healing (Chrysochoou et al., 2022) but also damaging if they are based on deficiencies like the medical model of disabilities (Cuellar et al., 2022). Additionally, my study shows how DEI and disability support services that are grounded in a one-size-fits-all culture of engineering education, which rests on notions of objectivity and cultural fetishes around enduring extreme suffering, may further harm the very students these programs are intended to aid. Invisible hidden cultural practices like weeding-out and explicit cultural pressures that make students resist self-care create resentment and suspicion towards the institution and seem to deter students from seeking accommodations that would improve their educational experiences and outcomes as well as their mental health and self-esteem.

Importantly, our study contributes more narratives from underrepresented students' perspectives on how they experience the culture of engineering, which was the first research question and focus of the study. While the research on the experiences of females in engineering education has grown considerably (Blosser, 2017; Faulkner, 2007;



Seron et al., 2018; Stonyer, 2001), our study is unique in that the participants themselves contributed their stories as female students who hold multiple complex and entangled identities like low-income and first-generation females, ambiguously racialized females, queer females, and females with disabilities. Our collaboration also provided contributions to the growing research about the mental health impacts of engineering culture and education on students, particularly for underrepresented students who are made to feel excluded and like they do not belong (Beddoes & Danowitz, 2022; Cross & Jensen, 2018; Jensen & Cross, 2021). We also provided rich narratives from the participants' voices that contribute to a better understanding of how extreme rigor, prestige-seeking, and rigid positivist pedagogies affect underrepresented students' well-being. We also showed how the culture of engineering is reproduced by the students themselves and the effects the culture has on their mental health. Importantly, we also showed the agency of the participants to resist and modify their responses to the cultural pressures towards self-care and building a community of support.

I believe that the direct recipients of the contributions of this collaborative project were the student participants and myself as we increased our understanding of our experiences within EHED as neurodivergent women by creating our own unique research community and a culture of vigor (Riley, 2017) based on care and epistemic pluralism. For the student participants, having the interdisciplinary spaces to critically reflect increased their understanding of their own experiences in the EHED culture and was an opportunity for personal growth and transformation (Baille & Armstrong, 2013; Beddoes et al., 2017; Moloney et al., 2018). The participants benefited from exploring their

understanding of their profession to gain insights into their purpose as future engineers and scientists (Beddoes et al., 2017). The participants also better understand their own turbulent experiences (Baille & Armstrong, 2013) of professional socialization into engineering culture in relation to their unique multiple identities, which was a goal of all three participants. However, another goal of the participants was to share the stories of their struggles with others but also their various forms of resistance to the harmful qualities of the culture, which they enacted to maintain their own mental health and well-being. Their generous and vulnerable sharing significantly contributes to increasing educators' understanding of underrepresented students' experiences, which can help with making changes in the culture of EHED so that future underrepresented students do not have the same struggles.

Because I was a learner in the process (Valenzuela, 2013), and I had to continually reflect and self-interrogate, I am also a beneficiary of the study. I benefited by coming to know myself and my assumptions about my own multiple identities as I worked with the participants and learned about their experiences. I learned how my U.S. academic and disciplinary training and my social identities affected the creation, implementation, and experience of this project; that is, as a White, cis-gendered, middle-aged, able-bodied, heterosexual, first-generation, working-class, neurodivergent female Ph.D. candidate and adjunct professor in the humanities, arts, and social sciences (HASS) at an engineering education institution using a research framework that was intended to break through positivist constraints in engineering education research (Riley, 2017). CRM (Nodelman, 2013) required me to constantly self-reflect and CLO theory (Nail,

2021) provided me with a framework in which I identified and resisted the cultural assumptions about rigor, positivism, and disciplinary and epistemic borders that underpin engineering culture (Riley, 2017). As an artist, my creative materialist framework provided me an opportunity to enact my unique *kinesthetic-onto-epistemology* in social science research, a theorization that emerged through self-reflection while designing this dissertation study. Most importantly, as an EHED researcher working to increase the participation of students from underrepresented communities in engineering, I learned directly from these student participants how they experience the culture of EHED and the socialization process.

Because our study takes place at a specific engineering educational institution, the Colorado School of Mines, our findings are particular to that campus, its academic departments, extracurricular activities, campus culture, and its ever-increasing diversity, inclusion, and access (DI&A) and student mental health initiatives. Therefore, our collaborative research contributed specific insights and stories about the school that can be utilized by community members to make the campus more inclusive and accessible and improve student mental health and well-being. Given the hegemony of positivism in the culture of engineering (Riley, 2017), I anticipate there may be resistance and even rejection of the study's findings and interpretations for some at Mines and in the larger engineering education and research community because of the conceptual framework and methods used were subjective. However, given the decades of research and exposition on the need for new approaches to understand and solve the stubborn lack of diversity in engineering, I hope that skeptics will be open-minded and allow the participants' stories

and my story to shift their perspective on how harmful the culture of engineering is for many in the community. Without creating a vigorous (Riley, 2017) inclusive, equitable, and accessible culture that embraces the variety of differences across students, I believe engineering will remain exclusionary.

### **Organization of Dissertation**

In the next chapter, I provided the context for my study by elaborating on my theoretical framework and the gaps in the literature that I introduced here. I began the chapter by explaining my theoretical framework before my review of the research literature. Both CRM (Berryman et al., 2013a) and CLO theory (Nail, 2021) provided theoretical lenses through which I critically contextualized the exclusionary aspects of EHED culture described later in my interdisciplinary literature review. Both theories argue that historical events must be included in contemporary research because these events have agency on current diversity efforts and research, so I began by reviewing the pertinent and foundational research about the history of engineering education as a relatively new discipline within the STEM paradigm. I also synthesized research that shows the historical and purposeful exclusionary development of engineering and EHED and how specific groups like women and racial and ethnic minorities were affected. I followed the historical review with a review of the current empirical research on how these historical agents manifest in today's engineering culture and how this culture, and its associated inequities and exclusions, are reproduced by students, faculty, and others through the professional socialization process. I identified the gaps in the EHED culture and socialization research that my study aimed to fill. I ended the chapter with a review

of the EHED research identifying the need for more epistemologically inclusive and culturally responsive methods (Riley, 2017) like arts-based research methods. In this last section, I described the knowledge gap between the recent EHED research that is seeking pluralistic methodologies while acknowledging that many engineering educators and researchers are not trained in interdisciplinary, critical qualitative methods and may resist alternative approaches (Douglas et al., 2010; Riley, 2017). However, I also reviewed the research literature from scholars in underrepresented communities that described their epistemological traditions, their conflicted history with Western STEM, and how the hegemonic positivist culture harms their students, thereby creating a barrier to increased participation. Scholars in disabilities studies and particularly neurodivergence research point to similar issues in higher education and engineering education specifically.

In Chapter Three, I explained my methodology and research design in detail and shared how creative materialism emerged as a neurodivergent framework for me. I shared my positionality in this chapter in detail as part of my ongoing self-interrogation as the researcher. I followed the requirements of CRM (Berryman et al., 2013b) and transparently shared how this study emerged relationally to my own intersecting identities, my research agenda of improving diversity in EHED, my academic goals of completing a Ph.D., and my unique creative materialist conceptual framework. I explain the context of the study at the unique location of the Colorado School of Mines, a small, elite, engineering-focused higher education institution, which is celebrating its 150th anniversary in 2024 with its well-established historical narrative and culture related to mining engineering. I included detailed participant profiles, which were reviewed, edited,

and approved by the participants. I used these profiles to elevate their voices and to show that despite sharing similar social identities, like being female, each had their own unique experience of the culture of engineering, which we showed is shaped by their families. I also show how I conducted my unique neurodivergent form of analysis and interpretation, including my use of visual art practices like drawing and painting.

In Chapters Four and Five, I shared the findings from our collaborative study and showed the participants' data and content that illustrate answers to the first research question about their experiences in the culture. I used a theme of visibility to organize the findings in Chapter Four. Because of the emergent finding that all four of us are neurodivergent and most likely on the autism spectrum, I put the findings to the second research question about how creative materialism functioned to answer the first research question in its own chapter. The theme of Chapter Five is transformations through the careful development of a research community culture based on care, trust, and vulnerability (Berryman et al., 2013b) which was crucial for the findings to emerge. I showed how the three methods of collecting data and generating content—conversational interviews, diaries, and creative practices, worked to triangulate our findings and transformational insights. However, I inserted my own voice in this chapter by including excerpts from my academic memos and emails with the participants to show how my realization that I am on the autism spectrum impacted the study and the participants. I do so because of the creative materialist framework that included culturally responsive methodologies that required transparency by me. I also described a few of the barriers that arose for the participants with the methods due to the interdisciplinary quality of

bringing in arts-based, subjective, and deeply personal methods into a positivist culture of extreme rigor.

In Chapter Six, I discussed the implications of the study with the existing literature, including how the process of socialization affects underrepresented students in higher education and specifically in the culture of engineering education. Here, I showed the entanglements of twentieth-century history and neoliberal higher educational policies that shaped institutional priorities away from teaching and towards faculty research and gaining and maintaining prestige. I showed how Mines' unique historical saga, and its cultural identity of extreme rigor is entangled with and shaped by the emergence of the ranking regime, which impacts student experiences and well-being. I also described the theoretical implications of my study for culturally responsive methodologies, new materialist theories, and arts-based research methods. In this chapter, I also offered my thoughts on future research using creative materialism but also describe the further research that is needed for engineering educators and researchers to better understand the experiences of underrepresented students and to ultimately make their campuses more inclusive and accessible to all. I ended with recommendations for Mines, engineering educators, and researchers, but also higher education more generally.

## **Conclusion**

In summary, the ongoing efforts in engineering education, and STEM education more broadly, have improved participation by students with underrepresented social identities in engineering, but barriers remain. EHED research is often deficit framed or

focused on marketing to students with underrepresented social identities and ignores larger systemic, cultural, and historic assumptions that silence differences and cover oppression (Riley, 2017). I identified that culturally responsive methodologies (Berryman et al., 2013a) are needed in which engineering students can share their experiences in their own voices. I used arts-based research methods (Leavy, 2017) as culturally responsive methods, which I combined with the new materialist contemporary loop object theory (Nail, 2021), to create a vigorous (Riley, 2017) interdisciplinary space for exploration and collaboration in which I as a Western-trained scholar shared power with the student participants in creating the research design. Together, the students and I contributed to our own understanding of the lack of diversity in engineering education and our own experiences of using this unique conceptual framework.



## Acronyms

ABR	arts-based research methods
BIPOC	Black, Indigenous, and People of Color
CLO	contemporary loop object theory
CRM	culturally responsive methodologies
EHED	engineering higher education
DEI	diversity, equity, and inclusion
DI&A	diversity, inclusion, and access
LGBTQ	lesbian, gay, bisexual, transsexual, and queer
IK	Indigenous knowledge
MEP	multicultural engineering program
STEM	science, technology, engineering, and mathematics
STS	science and technology studies

## Definition of Terms

- **Creative materialism:** my conceptual framework that combines Nail's (2021) contemporary loop object theory, culturally responsive methodologies, and arts-based research methods.
- **Coloniality:** an attitude of domination and ownership
- **Contemporary loop object:** Nail's (2021) theory for objects of knowledge that emerge from the processes and movements of science based on interpretations of quantum fields theory, chaos theory, and mathematical category theory.
- **Culturally responsive:** theories and methods that reject objectivity and acknowledge different cultural ways of knowing that are equivalent but different, and that require self-interrogation, power-sharing, and transparency.
- **Culture:** the signs, rituals, and messages that circulate as systems, but also beliefs and myths that give meaning and boundaries to a group
- **Diversity:** inclusion of all forms of social identity, including gender, sexuality, race, ethnicity, and disabilities
- **Engineering Higher Education (EHED):** post-secondary education activities focused on teaching the knowledge and skills necessary for the practice of professional engineering.
- **Entanglement:** concept from quantum field theory that describes the relational and material ways and challenges objectivity
- **Epistemic pluralism:** the rejection of the idea of one correct way of coming to know and creating knowledge.

- **Ethico-onto-epistemology:** Karen Barad's (2007) conception of integrating knowing (epistemology) and being (ontology) with an ethical relationality that produces reciprocal responsibilities.
- **Hybridity:** Nail's (2021) conceptualization of knowledge production as relational
- **Feedback loop:** Nail's (2021) conceptualization of the iterative and relational processes of generating knowledge.
- **Indigenous:** people and groups who were the first inhabitants of their ancestral land that have been colonized by a dominant group from outside
- **Indigenous Knowledge:** the knowledge unique to an Indigenous group's ancestral way of living in the world.
- **Interdisciplinary:** an approach to research, learning, and knowledge production that crosses disciplines and challenges the epistemic borders of academic disciplines
- **Intersectionality:** the unique mix of social identities a person has that complicates experiences of discrimination and oppression.
- **Intra-action:** new materialist conceptualization of the relationality of matter that rejects objectivity.
- **Kaupapa Māori:** Unique approach created in New Zealand that provided the Māori a framework to reclaim their ancestral ways of knowing and reject outside researchers' definitions and control, but generally now means reconnecting with a community's own historical culture and reclaiming the power to define their problems and solutions through equivalent but different cultural and epistemological practices (Smith, 1997).

- **Kinematic:** Nail's term for his theorization of the motions of science and the production of knowledge
- **Kinesthetic-onto-epistemology:** my conceptualization of how I come to know as an artist by combining my creative and intellectual practices; also a neurodivergent framework.
- **Kinetic operators:** Nail's (2021) term for the agency of history in present-day experiences and knowledge production that are usually undetected.
- **Know-how:** Nail's (2021) conceptualization of the process of coming to know through motion
- **Legacy Students:** White, cis-gendered, heterosexual, male students who are not first-generation students in engineering.
- **Liminal:** transformation through moving across borders and thresholds of knowing
- **Looping:** analysis and meaning-making process in creative materialism
- **Meta-stable patterns:** Nail's (2021) conceptualization of the emergence of objects from the flow of matter, which seem stable and discrete, but are in constant relational motion.
- **Meritocracy:** a system based on a hierarchal belief of some deserving inclusion based on certain characteristics over others without these characteristics who are deemed inferior.
- **Metrics of progress:** Downey's (2007) conceptualization of how society measures its progress.
- **Pedagogy:** an approach to teaching and learning

- **Pedesis:** Nail's (2021) term for the emergent quality of knowledge
- **Positivism:** epistemology and methodology of objectivity grounded in rationality, empiricism, and mathematics that dominates engineering education and culture.
- **Professional socialization:** the process by which students come to know their professional culture and practices.
- **Socio-technical dualisms:** a belief that engineering is only about solving technical problems, not the social, political, or economic problems with equity implications for underrepresented students and their communities.
- **Spacetime:** new materialist term based on quantum field theory that describes how space and time are not separate but exist together.
- **Troublesome knowledge:** interdisciplinary knowledge that is problematic for engineering students trained exclusively in positivism.
- **Turbulence:** theorization borrowed from chaos theory in which learning and coming to know is chaotic, emergent, and liminal processes that cannot be predicted but from which new meta-stable patterns of knowledge emerge
- **Underrepresented:** social identities whose participation in STEM is lower in proportion to the overall population of people with that identity

## **Chapter 2: Theory and Literature Review**

### **Introduction**

My dissertation proposal filled methodological and knowledge gaps that I identified in the engineering education and diversity, equity, and inclusion (DEI) research literature. In this chapter, I provide the context in which I attempted to explore my research questions:

1. How do underrepresented engineering students experience socialization into the professional engineering culture during their education?
2. How did creative materialism function to answer research question one?

I accomplished this contextualization in two parts. In the first part of this chapter, I described my theoretical framework. In the second part of this chapter, I reviewed the literature relevant to the key concepts through the lens of my theoretical framework. I chose to review my theoretical framework before my literature review as I believed doing so clarifies the historical, cultural, and epistemological differences between the various social identities I later reviewed in the research literature and how the culture of engineering affects student experiences; that is, it also allowed me to be more succinct and critical in my review of the literature. In the research, these differences were points of contention epistemologically and pedagogically that affect participation and must be

made visible to show the differences in student experiences in engineering, which was the purpose of my study.

## **Theoretical Framework**

### **Introduction**

I combine two theories to form my theoretical framework: *culturally responsive methodologies* (CRM) (Berryman et al., 2013a) and Nail's (2021) kinetic new materialist *contemporary loop object* (CLO) theory. I use these two theories together to create a theoretical bridge to the interdisciplinary space I created to explore my research questions in collaboration with three student participants. CRM (Berryman et al., 2013a) and CLO theory (Nail, 2021) were central to my methodological contribution that fills the gap in the EHED research literature calling for interdisciplinary (Adams et al., 2011; Baille & Armstrong, 2013; Cech, 2014; Karwat et al., 2014) and subjective (Moloney et al., 2018) research approaches to better understand underrepresented engineering student experiences. I used these two theories to support my use of arts-based research methods (Leavy, 2017) that together formed my conceptual framework of creative materialism, which I elaborate on in the last section of my literature review.

### **Culturally Responsive Methodologies**

#### ***Introduction***

Two main sets of theories inform CRM: *critical theory* and *Kaupapa Māori* theory, which is an Indigenous Māori framework from New Zealand. Culturally responsive methodologies expose the effects of power differentials that are embedded in

Western education systems, which includes engineering education (Berryman et al., 2013a). The *Kaupapa Māori* movement emerged in New Zealand in the 1970s and rejected the Western colonial forms of education imposed on Māori school children (Berryman et al., 2015; Smith, 1997). As a social justice movement to reclaim their worldview and use it as the basis of their children's education, activists in Kaupapa Māori refused to be silent on the impacts that Western educational practices had on Māori children and the community. These colonizing outsider practices were based on notions of objectivity that neglected the unique cultural and historical beliefs, values, and practices of the Māori people. Dr. Graham Hingangaroa Smith's doctoral thesis (Smith, 1997) was foundational to developing several elements of Kaupapa Māori, which I explain in more detail below.

To be clear, I am not Māori nor were any of the participants in this study, however I was open to Indigenous students participating when I designed the conceptual framework. I chose CRM for my dissertation research on engineering culture, following Nodelman (2013), Valenzuela (2013), and Bloomfield (2013), because these inclusive and culturally responsive principles required continuous interrogation by me of my own deeply engrained assumptions about learning and knowledge creation while collaborating with the participants. I also chose CRM for its praxis and emphasis on the ability of research practice to inform theory. As a disciplinary outsider to engineering education, I recognized that I needed to identify, respect, understand, and respond to the culture of engineering that the participants were being socialized into while collaborating with them in the study. As such, I chose CRM because I was open to working with any students



from any background rather than focusing on specific demographic groups and social identities. CRM methods are emergent and provided me the theoretical grounding to create a new shared culture between the participants and me that was inclusive of our differences. CRM are alternative frameworks that humanize research (Berryman et al., 2013b) and I chose this methodology to provide an equitable framework for me as a heterosexual, cis-gendered, abled-bodied, middle-aged, neurodivergent, White female, Ph.D. candidate, and EHED adjunct professor in the humanities, arts, and social sciences to collaborate with the student participants who are underrepresented in engineering education (Bloomfield, 2013). CRM provided a framework for me to constantly self-reflect on what I brought to the emerging relationships between the participants and myself and reminded me to interrogate my own disciplinary, ideological, and academic agenda of writing a dissertation and graduating (Valenzuela, 2013). Next, I will explain how CRM affected my research design.

My purpose in choosing CRM was to benefit both the participants and the Mines community but also myself as the researcher through using inclusive power-sharing techniques based on epistemic pluralism. The term *culturally responsive* purposively is used by CRM practitioners and theorists to indicate research that is participatory with the culture of the community that is the focus of the inquiry, which for my study included layers of culture. Our focus was on the culture of engineering, but our research community consisted of three engineering students from a variety of backgrounds and who hold multiple social identities that are underrepresented in EHED (Berryman et al., 2013a). In our collaboration, the culture of this new research community was emergent

and only became visible through our intra-actions (Barad, 2007) that were based on CRM principles of caring and building trusting relationships. In my study, my relationship with the research participants was complex and nuanced as the main identity under exploration was that of engineering students, and particularly underrepresented students. While I am an alum of this EHED institution, I am not educated in STEM as the participants were; I was crossing disciplinary borders (Valenzuela, 2013). However, each participant brought their own unique multiple and interdependent social identities to the study, which complicated how each participant experienced professional socialization and the EHED culture we were exploring. I used CRM as part of my framework to continually remind me of my positionality as an insider/outsider scholar who was conducting this study and to maintain power-sharing with the student participants (Nodelman, 2013).

CRM (Berryman et al., 2013b) required collaboration and building equity between me as the researcher with the participants to address the power differentials inherent in my research agenda of researching, writing a dissertation, and earning a Ph.D. While CRM recognizes that it is necessary to include the researcher's academic paradigm, I as the researcher was conscious that I was extracting the stories from the participants for my own personal, academic, and professional gain. Importantly for my study, and as I show later in the literature review, CRM principles offer an alternative to the positivism that dominates Western education but also EHED research approaches, which I relied on to maintain equity as much as possible (Berryman et al., 2015). Specifically, the CRM principles that I used continuously re-centered myself and my intra-actions (Barad, 2007) with the participants as an ongoing relationship. These

principles that I relied on included that knowledge is a co-created process that is in service to the community, despite the personal and professional gains I acquired. Together, guided by CRM, we explored the collective epistemic pluralism in our small research community using the interdisciplinary approach of creative materialism, which revealed the impact of being neurodivergent in the rigid positivist culture of engineering education more broadly. We explored the larger political, economic, institutional, and cultural contexts which we were immersed in while also recognizing our own goals with the research, which was focused on creating change within engineering culture toward greater inclusion and access for those who were not historically included.

I relied on the CRM principles of humility and empathy to create a dialogical space for the participants and me to be vulnerable as we explored their subjective experiences (Berryman et al., 2013b). I used these principles to maintain vigilant awareness that I was not harming the participants as they explored their own emotions but supporting them through transparently sharing my own experiences and insights and by being vulnerable as well. Through this process, we generated rich detailed aesthetic findings that transformed the participants and me (Barone & Eisner, 2012). This generative process was at times difficult to navigate and created epistemic turbulence for all of us as we moved through the research process. I carefully relied on CRM principles to guide the participants through this confusion toward clarity and reaching their goals of understanding their own experiences more clearly. I believe that utilizing these collaborative principles created a unique research community with its own emergent culture of trust, care, and openness from which to critique the epistemic hegemony of

positivism in EHED while also offering an interdisciplinary and epistemic pluralistic alternative to this dominant culture.

### *Theoretical Foundations of CRM*

Critical theory informs the epistemic power-sharing of the CRM framework, which identifies the domination of Western ways of knowing in modern education globally, making it a good fit for exploring EHED culture that is deeply tangled with Western positivism (Berryman et al., 2013b). Critical theory is related to critical pedagogy, which draws heavily on the liberatory work of Freire (2000). The inclusion of critical theory and critical pedagogy in CRM provided a means for the student participants and me as the researchers to bring our cultural lives into the processes of learning and knowledge production during our study (Cardno et al., 2017). Building on the requirement in critical ethnography for self-reflexivity of my own biases, critical theory added an expectation that I also equally examined the nature of my relationship with the participants (Nodelman, 2013), who are the local experts in both their own epistemic traditions, but also in their own experience of becoming an engineer. In using these critical approaches, we transparently shared our experiences but also our values and goals during the research process, which created an alternative learning and research space. I was not an outside expert whose role was to be an objective observer; I was a participant who was learning. Theoretically, CRM are informed by Indigenous, Latinx, LGBTQA+, and disability theories that are underrepresented in academia and EHED (Berryman et al., 2013a). CRM has overlapping features with postcolonial and feminist theories in the intentional examination of the politics of knowledge production that

occurs in academic research (Berryman et al., 2013a). The overlapping theoretical historic threads of CRM and new materialism, which I discuss in detail below, strengthened my theoretical framework.

Along with the Western academic tradition of critical theory, an Indigenous framework from the Māori of New Zealand, called *Kaupapa Māori*, also informs CRM (Berryman et al., 2013b). *Kaupapa Māori* utilized the political consciousness of the Māori people to change their children's education by rejecting the dehumanizing and degrading stories from Western outsiders about the Māori, which were part of the Western education system that Māori children attended. The movement centered on the Māori culture, language, values, epistemologies, and aspirations in the knowledge production process as a counter to the narratives created by outsiders that degraded Māori ways of knowing. *Kaupapa Māori* as a research methodology allows a research community to connect to its own historical culture and define their problems and solutions by using equivalent but different cultural and epistemological practices (Berryman et al., 2013a). I used this re-centering and re-claiming principle as a framework for the student participants and me to collaboratively create their unique research protocols.

*Kaupapa Māori* includes a unique cultural principle called *whakawhanaungatanga*, which is the protocol used when meeting new people (Berryman et al., 2013a, p. 11). This protocol involves the reciprocal sharing of one's cultural history and background, which for the Māori includes genealogical connections to one's ancestors and the land. The intention of this principle is to generate mutual responsibility

between the participants and researchers. While I am not Māori, I was deeply affected by this cultural concept and practice and I drew on the intention of this protocol in designing the study. I used the concept of openly sharing and introducing oneself transparently as a guide for approaching and introducing myself to the participants to build trust and rapport in our own unique way (Nodelman, 2013). By inviting the student participants to share equally while also being transparent about myself, we had a method for moving out from under the hegemonic pressures associated with positivism's objectivity that is the background of our research in EHED.

To summarize, I used CRM as a framework for checking my own power, agendas, and social identities in my relationships with the student participants as we collaborated and as I analyzed and interpreted our data and content. CRM provided a critical, decolonizing, and power-sharing alternative to positivist methodology and distant objectivity. I argue this approach was important because, as I show in the literature review below, research has identified positivism as a barrier to increasing diversity in EHED for students whose cultural background and identity are grounded in other epistemological frameworks. These alternative values we incorporated included: building relationships of trust and vulnerability through our unstructured conversations and sharing of our insights; elevating the participants' voices through extensively sharing their stories in their own words in the findings; prioritizing our human dignity while also being vulnerable in our sharing by caring for each other as we were transformed; embracing and using epistemological pluralism in the study through the use of different methods for data collection and content creation; recognizing and using our political

consciousness to transform our perspectives and provide control over our futures in academia as we seek to create change; and resisting the disciplinary power structures in higher education and engineering education that maintain hierarchies (Berryman et al., 2013a, p. 15). As I show next, Nail's (2021) CLO theory as a Western science-based framework based on the most recent quantum science and mathematical theories echoes elements of CRM's principles.

## **Contemporary Loop Object Theory**

### ***Introduction***

Nail's (2021) new materialist, kinetic theory of the contemporary loop object in knowledge production was the other component of my theoretical framework. Nail's (2021) contemporary loop object theory provided a provocative (Barone & Eisner, 2012) fit for my study in STEM because it is based on contemporary Western sciences like quantum field theory, category theory in mathematics, and chaos theory. With this study design, I theorized that what has been missing from EHED research on diversity is a material, emergent, relational, and historically responsive theory that resonates with different, but equivalent, ways of knowing (Riley, 2017). As I will show later in the literature review, EHED is dominated by Western positivism and CLO provides an alternative Western science-based approach that I theorized may be inviting and inclusive to engineers and engineering students who have difficulty working across disciplines. CLO theory has many overlapping features with CRM (Berryman et al., 2013a) that help the two theories work well together for interdisciplinary research.

Nail's CLO (2021) theory offers an alternative to modern Western scientific assumptions about how knowledge is produced. By updating the scientific method through his interpretation of the kinetic, relational, epistemological, and ontological implications of quantum field theory, mathematical category theory, and chaos theory, Nail pushes those trained in Western scientific research, like me, to reassess their epistemological assumptions about the superiority of positivism and related constructs like objectivity (Nodelman, 2013). Nail's interpretation makes the iterative qualities, relationality, and materiality of scientific labor visible by showing that this labor is the very process of knowing and knowledge production itself. In our study, the students and I generated data and content that was then analyzed and interpreted using CLO theory, along with elements of CRM and the critical EHED and DEI literature, to show how we generated new knowledge through our research experience.

CLO theory is part of Nail's *philosophy of movement* (2018; 2019; 2021). Nail (2018) argues that in the twenty-first century, we exist during a period of exceptional movement. Nail notes that there are more images (2019) and objects (2021), which also are in constant motion than previous humans ever experienced. Nail's purpose with his philosophy of movement is the creation of new Western ontologies, aesthetics, and epistemologies that allow us to re-view history, but by examining historical motions and processes. I theorized that Nail's emphasis on history was a good fit with CRM and its inclusion of history as affecting the present (Berryman et al., 2013a). Nail's (2021) contribution and purpose with his contemporary loop object theory is to uncover invisible, unknown, and ignored elements from the past that remain entangled with our



current conceptions and perceptions about how new knowledge is generated. In the case of our collaborative study, and as I will show later in the literature review, the theorization of history as a material process with agency in our experiences today was necessary to unravel invisible exclusions that are deeply rooted within the culture of EHED and Western academia in general. In the next section, I contextualize CLO in the new materialist lineage in Western philosophy, followed by an overview of the main concepts in CLO that are based on Nail's interpretations of contemporary science. I used Nail's CLO theory (2021) concepts of emergence, feedback, and hybridity during the analysis and interpretation process, which I described in detail in Chapter Three.

### *New Materialist Context*

Unlike the deeply rooted and ancient Māori principles that undergird CRM (Berryman et al., 2013a), new materialisms (Dolphijn & van der Tuin, 2012) emerged out of the postmodern critical theories of the last half of the twentieth century, including critical, feminist, queer, and ecological theories and science and technology studies (STS) (Braidotti, 2015). New materialist theories are diverse, interdisciplinary, and challenging of several aspects of Western epistemological and ontological traditions because of its new materialist roots in critical theory, making new materialisms a good fit with CRM principles that are also based in critical theory (Berryman et al., 2013a). New materialist theories often weave many historical and theoretical threads together and through each other making them resistant to easy categorization and organization. They go by several names, which are often used interchangeably: neo-materialism, feminist materialism, vibrant materialism, agential realism (Barad, 2007), speculative realism, and post-human,

to name a few. Post-qualitative methods (Lather & St. Pierre, 2013) is a term for research methodologies based on new materialist theory. Most new materialist theories are meant to be used, to be “put to work” (Dolphijn & van der Tuin, 2012, p. 103), in a praxis of theory problem-solving, and thus are a good fit for the student participants and myself to examine the students’ experiences in engineering higher education with CRM (Smith, 1997) and arts-based methods (Barone & Eisner, 2012; Leavy, 2015).

The work of quantum physicist and new materialist philosopher Karen Barad is foundational to much of new materialist theory and my creative materialism. Barad’s (2007) interdisciplinary theorization, called *agential realism*, uses quantum physics, queer theory, and feminist science and technology studies (STS) approaches. Barad provides several unique disruptive terms in agential realism that are now part of many new materialist lexicons, like *intra-action*. The commonly used term “interaction” implies discrete separate things coming in contact but remaining apart as theorized in positivist concepts of objectivity (Barad, 2007). In contrast, intra-action implies unbreakable relationality and reciprocity between all material things, including humans.

I used the term intra-action throughout the dissertation as it disrupted my learned reliance on notions of objectivity that permeate my Western education (Nodelman, 2013). Barad argues that Western scholars must overcome a “Cartesian habit of mind” (Barad, 2008, p. 807) in which we believe the human mind can grasp representations of the “separate” outside world from ourselves, and therefore “know” objectively. Because the student participants’ experiences of positivism during professional engineering socialization in EHED were a focus of our collaborative study, my use of intra-action

provided a conceptual bridge for me to show how positivism moves in EHED culture, pedagogies, and identities, which I also lay out in my literature review in the next part of this chapter. Intra-action also disrupts engineering disciplinary cultural traits related to positivism like rigor and the socio-technical dualism that I introduced in the first chapter, which were also foci of my study of underrepresented engineering students' professional socialization. The relationality of these EHED cultural traits and their history also required that I critically interrogate these relationships and new materialisms provided the term *entanglement* to conceptualize this relationality. The quantum physics concept of entanglement is used both by Barad (2007) and Nail (2021) to describe the historic emergent relationality of all things. I used the term entanglement to point toward the complex historical elements that have agency in higher education and must be uncovered and named as barriers to inclusive and equitable education. Nail (2021) provides the term *kinetic operators* in CLO theory to conceptualize this historical agency, which I elaborated on below.

Relationality, matter, and motion are key principles in new materialist theories, and I used them conceptually as part of my analytical and interpretive processes. In contemporary loop object theory (Nail, 2021), or what Nail calls *kinematics*, objects of knowledge are created by the process of measurement that characterizes Western science. This “measurement-in-motion” challenges traditional Western science and its epistemological tradition of positivism that is grounded in the static, ahistorical, reductive, universalized objectivity of Newton, Descartes, Kant, and Einstein (Nail, 2021). Interdisciplinarity is necessary to conceptualize this move past positivist

knowledge production, which fits well with CRM's principle of epistemic pluralism (Berryman et al., 2013a). Karen Barad's (2007) conception of integrating knowing (epistemology) and being (ontology) with an ethical relationality that produces reciprocal responsibilities— or *response-ability*, is called *ethico-onto-epistemology*. Nail (2021) elaborates on this integrated concept using a kinetic perspective to conceive of a *kinetic-epistemology*, or “know-how”. Both Barad and Nail's work implies that there is no objective representation or knowledge of an object of inquiry, but rather immanent knowledge that arises through the motions and interactions between objects and people. I expand on these authors' conceptions in my theorization of creative materialism that incorporates CRM, CLO theory, and arts-based research methods as a *kinesthetic-onto-epistemology*, which I elaborate on later in this chapter and Chapter Three. With the new materialist theoretical context and terminology established, I now turn to the specifics of CLO theory and how I specifically utilized it in my research design, analysis, and interpretive processes with the student participants.

### ***The Flow, Folds, and Fields of Matter***

Nail's (2021) CLO theory is a material and kinetic theory that shows the process of knowledge production, which I used in my interpretations of our generated data and content. By showing how we came to know through the embodied and material research process of intra-actions, analysis, and interpretations, CLO theory provided us with the means to achieve the ideological and epistemological transparency conceptualized in CRM (Berryman et al., 2013b). Nail (2021) uses several related concepts to describe the perpetual motion of matter in CLO that are derived from quantum field theory. In this

section, I briefly explain some details of Nail's theory as they informed my research design, but also because I used them for analyzing and interpreting the content generated in my study with the students. Nail uses the concepts of *flow, fold, and field* to describe the kinetic qualities of matter in motion that his theory is based on. There are three types of motion related to flow, fold, and field: *pedesis* or emergence, feedback loops, and hybridity. I include brief examples of Nail's interpretations of quantum field theory, category theory, and chaos theory to show how different his CLO theory and these emergent sciences are from traditional Western scientific positivist assumptions that academia, and as I will show in the literature review, EHED culture is built upon.

The flow of matter is the vibrating quantum field that is space, in contrast to positivist conceptions of objects in space (Barad, 2007). Everything in the universe is in motion, relational, and immanent. Nail (2021) argues that this continuous undifferentiated movement of matter disrupts positivist and constructivist theories of fixed human structures and states that rely on concepts of forces between objects to account for the changes in quality, magnitude, or direction of objects being measured in traditional scientific research. Nail also is critical of constructivism and argues that it theoretically preferences abstract thought and is a common framework to examine the history of science by preferencing metaphysical ideas rather than the historical, relational, and imminent material motion of science as Nail does with CLO theory (2021). Nail critically argues that the relational ontology theories, such as Latour's actor-network-theory, preference a permanent network structure that denies the continuous material emergent motion of the world. Nail (2021) also rejects vital materialism, a subset of new

materialist theories, due to the necessary construct in these theories of some sort of virtual permanent force between static objects that accounts for changes. Nail offers an example of waves in an ocean to illustrate his point; waves are not separate from the ocean but emerge as unique temporary forms with the movement of the ocean. The flow of matter is creative, continuous, and unstable. I was and continue to be, along with the student participants, history, and EHED culture, all part of this flow; nothing is outside of it. I theorized that Nail's (2021) interpretation is related to the concept of intra-action (Barad, 2007) and the relationality of CRM (Berryman et al., 2013a).

Nail (2021) conceptualizes folds as the process by which objects emerge from the flow of matter through intra-action. When flowing matter folds on itself through intra-action, a point of self-reference is created in space and time. Space and time in quantum field theory are not separate from each other but are the very flow of materiality, referred to as *spacetime* (Barad, 2007). In Nail's (2021) CLO theory, matter continues to fold, or loop, back to this point iteratively, and meta-stable patterns emerge that we perceive as discrete objects, from rocks to chairs to engineering students as well as research findings and dissertations. Through our body's repetitive process of materially sensing qualities and measuring quantities, patterns emerge in the flow of matter, like eddies in a river. I theorized the professional socialization process in EHED culture as a process of folding or looping and used this motion in my analysis and interpretive processes in this research study. Lastly, Nail (2021) conceives of fields as the structures of circulation that distribute and order these meta-stable patterns as fields of knowledge. Science, or knowing, is the process of objectifying moving matter into categories, disciplines, and

cultures, that is, turning the process of knowing into seemingly discrete objects of knowledge. Nail argues that scientists do not discover pre-existing objects. Rather scientists co-create objects through feedback loops that reorganize knowledge iteratively and continuously within fields. I theorize that this objectification process is what is countered with CRM principles like Kaupapa Māori (Berryman et al., 2013a), which theorizes this objectification as a colonial and ideological means of knowledge production and control, not objectivity. For this study, I used Nail's (2021) conception of fields of knowledge in the interpretation process to better understand how underrepresented students move in their field of engineering education. Additionally, through our collaborative research, we materially disrupted and re-formed the EHED cultural field of knowledge we were exploring as we move through the process iteratively.

### ***Conceptualizing the Motions of Knowing: Pedesis, Feedback, and Hybridity***

In this section, I described Nail's (2021) specific concepts of motion in contemporary loop object theory as I used these concepts in my analysis and interpretation of our intra-actions. Nail's contemporary loop object theory is an interdisciplinary synthesis that makes sense of the phenomenon of motion in knowledge creation. Nail describes this motion with three concepts: pedesis, feedback loops, and hybridity.

Nail chose the term *pedesis*, with its root word meaning "foot", to describe the unpredictable self-motion of matter (2018). Theoretically, Nail grounds this concept

ontologically in quantum field theory. Quantum field theory argues that all matter is in continuous motion in relationship to earlier positions in spacetime, but future trajectories and positions are not certain, only probabilistic in relationship to the previous positions (Nail, 2018). While matter, like me as PhD candidate and dissertation researcher, moves unpredictably, my motions are not random, but relational to where I have been. Indeed, it was this process by which my neurodivergent identity emerged. I began by using my arts-based research methods (Leavy, 2017) of generating content to conceptualize this project and creative materialism. Through this process, I emergently and iteratively made visible my own ways of coming to know how I know (Barone & Eisner, 2012). The generated content marked my motions through spacetime that I now describe and inscribe here textually (Nail, 2021). In our collaborative study, the student participants and I generated material content that was looped back into the process as feedback in the data collection and content creation but also in my analysis and interpretation motions to construct this dissertation.

This perspective epistemologically differs from positivist notions of isolating variables and controlling experiments, that is, imposing order from an intellectually perceived distance and separation (Barad, 2007). For example, my proposal emerged from my experiences of creating order out of chaos as I synthesized interdisciplinary research and theories with the problem of researching engineering students' experiences of socialization. In other words, my moving in relationship to research and theories was how my theorization came to be a known and ordered object of knowledge (Nail, 2021). Indeed, I experienced the formation of my proposal as embodied confusion and



turbulence by me as I had to actively resist my research methods training that is grounded in Western scientific principles of objectivity (Nodelman, 2013). In this way, I conceptualized the process of learning and coming to know as turbulence. I used this concept of turbulence as a lens for analyzing and interpreting how the student participants' content changed as they describe their experiences of socialization but also as we uncovered our own neurodivergent embodied ways of knowing.

Nail (2021) conceptualizes the motion of feedback loops as the process of folding or looping through the cyclical intra-actions of matter to form objects of knowledge. In the scientific process, these intra-actions occur through sensing the qualities and measuring quantities and magnitudes of matter in relation to oneself in spacetime. In our research, the student participants and I generated data and content iteratively. However, that content did not emerge in isolation, but in relation to our past motions, understanding, and experiences, including with family, which resonates with CRM's principle of knowledge production as a dialogical process grounded in community and culture (Berryman et al., 2013a). The participants and I adopted the language of looping to describe these feedback loops that marked the path of our movements through the research process. Our relational interpretive looping folded in not only the previous content we generated but also the research literature along with salient current events, like the Black Lives Matter movement and current political debates about critical race theory and diversity in the U.S. (Curran, 2023). I equate this relational looping process with the co-creative process and the holistic principle of CRM (Berryman et al., 2013a).

Eventually, using this iterative, chaotic, unpredictable looping we generated meta-stable patterns or fields of knowledge that are the final dissertation.

Nail (2021) uses hybridity to describe the historical relationality of all knowledge fields, a type of emergent interdisciplinarity in motion. Nail gives the example of the disciplinary field of quantum physics, which emerged from multiple disciplines, as a hybrid field of knowledge production. I will show later in my literature review the hybridity of STEM as a disciplinary field, in which each discipline—science, technology, engineering, and mathematics—is relational to the others rather than isolated disciplines. Nail interprets mathematical category theory for his concept of hybridity. Category theory uses arrows to show relationships and provides a kinetics of coordination, which shows mathematics as a process that mathematicians perform, that is, a process mathematics that describes rather than represents knowledge. In my study, I theorized Nail's hybridity with the CRM's principles of co-creation and constant reflection on power-sharing with the student participants (Berryman, et al., 2013b), with metaphoric relational arrows connecting us through the research process (Nail, 2021). Hybridity also theoretically supports CRM principles of holism, epistemic pluralism, interdisciplinarity, and the requirement of transparently showing the ideologies of change that we all brought to the study (Berryman et al., 2013b).

### ***Kinetic Operators***

The last CLO theory concept I need to explain for my study is Nail's (2021) concept of the *kinetic operator*. Following the quantum physics concept of an entropic operator, Nail's kinetic operator describes the relational agency between the objects of

knowledge that science measures during research. The kinetic operator describes and names how matter is historical and relational as it forms into meta-stable knowledge patterns or objects. Put another way, kinetic operators are entangled with material objects and their previous positions in the past. As an example, the historic contingent relationships of colonialism and exploitive research and educational practices imposed on the Māori community are kinetic operators in the emergence of the theory of Kaupapa Māori (Smith, 1997). For my study, I identified three primary kinetic operators in EHED culture that we collaboratively intra-acted with to generate content: positivism, rigor, and socio-technical dualisms. For our study, the student participants and I constantly showed and marked the motions of these kinetic operators in our data collection and creative practices that we sensed were moving in relationship to during our research.

Another example of how I used the concept of kinetic operators was in my development of the dissertation proposal and research design in relationship to CRM principles. I used kinetic operators as an analysis and interpretive lens in my critical self-interrogation, or feedback looping, which had to be continuously performed under CRM principles including *before* the research began (Berryman et al., 2013b). This process of looping provided points in the spacetime (Barad, 2007) of this project for me to sense, mark, describe, and eventually know how various kinetic operators, like my race, gender, age, professional educational attainment, disciplinarity, and eventually my neurodivergence were relationally entangled with this study. That is, as CRM asks, what are the ideological agendas that I brought to the project (Berryman, et al., 2013b)? The kinetic operators I identified included my academic training in research methods, my

intersecting social identities, as well as my historical experiences in EHED as both a graduate student and adjunct professor but also as a disciplinary outsider who is not trained in STEM, but in the humanities, fine arts, and social sciences.

I used Table 2 to organize the concepts of CRM, CLO, and scientific positivism for ease of understanding of how these frameworks are entangled but also their differences. I also illustrated how I synthesized these theories to form my conceptual framework of creative materialism, which I explained in detail at the end of my literature review in the next section.

Table 2: Theoretical Framework Comparisons

Conceptual Frame	CLO	CRM	Positivism	Creative materialism
Material world conditions for knowing	Flow, pedesis, emergent, unordered, indeterminant, turbulent, immanent, chaos, creative, continuous	Nature as a source of knowledge, liminality, process, ancestors, history	Discrete, predictable, knowable, idealized, property & resource, objects, linear progress story	Sensory, creative, embodied, material, emergent, iterative, historically entangled
Research & coming to know motions	Fold, loop, feedback, intra-action, sensing, measuring, qualities & quantities, habit, oscillation, vibration, bubbles, foam, socialization	Participatory, collaboration, aesthetic, dialogical, power-sharing, oral storying, openness, transparency, empathy	Isolate, manage, control, measure, rational, logical reduction, mechanistic	Interactive, dialogue, feedback loops, resonance, aesthetic, liminal, turbulence, self-reflexive, subjective, collaborative
Knowledge structures, characteristics, assumptions, purpose	Field, hybridity, historical, co-created, ordering & objectifying, circulation & distribution of knowledge, categorization, disciplinary borders	Holistic, epistemic pluralism, narratives, oral history	Theory, models, categories, additive, evaluative hierarchy, proof, truth, certainty	Interdisciplinary, kinesthetic-onto-epistemology, ongoing, praxis, ethics, positionality with field
Entangled kinetic operators	Western science & philosophy, colonialism, academia, race & gender & class	Transparency, humility, empathy about historical oppression, and political ideologies of academia	Conceptions of neutrality, objectivity, universal, timeless, apolitical-not contingent	Individual history & cultural aesthetics, power, identities, academia, ideology,

## **Section Conclusion**

In this section, I explained the theoretical framework on which my study was constructed. As I showed, the principles in culturally responsive methodologies (Berryman et al., 2013b) and Nail's (2021) theorization of his contemporary loop object theory fit well together as a framework to examine the role of positivism in EHED culture. I chose CRM because it reminded me to actively resist scientific Western-based epistemological assumptions and required that I name the historical, ideological, cultural, and epistemological kinetic operators (Nail, 2021) that I brought to the study, including my neurodivergence. CRM provided a process for my own self-interrogation in relationship to the research literature, the students, the campus, and my history, identities, agendas, and power (Bloomfield, 2013). I chose Nail's CLO theory (2021) as a theoretical framework that describes knowledge production as a contingently relational and iterative process, not one of individual discovery as is so commonly the narrative of STEM (Riley, 2008). I used CLO (Nail, 2021) theoretically as a culturally responsive methodology (Berryman et al., 2013a) that disrupted the Western scientific hegemony of positivism in my academic training. With CLO theory, I identified cultural and ideological positivist-related kinetic operators like the fetishization of rigor and the concept of socio-technical dualisms, which I introduced in Chapter One and explain in detail below. Nail's (2021) new materialist kinematic framework provided a Western science-based theory that moved around the perceived objectivity of positivism that is foundationally reproduced through EHED socialization, which I show in the literature review next. CLO theory also provided several new materialist conceptual terms like

intra-action, entanglement, and kinetic operators that I used to theorize coming to know as a turbulent, unpredictable, but ultimately ordered process. I used these concepts for analysis and interpretation to show how the students and I collaboratively came to know their experiences of being socialized as engineers. I also used these terms in my critical interdisciplinary literature review in the next section.

## **Literature Review**

### **Introduction**

In this section, I used my interdisciplinary literature review to show the context in which my study took place. To do this, I continued to fold in my theoretical frameworks of CRM (Berryman et al., 2013a) and CLO theory (Nail, 2021) to critically contextualize and problematize the literature findings that identified barriers to increasing participation in EHED. As I stated, positivism is identified as problematic and is related to the other cultural traits of extreme rigor and socio-technical dualisms that are also found to be barriers to addressing inequities in EHED. I showed through reviewing the research literature how the gaps in knowledge in the extant research were the sources of my research questions:

1. How do underrepresented engineering students experience socialization into the professional engineering culture during their education?
2. How did creative materialism function to answer research question one?

### ***Methodology for Literature Review***

Following the pedetic, hybrid feedback loops that Nail (2021) identifies as the motions of contemporary knowledge production, I described how my reviewing of the

literature, which is entangled with EHED, STEM, and diversity initiatives, emerged as a contemporary loop object (CLO) into the formal order inscribed here. This relational emergence occurred over several years, including before embarking on this Ph.D. journey in 2016, and I moved through the literature review in an ongoing looping motion. Through each round of research, I generated new insights that were then iteratively folded back into my review, from which the gaps in the literature emerged. As I described in the section above, I conceptualized this confusing process of sorting and synthesizing related research, theories, and methodologies across disciplines as the turbulence of coming to know. As I moved through this turbulence, I eventually formed the meta-stable field of knowledge that is this literature review, which according to Nail (2021), is an inscription that describes the process of coming to know.

Mapping the path I took, I used several variations of key search terms related to different aspects of my study, but with a diversity, equity, and inclusivity (DEI) lens that elevated the voices from the underrepresented communities (Berryman et al., 2013b). These terms includes engineering education, engineering culture, engineering history, engineering diversity, epistemic pluralism, culturally responsive methods, and arts-based research or arts-based inquiry. When I investigated a particular underrepresented community, I included various social identities with the previous search terms, like “engineering culture” AND feminist, to find critical research about women’s experiences in EHED culture. However, this formal search emerged from earlier iterations that were entangled with the kinetic operators associated with my experiences as both an insider and outsider at Mines and in EHED. These kinetic operators included being a White



woman with a mathematics phobia, which was related to dyscalculia and my neurodivergence that I was unaware of, who attained a Master of Science degree in a liberal arts department at an engineering school. However, it was through this experience with these identities that I became interested in and entangled with the problem of the lack of diversity in engineering. It was through my experiences and relationships during my Ph.D. coursework that I materially moved toward a more expansive conception of diversity beyond gender and the lack of females in engineering, which was the identity with which I initially identified the problem. It is this hybrid (Nail, 2021), and still-emerging, form of understanding that informed this document. Indeed, this dissertation document was the transformative space in which folding was inscribed until it became a formally ordered field of knowledge: a written published dissertation.

### *Criteria for Literature Selection*

I searched across several disciplines for my study to provide a holistic and historically grounded context to the lack of diversity in EHED. Examples of some of the disciplinary areas of scholarship I reviewed are higher education, engineering education, history of engineering, philosophy of engineering, and science and technology studies (STS), which is often combined with critical theories, such as feminist STS. I also reviewed literature related to EHED from identity-focused disciplines like Indigenous studies, postcolonial education, and Indigenous Knowledge (IK). The disciplines of sociology, anthropology, organizational studies, and governance were where I discovered research on the professional socialization process that was at the center of my study and formed one of my research questions.

I identified an interdisciplinary hybrid (Nail, 2021) complication to my research and review of engineering education: the field of STEM. In Chapter One, I introduced the complicated contingent relationship between the disciplines of engineering and science, which I developed in more detail in my review below. I found as I moved through my literature reviews that it was often difficult to find isolated research that focused specifically on *engineering* education diversity, which is a disciplinary knowledge gap that needed further research. Indeed, I found that a theme of interdisciplinary epistemological messiness runs through my review of the literature, which helped generate my second research question about methodology. In short, I reviewed research about both STEM and engineering education but prioritized EHED-specific research.

Lastly, while the focus of my research was U.S. engineering education, like Cech (2014), I found that there is an isomorphic (DiMaggio & Powell, 1983) quality to EHED culture nationally and internationally, with Western science and culture as the common denominator in some studies. I found many of the same cultural traits in international engineering education journals and included research from the UK, Australia, New Zealand, and Canada. Engineering is a global enterprise and I reviewed literature that discussed how the historic saga of EHED culture is reproduced across national boundaries. However, I also found there are cultures of engineering that are contingent on local histories and cultures, and other kinetic operators (Nail, 2021), which makes universal EHED standards impossible.

### ***Organization of My Literature Review***

Three main sections in my literature review emerged from my waves of searches for extant literature: historical, cultural socialization, and epistemic pluralism, which includes arts-based research methods. I began with historical literature to provide the context for EHED as a relatively new emerging academic area of research. I utilized Nail's (2021) historical re-viewing as a looping process that revealed kinetic operators with agency in today's EHED culture and research. In a power-sharing motion, I include critical EHED literature but also the historical-critical literature from scholars from underrepresented communities to provide a more holistic perspective about the lack of diversity in EHED, which is in keeping with CRM principles (Berryman et al., 2013a). In the next section, I reviewed the empirical DEI research about engineering culture and highlighted how the historical kinetic operators (Nail, 2021) I identified in the historical literature review section manifest today in the experiences of underrepresented engineering students. I identified several gaps in knowledge in the empirical research on professional socialization in the culture of engineering that my project addressed. In the last section, I turned toward methodology and epistemic pluralism and reviewed the recent but scant EHED research on the need for interdisciplinary methods for training engineers and in EHED research. I also included research and a few articles on neurodivergence in EHED specifically. I then reviewed literature from a few communities that are underrepresented in EHED to elevate their voices and their demand that EHED recognize that many epistemological traditions should be treated as equivalent but different. I ended the epistemic pluralism section with a review of the arts-based research literature that showed ABR methods as culturally responsive (Nodelman, 2013),

my theoretical argument that arts-based research methods are contemporary loop objects (Nail, 2021), and how ABR methods are used in STEM research.

### **Historical Contingencies of Engineering Education**

In this first section of my literature review, I showed the history that complicates diversity efforts in EHED. I did this to show the historical inequities in opportunity that underrepresented communities experienced when pursuing engineering education and careers that, based on CLO theory (Nail, 2021), still have agency today in EHED culture and underrepresented communities as kinetic operators. I showed this contingent quality of engineering education, the professions, and culture to counter notions in EHED about the ahistorical and apolitical nature of the field (Cech, 2013; Riley, 2008; Seron et al., 2018; Slaton, 2013), which are barriers to fully seeing the scope of the problem. I began with the complicated history of modern U.S. engineering about the unfolding impacts of the U.S. Industrial Revolution and the capitalist economy from which U.S. engineering emerged, that is as kinetic operators (Nail, 2021). I showed engineering as an emerging educational discipline as it attempted to extrapolate itself out as distinct from science over the last two centuries in the U.S. I also reviewed historical literature that shows how members of the underrepresented communities that are the focus of DEI efforts in EHED, and the participants in my study, experienced this history differently, setting up the next section where I reviewed empirical research on the culture and its effects on students.

### ***Engineering and STEM***

To begin, the interdisciplinarity of STEM in educational research is problematic when trying to examine engineering separately from the disciplines of science and mathematics. The acronym STEM conflates science, technology, engineering, and mathematics as one category of disciplines and professions to describe an important sector of the economy and national security (Bix, 2013; Seeley, 1999; Taylor, 2011). The historical purposes and valuing of engineering and technology were directly tied to broader national goals, which continue today (Bix 2013, Downey, 2007; Oldenziel, 1999; Riley, 2008; Seeley, 1999; Slaton, 2010). Conflating the four STEM disciplines ignores that each discipline, while related, has its own history, culture, and methodologies for research in the U.S. but also that STEM experiences historically vary widely when examined through various social identities. Women (Bix, 2013; Bray, 2007; Cech, 2013; Faulkner, 2007; Frehill, 2004; Seron et al., 2018) and BIPOC members of underrepresented communities in EHED (Lord & Camacho, 2013; Riley, 2008; Slaton, 2010) have a variety of unique historical relationships with each of the STEM fields that affect their participation in engineering today.

Women's access to the disciplines of STEM varied depending on the economic and political needs of the nation. The World Wars necessitated bringing women into jobs that were typically not considered appropriate for women to work in except in desperate circumstances (Bix, 2013). Outside of extreme circumstances, engineering was not encouraged for women, and they were funneled away from engineering education and professions and into science laboratories or the new field of home economics (Bix, 2013; Oldenziel, 1999). As the 2016 film *Hidden Figures* demonstrates, which is about African

American mathematicians in the 1960s NASA space program, both White women and women of color who pursued STEM professions faced workplace oppression, limits to their career advancement, and marginalization to the point of invisibility in the historic record (Oldenziel, 1999; Thompson, 2020). Other social identities have complicated histories with STEM as well, including religious identities that conflict with positivist epistemological beliefs about how legitimate knowledge is discovered, not revealed.

For example, several papers from an Islamic conference on science and technology in Indonesia (Kamali et al., 2016) describe the confusing cultural and epistemological situation for Muslims entangled with modern Western science and engineering. Islamic STEM contributions have a complicated history with Europe and the West going back to the Greeks and Romans. These complications are hidden as kinetic operators (Nail, 2021) in Western STEM narratives in which The Enlightenment occurred in isolation in Western Europe (Bakar, 2016). Islamic culture had centuries of science, engineering, and technological innovation before this knowledge returned to Europe during the Scientific Revolution in Europe during the sixteenth and seventeenth centuries. However, many contemporary Muslims have embraced Western science and modern lifestyles due to Western global cultural hegemony. Bakar (2016) argues that uncritical acceptance of Western STEM by Muslims creates a dichotomy with their centuries-old Quran-based values and epistemologies in which Muslims are called to be curious about and build their knowledge of the Creator's world.

And for Indigenous communities, terms like science and engineering as known in the U.S. do not match their cultural conceptions of these activities, which Indigenous

people have practiced for thousands of years (Bang & Medin, 2010). While not all the same, Indigenous cultures tend toward seeing people as relationally and reciprocally embedded in their communities and the natural environment that sustains them, which underpins CRM principles (Berryman et al., 2013a). For many Indigenous cultures, science, and engineering are based on oral narrative traditions (cole & O'Riley, 2017) and are performative acts that use protocols (Whyte, 2016), rituals, and ceremonies (Wilson, 2008) solely focused on benefiting their communities in specific practical ways. As an alternative that better captures Indigenous values, cole and O'Riley (2017) offer ESTEEM to replace STEM: ecojust-transspecies-equivalency-engendering-mutually (p. 33). For Native Americans and other colonized peoples, the history of colonization and genocide cannot be separated from Western science, engineering, and technology and the modern metrics of progress (Downey, 2007) that drive them; historical experiences in these communities are kinetic operators that matter today. These kinetic operators (Nail, 2021) are evident in the research literature that shows how Indigenous people's experiences of education in North America are entangled in unequal ways with coloniality (Bang & Medin, 2010), in which Indigenous histories, cultures, and epistemologies are demeaned, forbidden, and blocked by what Ahmed (2007) identifies as a phenomenon of whiteness.

Despite engineering being a global career in the twenty-first century, *engineering* is not a universal term across European cultures due to the entanglements of historical, cultural, ideological, epistemological, and economic kinetic operators. Lucena and colleagues (2008) conducted an ethnographic study examining how engineer competency

is defined across the U.S., European, and Latin American systems. Within Europe, the terminology for engineers is nationally and culturally based with dozens of terms used based on the type and duration of their education as well as their professional designation. Positivist desires for universal answers and transferable predictions are kinetic operators (Nail, 2021) in the drive for international, political, historical, cultural, and language alignments in EHED (Lucena et al., 2008). However, these kinetic operators are also impairments to achieving an international global standard of competencies for engineering education that industry desires in a neoliberal globalized economy that prizes efficiency. Given the unconditional reliance on positivism that is entangled with EHED and professional engineering practices (Bucciarelli, 2009), it is not surprising that the industry has universalizing goals. However, the drive for international standards based on the U.S. model exemplifies the criticisms by underrepresented communities that EHED is a hegemonic and assimilative practice (cole & O'Riley, 2017).

### ***The Emergence of Engineering Education***

Formalized engineering education and the professions are relatively recent creations that emerged contingently with the Industrial Revolution in the U.S. during the last two hundred years (Bix, 2013; Downey, 2007; Frehill, 2004; Oldenziel, 2009; Seeley, 1999). Kinetic operators (Nail, 2021) in EHED culture include the economic, political, and social dynamics of each era of U.S. history, but also the field of engineering's relationship with science. Formal training was not necessary to become an engineer before the twentieth century as most learning was in the form of hands-on apprenticeships (Bix, 2013; Oldenziel, 1999; Seeley, 1999). A shift occurred from relying



on the informal knowledge of shop culture to the formalization of engineering school culture, and from practicality to theoretical abstractions at the turn of the twentieth century as the complexity of technology grew (Bix, 2013; Oldenziel, 1999; Seeley, 1999). Engineers were required to use more mathematical and scientific theory in large industrial settings and World War II and the Cold War further shifted engineering education toward relying on positivist theory. By the 1960s, Seeley (1999) notes that EHED was grounded in abstract science and mathematical theories with little emphasis on practical applications. Engineering programs generated prestige and gained government funding through hiring qualified engineers, that is, those formally educated at an accredited engineering higher education program. Seely (1999) notes the relationship between merit, higher education, and the practical issues of funding research as central to the development of the post-World War II conception of engineering in the U.S.

Downey (2007) used historical documents related to the emerging field of engineering education in the U.S. to show the contingencies that influenced the emergence of EHED and uses two terms to describe the changes in how engineering was perceived and valued. *Territorial identity* refers to the specific place and time that affects perceptions and values about technology, such as the differences between technology in the pre-Civil War period compared to the Cold War era. *Metrics of progress* refer to how a society conceives of and measures its own success. According to Downey's (2007) research, the production and consumption of low-cost mass-produced goods and services were early but consistent modern metrics of progress in the capitalist U.S. society. Before

industrialization, U.S. engineering followed European models that focused on reducing labor costs, the efficient construction of civil engineering projects like the Erie Canal, and ensuring the safety, strength, and endurance of infrastructure. According to Downey, by the 1920s, U.S. cultural values shifted from a Victorian ethos of hard work and personal restraint toward modern values of individual prosperity, leisure, and personal satisfaction. Industrial corporations positioned themselves as arbiters of social progress that required free reign to produce the desired goods that expressed one's personality (Downey, 2007). The ongoing relationship between the engineering industry and EHED is a kinetic operator that must be more clearly examined for how it affects DEI efforts in engineering.

Historic research (Bix, 2013; Downey, 2007; Oldenziel, 1997; Riley, 2008; Seeley, 1999) shows that the corporate industry influenced EHED curriculums and expectations out of their need to have competent and skilled workers and continues to be a critical source of funding for engineer education, research, laboratories, and material today. Downey (2007) argues that the post-World War II period and the Cold War, with a visible Soviet Sputnik satellite watching the U.S. from the night sky, shifted the purpose of EHED and engineering in reaction to perceived outside threats. Communism threatened to control both economic production and consumption, removing the very purpose of engineering related to U.S. capitalist free-market ideologies and the emerging modern cultural value of individual self-realization through purchasing goods and services. A new metric of progress related to national security increased government research funding and private defense contracting for military needs, making corporations

extensions of the government. Downey (2007) argues that engineering in the U.S. continually modeled itself to serve the nation's capitalist and democratic needs. However, not everyone in the U.S. had equal access to prosperity and personal freedom, including in engineering education.

### ***The History of Identity in Engineering Education***

Riley (2008) argues that the limited career paths available to engineers in capitalist industry, research, and the military created many of the narrow cultural traits that are problematic for diversity efforts. In this section, I review research that shows the relationality of economic and political power and technology with the social identities that were historically excluded from engineering. Even the historic definition of "technology" changed over time, changes that were related to specific social identities and the social, economic, and political shifts in the U.S. (Oldenziel, 1999). Before the emergence of engineering as an educational discipline, the World's Fairs and other public expositions were an opportunity for inventors to showcase their inventions to investors (Oldenziel, 1999). Women were permitted to exhibit alongside men at these events (Boisseau & Markwyn, 2010). The definition of "technology" was broad and included language, textiles, clothing like corsets, and other non-mechanical devices (McGraw, 2003). Eventually, these opportunities were diminished with the creation of "women's pavilions" at the fairs where women's inventions were sidelined from the large-scale machinery and technology associated with the industry in the early twentieth century (Oldenziel, 1999). Public venues like the fairs and other popular media set the class,

gender, and racial associations with engineering for the U.S. public, but also for professional engineers and engineering educators.

Bix (2013), Frehill (2004), and Oldenziel's (1997; 1999; 2009) historical research traces the gendered concepts of the nineteenth and early twentieth centuries embedded in engineering culture as a romanization of fieldwork and the shop floor as where a boy became a man. In the U.S. before the 1920s, traditional notions of manhood and manliness were associated with Manifest Destiny (Frehill, 2004), in which White settler colonialists ideologically believed they were destined through divinity and exceptionalism to conquer and tame the continent (Dunbar-Ortiz, 2014) and what was perceived to be the rugged frontier (Frehill, 2004). These ideologies were and remain powerful kinetic operators in Indigenous experiences of genocide, removal from their land, and their marginalized political statuses (Dunbar-Ortiz, 2014), which I discuss in more detail below. Frehill (2004) explains how feminine spaces were designated as civilized urban areas, that is, something that a boy must escape from to become a man by confronting the wilderness and nature. Stories about apprenticeships in the field generated the myth of the "self-made man" and the engineering hero as the rugged romantic loner fighting nature, replacing the cowboy in U.S. arts and literature (Oldenziel, 1999). Literary examples of this persona can be seen in the works of Mary Hallock Foote (1847-1938) and Rudyard Kipling (1865-1936) (Oldenziel, 1999, pp. 120-125). Teddy Roosevelt is often used (Frehill, 2004; Oldenziel, 1999; Riley, 2013) to epitomize this self-made man mindset as he was an engineer, soldier, adventurer, and

U.S. president. Women working in engineering disrupted this gendered nature/civilization dichotomy by leaving their urban feminine spaces.

The White men leading the professional organizations for engineering that emerged in the early twentieth century stressed the importance of rigor and military-style discipline (Frehill, 2004; Oldenziel, 1999). These qualities were often equated with sports and outdoor activities in engineering recruiting materials, career advice, and practical skill discussions (Frehill, 2004). Today's summer field sessions, where engineering students do practical hands-on experiments in situ, are a historical remnant of this value of learning through hands-on experiences in the outdoors (Frehill, 2004; Oldenziel, 1999; Stonyer, 2002). As engineering locations, practices, and skills changed to meet the needs of the industrialized nation (Seeley, 1999), the conception of manliness also shifted to validate these changes. Women filled the growing vacancies in what was professionally designated as menial engineering clerical work, such as tracing and mathematic computing (Oldenziel, 1999). As more technical, theoretical, and mathematics-based engineer positions grew in demand with modernization, educated middle-class White men in engineering needed to equate desk jobs with masculine rigor, discipline, and hard work (Frehill, 2004).

The association of rigor with a specific gender developed professional rationales for exclusions from engineering, which over the years has fetishized rigor as an unquestionable pedagogical and epistemological requirement in EHED (Riley, 2008). Most women with an engineering degree (Oldenziel, 1997) were not allowed into higher echelons of the engineering profession from the mid-1800s into the twentieth century.

These more prestigious assignments included positions in management and good pay. Bix (2013) explored historical documents from MIT, Georgia Tech, and Caltech as case studies to show how women interested in technology were funneled into the new discipline of home economics, a seemingly feminine field of technology. Science was also an appropriate discipline for women (Bix, 2013; Oldenziel, 1999) though women were often stuck in laboratories doing menial labor with no prospect of advancement into management. A meritocracy based on perceived competency and abilities was crucial to keeping women, racial minorities, immigrants, and the working class out of engineering (Slaton, 2010). Frehill (2004) used hegemonic masculinity as a theoretical framework to analyze primary engineering historical texts from the end of the nineteenth century and early twentieth century, like *Engineering News* and the Society of Professional Engineers proceedings. Frehill shows how the overriding professional emphasis on strong character and endurance was intentionally used to eliminate those whom it was believed could not survive the stress and hardship inherent to engineering practice (Frehill, 2004; Slaton, 2010). Black Americans were also excluded from higher education faculty and administration (Anderson, 1993) and engineering careers, which Slaton (2010) argues was based on concepts of merit and rigor as political acts. However, conceptions of merit were intended to protect middle-class jobs for White men.

The Industrial Revolution in the U.S. rapidly created economic and social mobility opportunities but also fears and anxieties. White men feared competition from the influx of immigrants from southern and eastern Europe in the late nineteenth century (Oldenziel, 1999) and from the formerly enslaved Black people who were now free to

pursue skilled labor jobs (Slaton, 2010). Ideologically, the necessity of corporate clients and the politics of federal research funding and resources (Seeley, 1999) to advance technology placed engineers in middle management positions that required being loyal to owners and management over labor (Oldenziel, 2009). Managing the capitalist values of efficiency, profit, and utility for industry produced a conservative political ideology for engineers (Haverkamp, et al., 2019; Riley, 2008; Slaton, 2013). This ideology led to a distaste for collectivism and unionizing engineers, as well as a suspicion of labor unions. As I will show below, this conservative ideology in EHED culture contrasts sharply with the more collective values of women and BIPOC, as well as the principles of CRM (Berryman et al., 2013b). Seeley (1999) and Riley (2008; 2017) argue that the weight of tradition in EHED is a barrier to becoming more diverse, inclusive, and equitable and I theorize these traditions as kinetic operators (Nail, 2021). However, other entangled historic kinetic operators, like colonizing and educational policies, must also be identified in engineering education to improve diversity.

### ***The Morrill Acts and the History of Discrimination in EHED***

In the mid and late nineteenth century, the purpose of higher education expanded to meet the broader practical demands of a new urban, capitalist, global, and industrial nation by creating technical schools (Cohen & Kisker, 2010). The Morrill Acts of 1862 and 1890 created land-grant universities and colleges to educate the sons and daughters of farmers and mechanics to be proficient with the increased mechanical technologies found in homes and farms (Oldenziel, 1999). However, restrictions, exclusions, and oppression based on race, gender, and class as well as immigrant status are hidden kinetic

operators in the Morrill Acts story. According to Hughes and Windchief (2018) in their reframing of the Morrill Acts using tribal critical race theory, these policies were deeply entwined with concepts of Manifest Destiny and resonated with Downey's (2007) metrics of progress paradigm. Laws like the Homestead Act and Railroad Act of 1862 were created to increase and encourage settler colonialism and displace Indigenous communities (Hughes & Windchief, 2018). The U.S. government took the land from Indigenous peoples without payment or negotiation and forcibly removed and dispossessed Native peoples from their ancestral histories and cultures (Dunbar-Ortiz, 2014). This stolen land was later sold to finance the land-grant schools, a democratic hypocrisy that is rarely acknowledged in higher education (Hughes & Windchief, 2018; Wheatle, 2019). Another exclusionary element of these land grant policies was that a second Morrill Act was required to provide opportunities for Black Americans. The Morrill Act of 1890 required states receiving federal dollars for land grant schools to provide a second campus for non-White students (Slaton, 2010). Separate does not mean equal, however, and as Wheatle (2019) shows, equity was never the point of these pieces of legislation, despite how they have been mythologized in educational history as geared toward equity.

Slaton's (2010) seminal historical case studies show the myriad political, social, and economic factors that deprived Black and African Americans of access to quality engineering education. One of Slaton's case studies is the history of engineering education at the land grant school of the University of Maryland (UMD) from the 1930s to the 1950s Civil Rights era. Slaton argues that the Morrill Acts provided Maryland's



White leaders with a mechanism to perpetuate inequities. On the system's Black campus in Princess Anne, today referred to as UMD Eastern Shore, the curriculum was intentionally restricted to agriculture and trade education for Black students in contrast to the modernization that occurred at the all-White College Park engineering program. This two-tiered system resulted in lower pay, less prestige, fewer intellectual challenges, and restricted occupational opportunities for Black students desiring an engineering education (Slaton, 2010). While Downey (2007), Seeley (1999), and Riley (2008) established that the purpose of EHED in the U.S. was linked to professional opportunities in the industry, education research, and the military, Slaton (2010) clearly shows an orchestrated effort to find different places for Black Americans to fit in the emerging modern economic order. Maryland leadership funneled resources from industry, the military and government, and private patronage networks, which are crucial as career tracks (Seeley, 1999), to improve the quality of the Whites-only College Park campus (Slaton, 2010). The Eastern Shores campus in the 1940s was restricted to industrial vocational skills like construction, printing, and machinery mechanics; there were no degrees offered in more prestigious and economically lifting fields like civil, electrical, or mechanical engineering to the segregated Black students. Slaton argues that racist standards for rigor and meritocracy over the decades have naturalized the absence of Black engineers in the U.S.

### ***Colonialism and Engineering***

Indigenous peoples are unique in their minority status in the U.S. compared to other minority groups in the U.S. who also have histories of oppression (Deloria, et al., 2018). This difference primarily rests on political conflicts related to colonization of

Native lands and forced removal (Hughes & Windchief, 2018), broken treaties, and ongoing battles to retain sovereignty (Deloria, et al., 2018). Educational trauma remains in Indigenous communities from the forced assimilation of Native children into Western culture through education (Bang & Medin, 2010). Many Indigenous children were taken from their homes by U.S. government agents and placed in Indian schools (Dunbar-Ortiz, 2014) where their names and clothing were changed, their hair was cut and groomed into Western styles, and speaking their languages was forbidden, a practice that was not outlawed until 1978. A key historical political difference between Black American and Native American experiences in the U.S. is that White settler colonialists desired Indigenous land but had little use for the people (Kendi, 2016; Stein, 2017a). Indigeneity is not a racial category for the members of these sovereign nations and those who identify as Indigenous, but a political identity. It is essential to recognize the unique difference in political histories and community ties to science and technology between BIPOC people in the U.S. if diversity is to be achieved in engineering education.

Kendi's (2016) comprehensive history of racism in the U.S. is focused primarily on African American and Black people's experiences. However, Kendi also describes the myriad historical entanglements between Indigenous peoples and Black people within the structure of systemic racism. Both groups were the subject of common racist tropes by White people, but the groups also differ in important ways: Black Africans were kidnapped and brought to the American continents as slave labor to replace Indigenous people who were not considered by White people as robust physically (Kendi, 2016). What each group shares were being recipients of ongoing theories by those in power,

typically White land-owning and/or educated men, about the natural inferiority of non-European people, including questions and allegations of being sub-human (Maxwell, 1999). These ongoing justifications for demeaning Indigenous people are directly tied to concepts of intelligence, education, and possibilities of assimilation (Denzin et al., 2008) that must be considered in educational diversity efforts.

Historical research transparently shows the justifications that Europeans and White settler colonialists used to colonize and settle the land by removing American Indians (Dunbar-Ortiz, 2014). These arguments stated that for White progress to continue (Kendi, 2016) and for the U.S. to live up to its potential greatness based on whiteness (Ahmed, 2007), Indian removal and/or assimilation was necessary. Scientific theories about evolution were used as justification as well as comparisons between forms of technology, in which Indigenous technology was always deemed as inferior to modern Western technology (Kendi, 2016). This history shows the entangled kinetic operators (Nail, 2021) that affect many Indigenous people's relationships with STEM, but that go unseen or unacknowledged by the broader public and by educators (Deloria, et al., 2018). These justification narratives deemed Indigenous peoples as primitive and technologically backward—even using terms like caveman—which allowed disingenuous claims that the land was unsettled and unused. Racist settler colonial narratives were not hidden but discussed and promoted widely in media and policies to protect a self-defined superior whiteness (Dunbar-Ortiz, 2014; Frost, 2005; Mihesuah, 1996). The purpose of the narratives of primitiveness, wildness, and backwardness was for White culture on the one hand, to dehumanize Indigenous people, while

simultaneously and relationally defining White culture as modern, civilized, and evolving (Swensen, 2019) through technological progress (Downey, 2007) toward perfection (Kendi, 2016). This dichotomy in these historical technology narratives exposes the unnamed racial and ethnicity-based ideological exclusions in Downey's (2007) theory of the metrics of progress and territorial identity as universal national concepts. Politicians like Thomas Jefferson and Benjamin Franklin (Kendi, 2016) argued that the values and lifestyles of Native peoples were not compatible with modernity and the desire of the new nation to take its place as a global political and economic leader and competitor (Dunbar-Ortiz, 2014). Assimilative education measures resulted in a public narrative by the turn of the twentieth century of the "vanishing Indian" and romanticization of White people's perceptions of pre-Columbian and prehistoric people living freely in the wilderness (Mihsuah, 1996). This romantic derogatory narrative persists today (Frost, 2005) and contributes to the maintenance of settler colonialism across U.S. society, including in EHED.

These kinetic operators (Nail, 2021) are barriers to increasing Native student participation in engineering and must be made visible. However, Western sciences, culture, and education are beginning to recognize that these portrayals are not accurate (Crum, 1991). For example, the use of new LiDAR technology in archeology has radically altered previous notions about the size, sophistication, and complexity of pre-Columbian civilizations (Canuto, et al., 2018). Despite European claims of technological superiority, Indigenous peoples had advanced technologies based on their immediate practical needs but also their environment and the materials available (Rodriguez-

Alegria, 2008). When combined with the cultural value of innovating and creating only what was necessary for the practical benefit of the community, we can see that a difference in the values and purposes of technology accounts for the differences in forms of technology. However, Crum (1991) also describes how after Indigenous knowledge systems were destroyed and replaced by European systems of higher education, Indigenous people were prohibited from participating in European-style higher education despite easily understanding European knowledge.

### ***Section Conclusion***

My brief review of some of the historical research revealed a few of the countless kinetic operators that have agency in today's diversity efforts in EHED: the influence of history, culture, politics, and economics on STEM, intentional exclusions of women and minorities from EHED and engineering professions, and the role of White settler-colonial concepts of progress related to science, engineering, and technology. For my study, I used these kinetic operators (Nail, 2021) in my research design to collaborate with each student participant individually to design our intra-actions and how we generated content, but also to guide us in how we analyzed and interpreted our content. I now turn to place these historic kinetic operators (Nail, 2021) in the context of contemporary empirical research about the culture of engineering. In this next section, I theorized the process of professional socialization as a turbulent liminal process in which student bodies are categorized and sorted as engineer, or not engineer, using positivist notions of objectivity and entangled ideas about rigor and merit.

## **Engineering Culture and Professional Socialization Research**

### ***Introduction***

Having established the variety of historic entanglements and kinetic operators that different identity groups experienced, and from which EHED emerged as a discipline and profession in the U.S., I now turn to the empirical literature that describes how these historic material kinetic operators manifest in today's EHED culture. I begin with the hegemony of positivist epistemology, which I have shown is entangled with many other cultural beliefs in EHED, like rigor and socio-technical dualisms. Next, I review the limitations of previous trends in DEI research that rely on positivist notions of objectivity, linear progress and continuous improvement, and merit. I then turn to review the literature describing the EHED cultural traits linked to the history I laid out in the first section of the literature review. Finally, I review the literature on the professional socialization process as a site of conflict for underrepresented students in EHED today and I identify the specific gaps in this research that my project aimed to fill.

### ***Epistemological Hegemony of Positivism***

Western science is deeply entangled with engineering education and practices historically (Bix, 2013; Oldenzeit, 1999; Seeley, 1999). A defining aspect of engineering education and culture today is the unshakeable belief that legitimate truth and facts are discovered by the scientific method using mathematics with a positivist epistemology (Bucciarelli, 2009); all other knowledge production is considered nonfactual and subjective, and therefore inferior and unprovable as fact (Cech, 2014; Faulkner, 2007; Godfrey & Parker, 2010; Hess & Strobel, 2013; Heybach & Pickup, 2017; Karwat et al.,

2014; Leydens & Lucena, 2018; Riley, 2008, 2017; Slaton, 2013). Any type of spiritual, non-human, religious, creative, or subjective knowledge processes is irrelevant to engineering education in the U.S. (Acikgenc, 2016; Bakar, 2016; Bang & Medin, 2010; Black & Hachkowski, 2019; Castagno & Brayboy, 2008; cole & O'Riley, 2017; Deloria et al., 2018; Denzin et al., 2008; Kimmerer, 2013; Stein, 2017b; Whyte, 2016; Wilson, 2008). But because engineering relies on limited epistemological training, the cultural implications of positivism are often difficult for engineers and engineering educators to perceive and identify (Bucciarelli, 2009; Douglas et al., 2010; Riley, 2017).

Bucciarelli (2009) conducted a discourse critique on academic and professional engineer rhetoric using an engineering textbook, a peer-reviewed technical research article, and a business report and memo to uncover the implications of positivism for the profession and education. A primary finding was that engineering is dominated by hardcore instrumental rationality that narrowly defines the profession as the pragmatic work of using theories to solve technical problems. Mathematics is required as it is believed that anything that cannot be counted or measured is irrelevant, uninteresting, or insignificant to engineers. Bucciarelli (2009) argues that the presentation of simple reductive problems using logical analysis, the absence of context, and the unexamined assumptions about how the problem is identified in the textbook he studied create a limited vision of engineering practice in EHED. In the professional journal article and business memo, the author examined, there was no mention of people, just the mechanical problem within the discipline. Assumptions about the reader's disciplinary knowledge and providing only enough information to conduct a mathematical analysis of

the problem were standard in these texts. Bucciarelli concludes that these engineering texts do not reflect the messiness of engineering practices and rely on scientific universal rhetoric devoid of humans, culture, and history. Indeed, he found an emphasis on simplifying the problem to fit the model by constraining or eliminating the actions of people, machines, and natural phenomena (Bucciarelli, 2009). This narrow and invisible cultural attachment to positivism is problematic for EHED diversity research. However, a large portion of the extant trends in the EHED literature do not acknowledge problems with the culture of engineering but tend to focus on preparing and exposing students to STEM.

### ***Trends in EHED Research***

While there has been a consistent interest in increasing the diversity of students, faculty, and staff in engineering education programs, efforts tend to be number-driven, measuring for narrow goals and numerical targets (Baber, 2015). However, diversity efforts in higher education are often undermined when these quantitative goals are not met and financial resources for diversity efforts are reduced (Iverson, 2007). Some areas of improvement have been identified. Much of the research on EHED finds that student preparation and exposure to engineering before college increased participation, retention, and completion of EHED degrees (Lord & Camacho, 2013; Ma et al., 2017; Rice & Alfred, 2014; Taylor, 2011). Because of these findings, many of the DEI initiatives in engineering education continue to rely on marketing solutions that are grounded on positivist ideologies in which STEM and EHED are conceived as neutral but rigorous (Riley, 2017). The goals of these programs are to expose students in underrepresented



communities to aspects of EHED that are believed to make the discipline more attractive to the student. In other words, the student and their family and communities merely need to know engineering from the established cultural perspective of Western science that is perceived as neutral and universal (Heybach & Pickup, 2017).

For example, to increase girls' interest in STEM, in 2002, Rowan University invited seventh and eighth-grade female students to collaborative workshops to expose them to hands-on engineering practices and female engineers as role models (Hollar et al., 2002). These workshops included a hands-on module about how cosmetics are engineered that was intended to demonstrate that engineering is creative and connected to the everyday lives of teen girls (Hollar et al., 2002), an approach classified as "painting pink" that essentializes all girls as the same (Heybach & Pickup, 2017). In another example, in 2014, Google published a report that investigated what motivated women to pursue computer science education. Google's corporate recognition and commitment to diversity is based on a labor supply shortage that the report argues requires a long-term investment in education (Google, 2014), echoing the historical relationship between industry and EHED (Downey, 2007; Riley, 2008; Seeley, 1999). The findings were that "encouragement and exposure" (Google, 2014, p. 8) can build confidence in the skills necessary to be successful in computer science.

In another study, the National Center for Women and Information Technology's 2012 report "Girls in IT: The Facts" examined the social structures that influence girls' perceptions of computer science (Ashcraft et al., 2012). The authors of the report argued that exposure to the social relevance of computer science careers would lead to girls

choosing computing over other majors that are perceived to better help people and society or careers that are creative (Ashcraft et al., 2012). Within EHED, research shows that women are drawn to interdisciplinary engineering programs that focus on doing social good, like reducing inequality and increasing sustainability (Leydens & Lucena, 2018; Nilsson, 2015). Disciplines like geography are utilized to attract students from Indigenous communities to STEM programs by emphasizing the field's place-based pedagogies (Oyana, et al., 2015). These efforts have paid off as there has been success in creating more awareness about engineering as a desired and attainable educational and career path in minority communities (NSF, 2023). However, marketing approaches to increasing diversity in engineering assume there are no systemic problems within the institution of EHED, the professions, or the culture. Instead, the responsibility for increasing the participation of students in underrepresented communities is individualized to those students based on ideological and epistemological notions of positivism that assume universal reasons and rational agency on the part of all students who enter EHED and higher education in general.

### ***Deficit-based Research Trends***

A deficiency-based approach to educational research assumes the responsibility for success or failure is on the student and their communities. This approach does not critically examine how the historical structures of oppression and exclusion in EHED culture affect student retention and completion (Harper, 2010). Iverson's (2007) research on campus and organizational diversity initiatives found that programs that are merely rhetorical and do not directly examine the roots of the inequities in education may

perpetuate deficiency-based approaches that focus on student agency as the cause of low participation. These systemic and institutional barriers must also be exposed and examined as kinetic operators (Nail, 2021) that affect students choosing engineering and staying in programs or leaving (Cech, 2013, 2014; Baber, 2015; Frehill, 2004; Godfrey & Parker, 2010; Harper, 2012; Haverkamp et al., 2019; Leydens & Lucena, 2018; Seron et al., 2018). The rigidly reproduced cultural traits of engineering result in a type of isomorphic (DiMaggio, 1983; Cech, 2014) organizational saga (Clark, 1972) that perpetuates exclusions in EHED across campuses despite local efforts at inclusion.

Clark's (1972) theorization about the role of organizational sagas in education is salient here: These collective stories about the historical relationships between engineers and industry, global economic competition, and national security generates shared narratives, or sagas, which build an emotional bond between members the professional engineering community. These bonds, according to Clark (1972), require loyalty from the members to keep the sense of uniqueness that emerged from telling and retelling stories about the accomplishments and struggles of the group, which in EHED are based on gender, rigor, and meritocracy. Indeed, Clark's concept of organizational sagas (1972) can be theorized as contemporary loop objects, fields of knowledge, and kinetic operators (Nail, 2021) that iteratively and collectively emerged, are historic and relational meta-stable patterns or fields, and have agency in organizations today. Without critically examining the cultural factors that contribute to hostile environments that impact underrepresented students, engineering educators are ignoring barriers to their goals of increasing diversity (Cech, 2013; Haverkamp et al., 2019; Leonardo & Broderick, 2011;

Lord & Camacho, 2013; Ma et al., 2017; Mayes, 2014; Seron et al., 2018; Slaton, 2013). Having shown the historical nature of exclusionary kinetic operators in EHED culture and how positivism affects EHED research, I now review research that shows the form these cultural features take today.

### ***Engineering Education Culture***

Like the term engineering, culture is a contested term and concept that is hard to define across disciplines and communities (Bang & Medin, 2010). As theorized by CRM (Berryman et al., 2013a) and CLO theory (Nail, 2021), culture cannot be separated from a society's history, political ideologies and power structures, and ways of knowing and approaching learning. Bang and Medin (2010) point out that the term culture is also problematic for Indigenous communities as it has often been used in research to stereotype Native peoples as backward and primitive to contrast modern U.S. technological cultural assumptions and metrics of progress (Downey, 2007). With this historic caveat in mind, I focus specifically on professional culture, which is theorized by Seron et al (2016) as important to the lack of gender diversity in engineering. In their study of how sex segregation in engineering is reproduced through professional socialization, Seron et al. (2016) defines professional culture as the signs, rituals, and messages that circulate as systems (p. 181). Additionally, Cech (2013) describes professional culture as "sets of beliefs, myths, and rituals that give meaning to the intellectual content and practices of a profession" (p. 69) that form a social group with boundaries for those holding an engineering identity. This sense of identity in turn

justifies a sense of privilege for members of the group that makes exclusions easier to justify, that is, it forms a meritocracy (Riley, 2017).

As an example of this cultural research, Godfrey and Parker (2010) use Schein's cultural framework in an ethnographic case study to map the culture at a New Zealand school of engineering to uncover the shared beliefs and assumptions that underpin engineering cultural behaviors and norms. Data included material artifacts as physical symbols of the culture, such as written documents, campus buildings, and how people in this culture dressed to determine what connotated a sense of belonging (Godfrey & Parker, 2010). The authors found that engineering thinking relies on reductionist, mathematical, and positivist approaches that can be measured and quantified for practical, utilitarian problem-solving. Extreme rigor and hardness are central to engineering education, reflecting the overwhelming time-consuming workload that is often described using extreme adjectives of suffering and survival such as "horrific" and "living hell" (Godfrey & Parker, 2010, p. 12). There is relatively little research on the mental health implications on students who experience these stressful environments as they become engineers (Coley & Jennings, 2019; Cross & Jensen, 2018; Danowitz & Beddoes, 2020), despite public perception that the extreme rigorousness and suffering are reasons why students do not choose engineering (Kennedy et al., 2018).

### ***Mental Health in Engineering Culture***

There is emerging research on how the culture of engineering affects student mental health. Engineering students experience higher rates of mental health issues like

panic disorders, PTSD, anxiety, and depression compared to students in other majors regardless of identity, but rates climb substantially for both White women and women of color (Danowitz & Beddoes, 2020). Indeed, students arrive at college with multiple entangled social identities, which mattered in the research. For example, Danowitz & Beddoes (2020) found that bisexual women in EHED experience the highest levels of panic disorder at eleven times the national average. Cross and Jensen (2018) found that students promote a culture of stress by identifying stress with engineering education and their emerging professional identities. This promotion contributes to an impression of exceptionalism and elitism that deters some students from considering engineering. The authors used a survey of 1,203 undergraduate student participants at one large public university's engineering school to identify the contingent relationships between a student's identity in their major and their perceptions of stress and inclusion (Cross & Jensen, 2018). They found that engineering students felt pressure to claim group stress and anxiety as part of their identity as an engineering student to feel like they fit. However, in a later study, Jensen and Cross (2020) found using quantitative surveys and social identity theory (SIT) with undergraduate engineering students that female and first-generation students' perceptions of belonging in the culture of engineering impacted their mental health. As there is little research on mental health in EHED, I see this as a gap in the research that we helped fill by keeping mental health as an entangled kinetic operator (Nail, 2021) related to the cultural trait of rigor as the student participants explored their experiences in EHED.

### ***Rigor and the Meritocracy in the Culture of Engineering***

Rigor, or the extreme difficulty associated with the intentionally heavy workloads and difficult subject matter in engineering education, is central to EHED's conception of producing qualified professionals for industry (Blosser, 2017; Godfrey & Parker, 2010; Leydens & Lucena, 2018; Lord & Camacho, 2013; Riley, 2008, 2013, 2017; Seron et al., 2018; Slaton, 2013). I showed the historical cultural roots of rigor in the first section of my literature review, which research showed is entangled with early and changing concepts of masculinity associated with White professional and upwardly mobile men at the turn of the twentieth century (Frehill, 2004). Today the concept of rigor is epistemologically embedded in higher education teaching curriculums and research in general (Riley, 2017). Rigorous is used as a ubiquitous adjective to signal validity in education programs and research across disciplines. However, research shows EHED's concepts of rigor are ideological, cultural, pedagogical, and epistemological kinetic operators entangled with the emergence of engineer identities for those who attain their EHED degrees; rigor is crucial to the professional engineer organizational saga of achievement and exceptionalness (Clark, 1972).

Riley (2017) used autoethnography to explore her experience of rigor as both an engineer and scholar in EHED. Rigor, she argues, is a sexist process of selection to maintain disciplinary boundaries based on the narrow belief in the supremacy of Western science. EHED research shows that rigor is also associated with positivist notions of validity in EHED research (Douglas et al., 2010) and contributes to the resistance of pedagogical change in EHED (Leydens & Lucena, 2018) as rigor is assumed to be necessary to produce competent engineers (Riley, 2017). The concept of rigor is used by

faculty as a “weeding out” (Godfrey & Parker, 2010) process during socialization to identify and eliminate any students who struggle to persevere in their programs. This type of “sink or swim” approach leaves no room for helping those struggling because doing so is believed to reduce the rigor of the program that is necessary for creating competent engineers (Riley, 2013). The saga of engineering (Clark, 1972) rests on the notion that only those who persevere through rigorous pedagogies and curriculums merit the professional status of engineer (Cech, 2013, 2014; Godfrey & Parker, 2010; Haverkamp et al., 2019; Leydens & Lucena, 2018; Seron et al., 2018). Research on rigor in EHED shows that surviving creates a sense of pride, bordering on arrogance, and a shared identity in engineering students, much like Clark’s organizational saga (1972). However, this cultural and disciplinary conception of rigor creates a hierarchy between engineering disciplines based on a gendering of learning that equates difficulty and hardness with men and masculinity. Godfrey and Parker’s (2010) research shows that women who remain and survive in EHED are confronted with the need to redefine themselves with these gendered concepts about how they learn to be professional engineers. Riley (2013) argues that controlling one’s emotions, passions, and body through long work hours and sleep deprivation are related to the rigor of engineering education and the professions. These historical exclusionary kinetic operators (Nail, 2021) and their entanglements with gender and other social identities that underrepresented students hold were another area that the student participants and I explored in our study.

### ***Defining Engineering Culture with Gender***



Research shows that the gendered constructions entangled with engineering culture are barriers to increasing diversity. These gendered and sexist cultural kinetic operators (Nail, 2021) in the culture define engineering work, create hierarchies among engineering fields, and impact the acceptance of diverse research methods. The empirical EHED research shows that professional engineers and associated industries continue the history of determining what is considered legitimate technology and who is considered a legitimate engineer (Blosser, 2017; Cech, 2014; Godfrey & Parker, 2010; Godwin, 2016; Faulkner, 2007; Haverkamp et al., 2019; Karwat et al., 2014; Leydens & Lucena, 2018). Research continues to show that by restricting the definition of an engineer to problem-solving with technology using mathematics, this definition belies the variety of tasks engineers undertake, including the managerial, communication, interdisciplinary, and team aspects of most engineering jobs (Blosser, 2017; Cech, 2014; Godfrey & Parker, 2010; Godwin, 2016; Faulkner, 2007; Haverkamp et al., 2019; Karwat et al., 2014; Leydens & Lucena, 2018; Riley, 2017). Research also shows that certain engineering disciplines are valued more than others by using gender stereotypes about the type of work that is performed (Blosser, 2017; Cech, 2014; Faulkner, 2007; Godfrey & Parker, 2010; Godwin, 2016; Foor & Walden, 2009; Haverkamp et al., 2019; Karwat et al., 2014; Riley, 2008). Specific engineering disciplines are hierarchically sorted and categorized as more masculine and others as more feminine, with masculine disciplines perceived as more rigorous, and therefore “real” engineering and more prestigious (Godfrey & Parker, 2010; Faulkner, 2007). Rigorous engineering requires the use of mathematics and working directly with technology and is identified as more masculine (Riley, 2008).

Engineering disciplines closer to management and people are valued as “less rigorous” than “real” engineering and therefore, more feminine (Blosser, 2017; Faulkner, 2007; Godfrey & Parker, 2010). As an example of these characterizations and their reproduction, Blosser (2017) interviewed chemical engineering faculty, which is considered a gender-neutral engineering discipline, as to why they thought gender participation varied across disciplines. Blosser found that faculty reproduce the gendered conceptions through their narratives about their own discipline but also other engineering disciplines. Interestingly, these gender associations with specific engineering disciplines vary globally, reflecting the contingent nature of engineering culture and practice that Lucena et al., (2008) found in their examination of European, U.S., and Latin American engineering competencies. For example, computer science is considered appropriate for women in Malaysia in contrast to the U.S. where women’s participation remains low (Blosser, 2017). The narrow definition of U.S. engineering as a purely technical practice that hides or ignores the historic, social, political, and economic dynamics at play in engineering history, education, and practice is referred to as the sociotechnical dualism (Faulkner, 2007; Leydens & Lucena, 2018). The sociotechnical dualism is a kinetic operator (Nail, 2021) that masks barriers to making EHED more diverse, inclusive, and equitable by claiming neutrality and universality in engineering, technology, science, and education.

### ***The Socio-technical Dualism in Engineering Culture***

The sociotechnical dualism, resulting from positivist beliefs about the universal neutrality of the design, production, and applications of technology, produces beliefs that

engineering education and professions, as well as their technologies, exist in a vacuum that is ahistorical and apolitical (Baber, 2015; Cech, 2013, 2014; Harper et al., 2009; Hess & Strobel, 2013; Pawley, 2017; Riley 2013; Seron et al., 2018; Slaton, 2010). Research shows that ahistorical and apolitical beliefs are problematic for diversity efforts in EHED as they eliminate the necessary space for underrepresented students to identify, name, express, or address harmful experiences during their education and in their professional careers (Cech, 2013; Riley, 2008) such as racial microaggressions (Lee et al., 2020). The cultural assumptions about neutrality that are embedded in Western sciences have been identified as problematic for increasing diversity in EHED by feminist scholars of STEM (Godfrey, 2007; Haraway, 1988; Harding, 1995; Heybach & Pickup, 2017; Lather, 2010; Seron et al., 2018) critical race scholars (Baber, 2015; Harper, 2010; Slaton, 2010), LGBTQ researchers (Haverkamp et al., 2019; Riley, 2013), researchers who study disabled engineering students (Riley, 2013; Slaton, 2013), Indigenous scholars (Bang & Medin, 2010; Black & Hachkowski, 2019; Castagno & Brayboy, 2008; cole & O’Riley, 2017; Deloria et al., 2018; Denzin, Lincoln, & Smith, 2008; Kimmerer, 2013; Stein, 2017b; Whyte, 2016; Wilson, 2008), and Muslim scholars (Acikgenc, 2016; Bakar, 2016). These robust research findings contribute to my selection of CRM (Berryman et al., 2013a) as part of my theoretical framework to elevate the personal social identities and epistemologies of the student participants as a counter to positivist notions of neutrality in EHED. This perceived neutrality in EHED culture also masks the conservative political ideologies that are unseen barriers to increasing participation in engineering from underrepresented communities.

### *Political Ideologies in EHED Culture*

Like Downey (2007), Riley (2008) argues that U.S. engineers perceive their purpose as serving society within the dominant culture through their rigorous hard work and dedication to completing a technical task. The problem Riley identifies is that engineering education does not include developing the critical thinking skills that provide the means to identify the contingencies of history, politics, economics, and culture that influence EHED participation (Riley, 2008; 2017). Riley (2008), Cech (2013; 2014), Douglas (2015), Pawley (2017), and Seron et al. (2018) are a few of the EHED scholars who argue that many engineers do not recognize the inherent political assumptions and biases about their profession and education processes or in their positivist epistemologies. Political ideologies reflect the values and beliefs about how political and economic power is allocated in a society. Research shows that the historic conservative ideologies in EHED and the professions manifest as accepting authority without question, which also negates political criticisms about the culture of engineering (Cech, 2013, 2014; Harper, 2010; Leydens & Lucena, 2018; Riley, 2008, 2013). This unquestioned acceptance of authority manifests in industry and business as management-level loyalty to the firm (Godfrey & Parker, 2010; Haverkamp et al., 2019; Leydens & Lucena, 2018; Karwat et al., 2014; Riley, 2008) and through engineering as a global profession. For example, Lucena et al. (2008) show how the U.S. engineering accreditation agency, ABET, was making concerted efforts to become the globalized arbiter of standards for EHED. The problem is that the histories, purposes, and cultural factors unique to each nation and region make a universal one-size-fits-all understanding of competency nearly impossible.

Additionally, the historic marginalization, oppression, and exclusions of women and racial minorities (Oldenziel, 1999) mean that students coming into EHED may have political ideologies that are more liberal and progressive in contrast to EHED's notorious conservatism, resulting in conflicts during socialization (Cech, 2013, 2014; Harper, 2010; Haverkamp et al., 2019; Heybach & Pickup, 2017; Karwat et al., 2015; Leydens & Lucena, 2018; Riley, 2008, 2013; Seron et al., 2018; Slaton, 2013). The different ideologies that underrepresented students bring with them to EHED must be better understood to improve diversity in EHED. I turn now to the research on professional socialization as the process by which students become professional engineers; that is, how socialization acts as a contemporary loop object (Nail, 2021) that generates meta-stable patterns or fields like professional engineering culture. This research is empirical and provides insights into student experiences that inform my study and was an ethical guide for my proposed intra-actions (Barad, 2007) with the student participants.

### ***Professional Engineering Socialization Process***

#### *Introduction*

CRM (Berryman et al., 2013a) and CLO theory (Nail, 2021) theorize knowledge as an iterative, embodied, and relational process of coming to know that is entangled with the people, history, and setting in which learning takes place. In this research study, I built on Seron et al.'s research (2016; 2018) on professional engineering socialization. They theorized professional socialization as a process that indoctrinates students to prepare them for their future careers and work environments (Seron et al., 2016; 2018). The culture of Western engineering is reproduced (Seron et al., 2016; 2018) through the

various rituals, traditions, practices, and symbols used to convey the profession of engineering to students by faculty, administrators, and professional internships (Riley, 2008; 2013). Seron et al (2016; 2018) argue that professional socialization into gendered occupations like nursing and engineering perpetuates diversity gaps and reproduces sex segregation. The beliefs and practices unique to the occupational culture must be accepted by the neophyte to persist through their education to a career. They define this process for students as twofold (Seron et al., 2018). One is that students must achieve mastery of the skills and specialized knowledge of engineering. The other aspect is the necessity of creating an alignment between the occupational culture and their personal values. I identified a gap in the research that demonstrated a need to examine the conflicts arising from this process of professional alignment.

Searching for the causes of sex segregation in the professional workforce, the authors' (Seron et al., 2016) analysis of interviews and diaries of undergraduate engineering students over four years identified rituals as key to students' professional role attachment or rejection. Students are taught professional mindsets, values, and practices through traditions like freshmen orientation during entry into the engineering programs, through group and lab work with their cohort, and during summer internships and jobs (Seron et al., 2016). In a further study of the same data (2018) Seron and colleagues showed that female engineering students recognized their marginal status in engineering education, despite outwardly celebrating traditional characteristics of femininity and feminism. The hegemonic ideology of meritocracy and individualism in engineering culture means their criticisms about their marginalization as women are muted (Seron et

al., 2018). Additionally, successful female engineering students and professionals become agents who reproduce engineering culture through socializing other women. Cech (2014) argues that the meritocratic ideology of engineering results in the depoliticization of social justice issues during the engineering education socialization experience. In a 2014 longitudinal study with 326 undergraduate engineering students over four years at four different engineering programs, Cech exposes the decline of student interest in social justice issues over the engineering education process, resulting in what she terms a culture of disengagement. It is through the professional socialization process that the various social identities of underrepresented engineering students can conflict with the culture of engineering education.

### ***Socialization of Students with Multiple Underrepresented Identities in EHED***

Researchers identified that having multiple underrepresented identities is salient to student experiences of socialization into the professional engineering culture (Lord & Camacho, 2013; Rice & Alfred, 2014; Tate & Linn, 2005). For example, Lord and Camacho's (2013) mixed methods case study of Latinx students used the metaphor of the borderlands of education to study the social forces that create the gendered and racialized borders that are experienced by these students. They showed that the salient identities related to their experiences in EHED differed for men and women, with Latinas citing gender stereotypes as more salient than race. In a different study, Rice and Alfred (2014) used an ecological model to explore how professional African American women engineers successfully navigated through K-12, EHED, and into their profession of which there is little research. The authors found through interviews with nine participants with a

minimum of ten years of professional engineering experience that two main microsystem or individual factors were salient related to the women's intersecting identities: a strong self-image, like being proficient at math and science, and determination and perseverance. The women in the study reported that having their competency in math and science confirmed by others, like family and teachers, affected their self-image and increased their sense of fitting in as an engineer, despite experiences of marginalization in relationship to their race and gender. Our findings validated their study.

Rice and Alfred's 2014 research showed continuity with Tate and Linn's 2005 study of how women of color's identities shape their experiences in EHED and that their multiple identities—academic, social, and intellectual—helped them persist through their programs. The participants, who identified as African American, Mexican American, Filipina, Biracial, and Multiracial, shared that due to the few women of color in their engineering majors, they were paradoxically both invisible and hyper-visible in their programs (Tate & Linn, 2005). Their invisibility emerged from the low participation by women of color in their engineering field but was countered with hyper-visibility, for example when people noticed when they were not in class. While these women reported that as they successfully navigated their academic identities as engineering students, their social identities like their race, ethnicity, and gender, became highly salient and were used to make them feel different and that they did not belong. For two of the five participants, it was their first experience of their racial identity as most salient in their education because people would point out how they were different, which was a new experience for them in the whiteness (Ahmed, 2007) of engineering spaces.



The socialization process for lesbian, gay, and bisexual (LGB) engineering students also reflects the complexities of intersecting identities in the heteronormative culture of engineering (Cech & Waidzunas, 2011). A critical literature review by Jennings and colleagues (2020) showed that there is scant research on the experiences of LGBTQIA+ engineering students despite the growth of DEI research on the experiences of women and students of color in engineering education. The limited research shows that students with LGB identities experience hostility, isolation, stress, and anxiety, but also the salience of their intersecting identities (Cech & Waidzunas, 2011; Haverkamp et al., 2019; Riley, 2013). Cech and Waidzunas (2011) conducted interviews and focus groups with seventeen LGB students in an engineering department at a major U.S. college. Eleven of these students identified as gay with two lesbians and four students who identified as bisexual. Two of these eleven students identified as Asian, six as Chicano or Latino, and the remaining nine students identified as White. Their findings were that these students have unique experiences of exclusion in the meritocratic, ahistorical, and apolitical culture of EHED that disadvantages them. There was less tolerance of LGB students and more biases toward heteronormativity and masculinity in engineering disciplines that were more technical and hands-on, like mechanical, aerospace, and civil engineering. Bisexual students faced a heteronormative dichotomy that made the stereotypes they experienced unique, which our study's findings also uncovered. The Asian students, however, did not report their race as more salient than their other identities in contrast to male and female Latinx students. Overall, all these students reported being questioned about their engineering competency based on their intersecting

identities, which adds further complexity to their marginalized status (Cech & Waidzunus, 2011).

Haverkamp et al (2019) found that engineering culture is constructed through social interactions that may require those who experience hostility in EHED culture to leave or seek outside support. In their autoethnographic research on the experiences of two transgender and gender nonconforming (TGNC) engineering students using a resiliency framework for analysis, they found that TGNC students must find support outside of EHED as they navigate spaces between what feels like two different cultures—trans and engineering. The students describe engineering culture as heteronormative, cis-gendered, and hegemonically masculine and apolitical. As one of the students began transitioning while in school, she felt excluded from group projects. Due to the stressful culture based on rigor and merit, group work is crucial to success in EHED, so feeling unwelcome and hiding one's identities affects academic outcomes. One of the participants experienced so much distress about her safety around cis-gendered male peers, she became physically ill and chose to leave EHED, which the authors (Haverkamp et al., 2019) describe as a form of powerful resiliency for this student. The authors also identify the unique liminal spaces that TGNC students experience in engineering where the intersectionality of their identities emerges.

Riley (2013) reaffirms Frehill's (2004) history of embodied and ableist definitions of masculinity that is still exemplified by personas like Teddy Roosevelt, however, gender concepts related to physical ability in engineering continue to evolve as do the related traits of rigor and meritocracy. Riley conducted a discourse analysis of the

diversity exhibit at the 2012 American Society of Engineer Education (ASEE) annual conference using queer and disability theory to explore why disabled students are invisible in EHED. Her findings were that by the late twentieth century, the concept of masculinity in engineering became disembodied, without emotion or physicality. Riley cites the late Stephen Hawking as a representation of the bodiless mind beyond emotion and senses that epitomizes the sociotechnical dualism in EHED. This conception of masculinity and the power associated with the White, cis-gendered, able-bodied, heterosexual male in engineering is ignored and rendered invisible in EHED culture (Riley, 2013). Riley reports how disturbing racist and sexualized masculinity continues to be enacted through a disciplinary language of violence. An example she shares is the mnemonic device for memorizing the color codes of resistors: “Black Boys Rape Our Young Girls But Violet Gives Willingly” (Riley, 2013) which was still used as of her research in 2013.

Svyantek (2016) shows the absence of research on disabilities in engineering in her literature review of conference papers from the American Society of Engineer Education (ASEE) conferences 2010-2015. Like Bucciarelli’s (2009) discourse critique of engineering rhetoric, four-fifths of the 142 papers the author reviewed discussed disability in terms of the Americans with Disabilities Act (ADA) accommodations and requirements in design projects, while few were focused on the inclusion and access of actual disabled engineers and engineering students (Svyantek, 2016). Slaton (2013) further exposes not only the absence of STEM students with disabilities in engineering education, but a dearth of research as well and asks, how does the culture of STEM

discriminate against bodies with physical disabilities, and what are the origins of these exclusions? Using the case study of a blind undergraduate chemistry student's experiences in a school laboratory, Slaton argues that it is the socialization process, which is based on notions of normalcy, performance, and identity, which perpetuate the exclusionary and oppressive environments in STEM. Using a combination of disability studies and engineering studies the author explains the socially constructed nature of ability and disability as dichotomies of health and illness and their essentializing relationship with STEM abilities. Indeed, Slaton (2013) argues producing engineers is a political act that relies on neoliberal ideologies of meritocracy and individual agency and ability. But Slaton also argues that producing engineers is based on a historically idealized masculine culture of physical functionality and biological abilities. During socialization, these abilities must be measured, evaluated, and assessed to produce hierarchal orders of merit. Slaton's (2013) research showed that because EHED is idealized as having objective standards, when professors accommodate disabilities, for example by using auditory instead of visual measurement apparatuses, it may be perceived by some as less pedagogically rigorous and unfairly giving disabled students special treatment. Here, again, is the kinetic operator (Nail, 2021) of the deficiency lens (Harper, 2010) with its emphasis on individual student ability, agency, and self-esteem, rather than, as Slaton (2013) calls for, a focus on the institutional norms of EHED that resist accommodating different bodies.

There is relatively little research on autism and neurodivergence in EHED or STEM. Chyrsochoou, Zaghi, and Syharat (2022) argue in their literature review that

common perceptions about autism and neurodiversity are barriers to participation for neurodivergent students to enter engineering. The authors reject the medical model of neurodivergence as a deficit or disorder that must be fixed; rather they seek to empower neurodivergent students to identify and leverage their unique strengths by using a social ecology approach. In their review, they found that the industry is beginning to appreciate the range of skills and cognitive diversity that neurodivergent students may have, including the ability to recognize patterns, visual-spatial abilities, systems thinking, divergent and creative thinking, intuition, and insightfulness (Chyrsochoou et al., 2022). They note that these skills are all correlated to innovation and productivity in engineering. However, they argue that the current culture of engineering as well as the tightly packed curriculum based on ABET accreditation does not support students who think differently through exploring and experimentation. They note that engineering is slow to change and is based on a one-size-fits-all model that is not conducive to neurodivergent learning. Additionally, disability services and legal requirements like the Americans with Disabilities Act (ADA) are based on the medical model of deficiencies that influences campus culture and faculty's perceptions of neurodiverse engineering students' abilities and work habits. Often faculty follow disability services accommodation requirements but do not work individually with the students to develop their strengths, build positive identities and self-esteem, or help students learn to advocate for themselves and develop a sense of belonging. The authors (Chyrsochoou et al., 2022) call for a paradigm shift in EHED that includes smaller class sizes at R1 research universities, where faculty are not primarily focused on teaching due to tenure and

promotion requirements. They also argue that the Covid-19 pandemic demonstrated higher education is capable of flexibility in assessment methods. They also recommend removing weed-out classes and highly competitive courses in which neurodivergent students are at a disadvantage, which also contributes to faculty perceptions that accommodations are cheating. They recommend that neurodivergent faculty should also make themselves visible as role models to increase neurodivergent students' sense of belonging (Chyrsochoou et al., 2022).

Taylor and colleagues (2019) conducted a study with 60 students using SAT scores and grade point averages to test how ADHD characteristics and aptitudes, including creative or divergent thinking, contribute to student performances. Using multivariate regression models, they found that ADHD characteristics negatively predicted GPAs and traditional measures of performance in engineering education, but were predictive of creativity and divergent thinking, or the ability to create multiple solutions to complex problems. They defined creative aptitude as divergent thinking, fluency in creativity, originality, flexibility, and the ability to elaborate. Creativity is argued as desirable in the engineering industries by Chyrsochoou, Zaghi, and Syharat (2022) and crucial to the creativity of the professional engineering workforce. Taylor and the team (2019) concluded that GPA and SAT scores are not accurate measures of neurodivergent students with ADHD characteristics. In their study they also found that neurodivergent students avoided accommodations because they believed they were not necessary, they feared a stigma in the intense rigorous culture or were not aware of the resources available to them (Taylor et al., 2019). There was also a sense of not wanting

special treatment and a desire from students to handle things themselves. The authors also call for paradigm changes in engineering education away from rigidity and towards rewarding neurodivergent ways of knowing and providing opportunities and encouragement.

Autoethnographic narratives of two neurodivergent students were used by Cuellar and colleagues (2022) using the social model of disabilities studies that examine structural and discourse barriers. Their study was an effort to share the lived experiences of these students as part of natural differences that occur biologically among humans. In their study, the two participants wrote about their experiences based on prompts given by the research team. Analysis was conducted by the researchers by looking for key themes that were connected to the research literature and then synthesizing these findings. One participant received a childhood diagnosis of her autism and came to college with help from high school mentors, which eased her college experience. The other was diagnosed with ADHD as an adult student who described his failed attempts to manage his differences on his own while not understanding how he was different. The participant described how he had to undo engrained habits but also the cognitive dissonance his diagnosis created for him based on how it provided him with a new understanding of himself while other people saw him as the same. This participant called for more research on the emotional experiences of being diagnosed as an adult student, which my study contributes to. These authors (Cuellar et al., 2022) also called for a paradigm shift in engineering education and research that includes neurodivergent student participation and that provides agency and choices to the students. By utilizing universal designs for

learning (UDL), the authors argue that the burden to advocate for themselves is removed for neurodivergent students.

### ***Effects of Socialization on Student Bodies***

In this section, I highlight some of the common effects of the socialization process into EHED culture that the research shows are experienced by underrepresented students. For many of the students in this research literature, the silence imposed through the sociotechnical dualism and related cultural traits prohibits discussing their experiences of oppression. This silencing can create fears of marginalization for those who speak up about their experiences through criticism by peers and faculty and critics are deemed whiners who do not merit engineer status (Cech, 2013). Women engineering students are shown in the research to internalize a meritocratic belief that hardships were required on their part because by acclimating to the culture, they come to believe that they are exceptional women who are attempting to enter a demanding, but unbiased, discipline (Seron et al., 2018). The research shows how the hidden dimensions of the culture damage self-efficacy and create feelings of inadequacy (Cech, 2013). There are also ideological effects seen in female engineering students who Seron et al. (2018) found often assume an anti-feminist stance through acceptance of the ideology of meritocracy. Faulkner (2007) created the term *gender in/authenticity* to describe the pressures on women to reproduce the dominant culture. Across the research, women regardless of race, are consistently identified and primarily seen through their gender identity in EHED, rather than first being identified as engineers.



The small amount of research on TGNC engineering students who experience the heteronormative culture in EHED shows that they often fear for their personal safety (Riley, 2013) but also experience distrust, distress, and anxiety that can manifest as physical illness (Haverkamp et al., 2019). Research shows that students must counter stereotypes by downplaying TGNC aspects of their lives while proving their engineering capabilities (Cech & Waidzunas, 2010). Cech and Waidzunas' (2010) research shows that extra work is required by these students to navigate EHED as they fear they may jeopardize their future careers in a "don't ask, don't tell" environment where feelings and politics are irrelevant to engineering and thus left undiscussed. Heteronormative stereotypes about gay men were found to discredit their perceived competency as engineers, while conversely, lesbians with what are considered more masculine characteristics were often seen as more capable than gay male engineers (Cech & Waidzunas, 2011). Isolation is a common experience for LGBTQ students in engineering, but also for students of color.

Research shows that for students of color, entry into a predominately White EHED can bring their racial identities to the forefront of their educational experiences for the first time (Seron et al., 2018; Tate & Linn, 2005). The effects of the hostile, unfriendly, unsupportive, and stressful racist culture on students result in feelings of alienation, marginalization, and isolation (Harper, 2012; Lord & Camacho, 2013). Lord and Camacho's research (2013) found that Latinas report receiving questions about their commitment to engineering and insinuations about their abilities, even shock, and surprise by their peers that they are in EHED. Because there are so few women of color

in EHED, research shows that they lack a collective voice and suffer from stereotype threats, or situational fears of confirming racial, gender, and ethnic stereotypes, which decreases their confidence in their own abilities (Lord & Camacho, 2013). And from a disabilities research perspective, studies on neurodivergence show that the culture of engineering and rigid reliance on narrow forms of testing and assessment affect neurodivergent students' mental health and sense of belonging (Chyrsochoou et al., 2022; Cuellar et al., 2022; Taylor et al., 2019). Slaton (2013) argues that students who require longer than the standard four to five years to complete an undergraduate engineering degree are perceived by industry as epistemologically less promising and accomplished, which also reduces students' confidence. I used the effects the culture has on underrepresented students described in the empirical research to inform my study's methods and to create a starting set of interview prompts that were then built on and customized by the participants and me as the study progressed (Berryman et al., 2013a).

### ***Strategies for Resiliency, Coping, and Success***

Understanding the strategies described in the literature about how students develop resiliency to cope and succeed in EHED was critical for me to conduct anti-deficit research with underrepresented students (Harper, 2010), but these strategies also are kinetic operators (Nail, 2021) in EHED that were uncovered in our collaborative study. Godfrey and Parker (2010) show in their research that relationships, group learning, and peer teams are considered especially important to survive the rigorous program, with fitting in and having a sense of belonging important for success as an engineering student. Liptow and colleagues (2016) investigated the impact of a first-year

engineering student success course for first-generation underrepresented students. The course increased a sense of belonging for students of color while also broadening their understanding of engineering and that minority engineers are needed in the professions. On a macro level, Rice & Alfred (2014) found that support was crucial for African American professional women engineers. This support came from family and friends, teachers and counselors, pre-college programs, financial and other school resources, a personal minority network including professional student engineering associations like the National Society of Black Engineers, mentors in the workplace and managerial support, and flexible corporate structures. Lord and Camacho's (2013) mixed method study using a metaphor of borderlands of education found that Latinas redefine what success means for them, which includes learning to fail and being less focused on grades, as well as standing up for themselves. Professional student organizations like the Society for Hispanic Professional Engineers (SHPE) also provide the support that Latinas require to persist (Lord & Camacho, 2013). Tate and Linn's (2005) multiple identity theory-based study of the experiences of women students of color in EHED also includes how social identity conflicts required utilizing peer groups as important networks of support that help alleviate students' sense of not belonging and feeling different. This support often includes social groups outside the engineering community and off campus. Neurodivergent faculty can support neurodivergent students by transparently sharing their own identities and being visible role models. Additionally, engineering education can utilize UDL methods so that neurodivergent students do not have to self-identify, which increases their sense of belonging (Chrysochoou, Zaghi, & Syharat, 2022). I used

these findings in the research that support systems are crucial to student success in engineering as one starting prompt for the unstructured interviews with participants.

### ***Conclusion***

I identified several gaps in the knowledge from my review of EHED culture and professional socialization research, which generated my first research question. These gaps informed my collaboration with underrepresented engineering students as I used them to create a set of starting prompts for the unstructured interviews with the participants in which the participants chose what was salient to their own experiences (Berryman et al., 2013a). Several of the EHED traits described in the literature are kinetic operators (Nail, 2021) that needed further study, like the mental health effects of extreme rigor and a culture of stress. The effects of the socio-technical dualisms of EHED are also kinetic operators that the students and I collaboratively explored. And lastly, support networks are important to underrepresented student success and I included this item in the interview prompt list. In the next section of my literature review, I focus on the methodological and epistemological research related to DEI in EHED, which is the focus of my second research question.

### **Epistemic Pluralism in EHED Research**

#### ***Introduction***

In this section of my literature review, I identify the methodological gaps in knowledge production related to the positivist hegemony in EHED that I identified above, which my study fills. I begin by reviewing the recent and limited EHED research

about epistemic pluralism that attempts interdisciplinary, neurodivergent, and subjective methodologies. I follow my review of this EHED research with a synthesized review of the epistemic diversity literature from just a few of the underrepresented communities in EHED that describe culturally responsive methods (Berryman et al., 2013a), including Indigenous, Confucian, and Islamic traditions to show the variety of conceptions about engineering beyond the narrow Western-based culture that dominates EHED in the U.S. (Riley, 2017). Next, I review the arts-based research (ABR) methods literature to demonstrate how ABR is a culturally responsive method for my study, and even neurodivergent. I end my literature review by showing how all these pieces fit together to create my conceptual framework of creative materialism.

### ***New Methodologies for EHED Research***

As EHED continues to emerge in a diverse global world with goals of inclusivity and equity (ABET, 2022), researchers in engineering education are increasingly aware of the limits of their epistemological reliance on positivism (Riley, 2017). There are a few patterns in this emerging empirical research that my study explored, like the exclusionary aspects of hegemonic positivism (Baille & Armstrong, 2013; Moloney et al., 2018; Riley, 2017), including in EHED research approaches and the positivist paradigm's inappropriateness in trying to solve complex historical social problems like the lack of diversity in EHED (Douglas et al., 2010). Another factor related to my study's methods is the messiness and difficult nature of interdisciplinary work (Baille & Armstrong, 2013; Beddoes et al., 2017; Douglas et al., 2010; Moloney et al., 2018), which I theorize as liminal turbulence using CLO theory (Nail, 2021). Researchers from CRM studies also

report on the necessity of being responsive, the extra labor involved, and the unexpected surprises that may occur during the research with interdisciplinary and responsive methodologies (Berryman et al., 2013b; Bloomfield, 2013; Nodelman, 2013; Cardno et al., 2017; Valenzuela, 2013). Because there is limited research on epistemic pluralism in EHED, I describe these studies in some detail as they inform my project.

In 2010, Douglas and colleagues conducted a literature review of submitted papers to the American Society of Engineering Education (ASEE), the *European Journal of Engineering Education*, and subsequent conferences and workshops to address the lack of training for EHED researchers in qualitative research methodologies. They argue that EHED researchers require a multiplicity of epistemological frameworks from which to examine inequities and exclusions in their field. They found there were no discussions in the literature about epistemological exclusions, meaning that awareness of the problem was low and there was possible resistance to change (Douglas et al., 2010). ASEE is the primary organization of research on engineering education in the U.S., so the lack of alignment between the theoretical frameworks, problem framing, and research designs in many papers reviewed is problematic. In the workshop content they reviewed there was a reliance on quantitative research method terms like causal relations, validity, control, and hypothesis, as well as a continued belief in the necessity of control groups in research and the generalizability of findings. However, participants came to know the complexity of their situation as related to diversity in EHED despite discomfort with qualitative presentations. The authors identified several cultural challenges similar to those found in Bucciarelli's (2009) rhetorical critique, including a mechanistic approach to research,

unquestioned assumptions about knowledge creation, and the need to remove negative judgments about qualitative methods being deviant and abnormal within engineering as a discipline (Douglas et al., 2010). The authors argue that with increased exposure and training for engineering educational researchers, trust in interdisciplinary research will grow, and eventually, a space will be created for marginalized scholars to do research without fear of being silenced. I hope that my study aids in building this necessary trust by contributing my creative materialist framework to the EHED research.

Baille and Armstrong (2013) challenged the positivist discourse in EHED using threshold concept theory to map the liminal transformation process that occurs during learning, while also arguing that the epistemological values embedded in EHED perpetuate inequities. The authors found that this epistemic myopia is difficult to identify in one's own discipline as disciplinary values become common sense and are taken for granted as the way things are done. Using an interdisciplinary team from history, Asian and Indigenous studies, anthropology, philosophy, law, and science and technology studies (STS), the researchers (Baille & Armstrong, 2013) asked participants what key ideas, concepts, and sources from their own disciplines' epistemological frameworks would help an engineering student cross their disciplinary boundary to better understand the humanities and social sciences. Their findings indicate that negotiating different knowledge structures in interdisciplinary work is difficult as there are multiple ways of thinking. Engineering students had trouble challenging their preconceptions about society and dealing with uncertainty because of their positivist training that emphasizes finding one right answer (Bucciarelli, 2009), meaning they have no mechanism to deal with

ambiguity or question their assumptions. Students became stuck in their liminality, never crossing the threshold or passing through the gateway on the other side with their new knowledge firmly embedded and irreversible (Baille & Armstrong, 2013). Instead, the authors found that these students existed in a suspended state of mimicking knowledge without understanding it, oscillating back and forth in the liminal space of learning troublesome knowledge, or knowledge that their education did not prepare them to learn epistemologically. Their recommendations (Baille & Armstrong, 2013) include EHED students mixing with students from other disciplines to question each other's assumptions. They argue that engineering students need the time and space to sit with troublesome knowledge to develop comfort with the turbulence of self-reflexivity and not knowing, in contrast to the mechanistic positivist emphasis on finding one right answer that Bucciarelli (2009) describes.

Beddoes and colleagues (2017) also researched this messy interdisciplinary space by examining the personal epistemologies of engineering students. They define personal epistemology as discursive positions related to knowledge and knowing that include the person's relationship to the context and setting. The authors used two cohorts of ten and fourteen students in a longitudinal study from 2011 to 2014 in which they conducted biannual semi-structured interviews and phone call check-in every two weeks. Beddoes and the team's (2017) findings, like Baille and Armstrong's (2013), were that crossing disciplinary boundaries is messy due to the plurality of ways of finding meaning, which is difficult to translate across disciplines and make thematic comparisons. Beddoes and colleagues. (2017) describe that the rigidity of disciplinary knowledge creates



epistemological uncertainty, which, like Baille and Armstrong (2013) found, is troublesome for EHED students who pedagogically are trained with assumptions related to positivism as Bucciarelli (2009) described. Beddoes and the team's (2017) process with students generated new topics and questions about theoretical frameworks that aided the engineering students through a better understanding of their own professional development. They also uncovered that engineering students have significant doubts about their own abilities to think critically about their profession, which contributes to epistemological uncertainty. Their recommendations include pedagogical changes in EHED that shift away from lectures that imply simple solutions that are provided by the authority. More research is needed from individuals in their own words but also more research about how this epistemological confusion affects attrition in EHED (Beddoes et al., 2017). These last two points describe the gap that my project methodology addressed by providing space, time, and resources for self-reflexivity by the participants about their experiences as engineering students.

Moloney and colleagues (2018) uncovered methods that provide engineering students with the ability for self-reflexivity about their career choices with their own cultural values that they brought to EHED. The researchers conducted a workshop on fostering pedagogical subjectivity with fourteen participants with daily discussions, case studies, skill-building, and free writing. Subjectivity is theorized as problematic in positivist-based methods; however, the authors argue that the material work of engineering requires subjective awareness for engineers to understand what their creations mean to society (Moloney et al., 2018). Additionally, they argue that engineers

must come to know that positivism and rationality cannot solve every problem. Rather the authors argue that experience, intelligence, and responsibility are also necessary to holistically understand a problem. Like the other research, the interdisciplinary work Moloney and colleagues conducted was found to be difficult because it is challenging to maintain self-awareness for long durations and design across disciplines.

Methodologically, the authors utilized aesthetics like colored paper and markers for the free writing exercises to disrupt the participants' habits of academic writing. They found that the free writing became easier for the students and more reflective over the week of the workshop, which was replicated with my participants. Their (Moloney et al., 2018) findings were that subjective reflection increased engineering students' awareness of their assumptions and created growth opportunities.

In summary, the EHED research using qualitative and interdisciplinary methods indicates that there is a large gap in empirical research that my study filled. While EHED research wrestles with its cultural barriers to epistemic diversity, research literature from underrepresented communities explains and describes their own epistemic traditions that they see as equivalent but different. Many of the same themes described in the EHED epistemic research above are included in these cultural epistemologies.

### ***Epistemologically Equivalent but Different***

My purpose in this section of my literature review is to provide context for my use of interdisciplinary and creative arts-based research methods (Leavy, 2017) as culturally responsive (Nodelman, 2013) and as providing epistemic pluralism. Through

this chapter, I showed the profound yet unseen kinetic operator (Nail, 2021) of positivism that research consistently shows is problematic in EHED culture and that manifests as the fetishization of rigor and socio-technical dualisms. As I have shown, in EHED culture, pedagogy, and the professions, multiple non-scientific ways of knowing are suspect and deemed inferior by engineers for their perceived lack of mathematical objectivity, certainty, replicability, and universality (Riley, 2017). I used Nail's CLO theory (2021) as a Western science-based methodology that denies the claims of objectivity to counter this cultural trait theoretically. Based on the literature, there are emerging movements towards epistemic pluralism and interdisciplinarity in academia that seeks to remove the ideological hierarchy that places positivist methods at the apex of all knowledge generation.

A common argument in the literature I reviewed below is for respect and reciprocity from Western STEM practitioners, educators, and researchers, and from the education community in general, for these well-established traditions of knowing. While EHED researchers grapple with the liminal epistemic turbulence engineering students experience as they move through interdisciplinary learning (Baille & Armstrong, 2013), it is important to emphasize the additional turbulence that underrepresented students experience, as found in the research on mental health (Danowitz & Beddoes, 2020). As cole and O'Riley (2017) argue, Native American students are required to learn STEM disciplines in school; however, non-Native students do not have to learn the different, but equivalent ways of knowing the material world through an Indigenous perspective, despite their society's accumulated wisdom that would benefit global modern society

generally. Researchers argue that there are harmful effects on Indigenous students who constantly dwell in the liminality of crossing cultural borders in education which is underappreciated in STEM education (Bang & Medin, 2010; Black & Hachkowski, 2019; Kimmerer; 2013). The research I reviewed on different ways of knowing and other embodied experiences of EHED covered in the empirical research on socialization section above also showed the need for reciprocity and respect for differences (Chrysochoou et al., 2022; Cuellar et al., 2022; Heybach & Pick up, 2017). EHED cannot be more diverse if the culture does not become meaningfully more inclusive and equitable epistemologically and pedagogically (Riley, 2017).

Heybach and Pickup (2017) use feminist science studies, new materialism, and decolonial approaches to frame an onto-epistemological challenge to positivist trends in EHED research. They conceive the hegemony of Western science in all STEM fields as a socio-cultural enterprise shaped by a masculine ontology. Like Nail (2021), Heybach and Pickup (2017) argue that Western science has an illusion of objectivity and value-free inquiry in its search for complete knowledge and control over the mind and nature. Heybach and Pickup's goal is not to replace the current biased science with a feminist science, but the acceptance that the doing of science, engineering, and mathematics as women brings diversity to problem identification and solution formation. The authors argue for a queering of the gender and disciplinary boundaries in STEM in which a gender-free science can emerge with new, complex, and different scientific inquiries, much like Riley's argument for vigor over rigor in EHED (2017).

Similarly, in their re-storying of STEM by performing survivance, Indigenous scholars cole and O'Riley (2017) describe STEM education as a closed economic system of empire building, a form of cognitive imperialism that seeks power over the material world with dire consequences such as climate change. The authors argue that imbalances are created when STEM education is uncritically imposed on the so-called "developing" world, a form of a state-military-industrial-education complex (cole & O'Riley, 2017). They call for disrupting this hegemony not by replacing Western science and engineering with Indigenous versions but by recognizing that there are many tributaries of knowledge available. Like the EHED literature above, they call for an epistemological democratic framework that welcomes the multiplicity of knowledge structures and processes in the world. However, there are risks with merging interdisciplinary and intercultural understandings of knowledge production. I chose CRM (Berryman et al., 2013b) as part of my theoretical framework to increase my awareness of these risks in how I intra-acted (Barad, 2007) with the student participants and also how I analyzed and interpreted the content we generated.

I synthesized patterns that emerged in the epistemic diversity literature below to show some of the similar epistemological ideas that exist across these traditions. My intention is not to essentialize all epistemologies other than positivism as the same. Indeed, each culture and identity have different historical kinetic operators (Nail, 2021) with Western culture and STEM, especially in relationship to colonization. Indigenous tribes across North America are unique while sharing some characteristics and Islam reaches across the globe and cultures, meaning each Islamic society and individual has

different entanglements with Islam—and Western coloniality and science. However, by showing the multiplicity of ways people come to know, I strengthen my argument for my unique methodology in this study that uses CRM as a central component of the framework based on addressing these epistemic differences (Berryman et al., 2013a).

### ***Interdisciplinary Cross-Cultural Research and Learning***

The authors I reviewed all recognize that despite the difficulties of crossing disciplinary and cultural borders, the work is necessary, which resonates with previous research using CRM (Berryman et al., 2013b; Bloomfield, 2013; Nodelman, 2013, Valenzuela, 2013). The urgency of doing this work manifests across the literature and calls out the distressing material results of the unbridled acquisition of knowledge in modern Western science and technology that are grounded in narrow epistemic, economic, and political ideologies (Baker, 2016; Baker & Batchelor, 2016; Bang & Medin, 2010; Black & Hachkowski, 2019; Castagno & Brayboy, 2008; cole & O’Riley, 2017; Kartanegara, 2016; Zhu, 2020). Concepts about one “correct” but limited epistemological method in all education is argued to be a Western perspective that must be overcome (Bang & Medin, 2010; Castagno & Brayboy, 2008; cole & O’Riley, 2017). Pluralities of ways of approaching knowledge formation are valued in this literature through recognition of the complexity of the material and human worlds (cole & O’Riley, 2017). Cultural methods discussed in the literature for coming to know include iterative imagining of other people temporally and spatially (Bang & Medin, 2010; Zhu, 2020), creativity (Castagno & Brayboy, 2008), and know-how (Zhu, 2020). For many cultures and identities, coming to know is conceptualized as an iterative, circular process that

emerges through collaborative observation and creative, visual, and hands-on practices (Black & Hachkowski, 2019; Castagno & Brayboy, 2008) with a holistic perspective (Wilson, 2008). Indeed, Riley's conception of vigor (2017) instead of rigor in engineering culture embodies these characteristics.

*Balance, Relationality, and the Big Picture*

Unlike the narrow U.S. metrics of progress described by Downey (2007) that are kinetic operators (Nail, 2021) in the epistemic culture of EHED, much of the research literature I reviewed here describes that the primary purpose of knowledge creation is to create and maintain balance in society and avoid extremes by using collaboration and consensus (Bakar, 2016; Bakar & Batchelor, 2016; Bang & Medin, 2010; Black & Hachkowski, 2019; Castagno & Brayboy, 2008; cole & O'Riley, 2017; Kartanegara, 2016; Zhu, 2020). Indeed, Black and Hachkowski's (2019) research showed that individualism is culturally perceived as a disorder in Indigenous communities, which is problematic for students with these cultural epistemological values that attempt to learn in an EHED culture that fetishizes individuality through concepts like merit and rigor. Cultural values that emphasize ethical relationality and responsibility are repeatedly contrasted in the research with the goal-oriented and narrow conception of knowledge found in EHED (Bakar, 2016; Bakar & Batchelor, 2016; Bang & Medin, 2010; Black & Hachkowski, 2019; Castagno & Brayboy, 2008; cole & O'Riley, 2017; Kartanegara, 2016; Zhu, 2020). Reflection on the bigger picture with a holistic lens is valued as critical to understanding the specifics of a situation (Bakar, 2016; Bang & Medin, 2010; Black & Hachkowski, 2019; Zhu, 2020) while reduction to one answer is not considered valuable

without also understanding the wider context. As CRM emerged from the Māori tradition of resisting hegemonic Western education (Smith, 1997) with Kaupapa Māori, my inclusion of culturally responsive principles in the framework addresses and preemptively addresses these colonial aspects of EHED and Western research approaches.

### *Intergenerational Responsibility*

Confucian (Zhu, 2017; 2020), Islamic (Bakar, 2016), and Indigenous (Bang & Medin, 2016) traditions assume historical and generational perspectives in knowledge production; ancestors, both in the past but also the future, are relationally considered in present-day knowledge production as well as the development of technologies (cole & O’Riley, 2017; Black & Hachkowski, 2019; Kimmerer, 2013). The long-term impacts of knowledge creation and changes in how knowledge production is conceived and valued from the past are taken into consideration when coming to know about the present (Açıkenç, 2016; Bakar, 2016; Zhu, 2020). Responsibility to these ancestors includes the oral narrative traditions in which Indigenous scientific knowledge is passed down (cole & O’Riley, 2017), while the written knowledge in Confucian (Meng & Uhrmacher, 2017) and Islamic traditions (Bakar, 2016) carries these ties to the past and future. Responsibility to these ancestors is a unique cultural attribute in contrast to Western metrics of progress that prioritize future progress, individualism, and material production and consumption (Downey, 2007). By incorporating CRM into my framework (Berryman et al., 2013a), I charged my study with ethical responsibility to the participant and the Mines community, to EHED and higher education broadly, and also to future underrepresented students who will benefit from our contributions.



### *Sources of Knowledge*

The research showed a range of sources of knowledge and how knowledge is transferred in a community that differs from the narrow pedagogical conceptions in EHED. In Indigenous traditions, oral narratives are reliable and ancient stories that are passed down through generations related to a tribe's specific land use, maintenance, and design (Whyte, 2016). Engineering education culture historically has dismissed oral knowledge as inferior, illegitimate, and unverifiable compared to written language and texts (Bang & Medin, 2010; Bucciarelli, 2009; cole & O'Riley, 2017; Denzin et al., 2008; Douglas et al., 2010). Another important difference with positivism found in the literature is the incorporation of non-human voices from what in Western paradigms is referred to as nature. The interdependence and relationality across the material world are integral to Indigenous ways of knowing (Black & Hachkowski, 2019; Castagno & Brayboy, 2008; cole & O'Riley, 2017; Wilson, 2008). Indigenous knowledge sources include non-human actors that reside in Indigenous people's ancestral lands that are respected as knowledge keepers and relatives (Bang & Medin, 2010). This Indigenous land-based epistemology includes learning with nature by listening to nature; listening is a key value in Indigenous cultures that often is demeaned as shyness in Indigenous students in Western education out of ignorance (Black & Hachkowski, 2019). Silence and being quiet are cultural presentations of difference that are often mistaken as learning disabilities and a lack of intelligence (Castagno & Brayboy, 2008) due to how Western education defines smartness (Leonardo & Broderick, 2011). Both Indigenous (Black & Hachkowski, 2019) and Islamic traditions (Bakar, 2016) value spiritual revelation as a form of knowledge,

which is considered precious in the Islamic paradigm (Bakar & Batchelor, 2016) and a compliment to reason in Indigenous ways (Kimmerer, 2013), compared to the secularization of Western science (Acikgenc, 2016). Revealed knowledge is seen as a remedy to bringing balance back to the world that has been dominated by Western science (cole & O'Riley, 2017) and its associated metrics of progress (Downey, 2007); it is not a replacement but an equivalent perspective that can lead to healing, especially in North American Indigenous communities and their traumatic histories with Western education and conflicts around their sovereignty (Bang & Medin, 2010).

### *Ethically Restricted Knowledge*

Bakar (2016) describes the Islamic moral paradigm that guides science and technology toward the benefit of society. The Quranic value of this paradigm restricts the development of new knowledge and technology purely out of curiosity. In contrast, Bakar argues, Western engineering and science declare themselves value-free and democratically open to mere curiosity, which could potentially be harmful to society in the future. These restrictions on knowledge are also found in Indigenous paradigms that are focused on bettering the community rather than the individual (Bang & Medin, 2010; Black & Hachkowski, 2019; Castagno & Brayboy, 2008; cole & O'Riley, 2017). To those trained and assimilated in U.S. and Western secular education, the idea of restricting knowledge contradicts democratic ideals of free access to information and the curiosity that is cultivated in U.S. education systems.

### *Section Conclusion*

In summary, in my literature review so far, I have shown the historical kinetic operators (Nail, 2021) that are entangled in EHED's cultural identity that research shows are barriers to creating the inclusive and equitable learning environments that students need. The research shows that these barriers include: the notoriously difficult and stressful culture of engineering education that increases the turbulence of learning and coming to know how to be an engineer because of the entanglements of ideological positivism; the fetishization of rigor; and socio-technical dualisms that remove engineering and technology from society and create a hierarchy across engineering fields using a gender lens. Research shows that underrepresented students experience higher levels of mental health distress in EHED culture, which contributes to attrition. The intersecting identities of engineering students are salient in relationship to the culture of EHED, and a paradoxical sense of invisibility and hyper-visibility is experienced by women of color. The entanglement of history, coloniality, positivism, and U.S. metrics of progress that Downey (2007) describes all have agency as kinetic operators (Nail, 2021) and were threads of inquiry that the student participants and I explored. I showed the research that argues there are dangers in the hegemony of positivism and its associated cultural traits in global STEM efforts, and how EHED epistemological pluralism research identifies how restricting EHED pedagogy to positivism creates barriers for engineering students to work and learn across disciplines. I now turn to how my choice of arts-based research methods fit with the literature I covered and as a component of my creative materialism.

## **Arts-Based Research Methods**

### ***Introduction***

In this final section of my interdisciplinary literature review, I describe how arts-based research (ABR) methods are culturally responsive (Berryman et al., 2013a) and are contemporary loop objects (CLO) of knowledge production (Nail, 2021). I also show how ABR methods are possibly neurodivergent methods. I begin with some background on ABR methods and their theoretical lineages. I then explore the literature that resonates with my conception of ABR methods as CLO (Nail, 2021). Following the theoretical considerations, I review some research showing ABR methods as CRM (Nodelman, 2013). I also briefly review a few ABR projects related to STEM education to demonstrate the ability of ABR methods to be used across disciplines. I end Chapter Two by bringing all these elements together—theories, gaps in the research, and ABR methods—to explain my conceptual framework of creative materialism.

### ***Background on Arts-based Research Methods***

Arts-based researchers use the creative arts for research in society by leveraging the evocative and provocative qualities of creativity as they explore and describe experiences, thereby creating new ways of knowing (Barone & Eisner, 2012; Leavy, 2017). Arts-based research methods are part of a branch of Western qualitative research theories and practices from the twentieth century (Barone & Eisner, 2012; Leavy, 2017; Rosiek, 2018b). The use of embodied, creative, and aesthetic forms of knowing for research go by several names, including arts-based research methods, arts-based inquiry, a/r/tography, arts in qualitative research, critical arts-based inquiry, performative inquiry,

living inquiry, scholartistry, and poetic science, to name but a few (Leavy, 2015). These different lineages have a variety of theoretical bases related to their names, like a/r/tography, which blurs the categorical distinctions for artists who are also researchers and teachers (Holbrook & Pourchier, 2014). ABR methods incorporate a variety of theoretical frameworks. These theories include the pragmatism of Dewey and Eisner (Barone & Eisner, 2012) to the constructivist, post-structuralist, and critical theories often used in social justice and community-based participatory research. However, I theorize that arts-based methods are kinesthetic contemporary loop objects (Nail, 2021) and that new materialist theory fits well with ABR.

### ***ABR Methods as Contemporary Loop Objects***

Nail's (2021) contemporary loop object emerged from his interpretation of quantum, chaos, and mathematical category theories. Rosiek (2018a; 2018b) is one of the few ABR authors whose work shows the ethical and theoretical connections across new materialist theories and ABR methods. Rosiek also theorizes new materialisms connections to Indigenous ways of knowing (Rosiek et al., 2019), which connects with quantum field theory that is cited by Indigenous scholars cole and O'Riley (2017) as the most similar Western conception to Indigenous ways of being and knowing. As an example of new materialists' use of ABR methods, Douglas and colleagues (2021) Project Re-Vision used filmmaking to create new understandings of the experience of autistic people that was grounded in the new materialist theories of Barad and Haraway. Their study framed autism as an emergent experience in relationship to space and time and the biomedical gaze that dominates narratives about autistic experiences as

disabilities. Bringing all these ideas together, I theorized that arts-based methods act as contemporary loop objects of kinesthetic material knowledge production (Nail, 2020) that are culturally responsive (Nodelman, 2013), but through the study it became apparent to me that arts-based research methods are also possibly neurodivergent based on how they fit my own cognitive differences.

As an example of the resonance of Nail's (2021) contemporary loop object with aesthetic education research, Uhrmacher, Moroye, and Conrad (2016) explored the aesthetic and religious experiences of learning with flow experiences to better help teachers understand student experiences and facilitate their learning. The authors explored Dewey's texts *Art as Experience* and *Common Faith* in conjunction with Csikszentmihalyi's books on flow to theorize and show how students' experiences constantly change as they learn and how using their imaginations, sensory perceptions, and skills creates meaning. They recommend that teachers who facilitate a variety of these experiences with students create the conditions for meaningful knowing with "wow" moments of insight. Like in CLO theory (Nail, 2021) Uhrmacher and colleagues (2016) theorized material, emergent, and relational processes of coming to know, which fits with Riley's conception of vigor for engineering culture (2017).

In another example, like Nail (2021), Grushka and colleagues (2020) agree that images are prolific in the twenty-first century and that vision and visuality dominate how we see ourselves and act in the world in relational, embodied, and intersubjective ways. They argue that this pictorial turn creates intuitive opportunities to imagine possible futures that are always becoming, rather than merely representation. Visual pedagogies

create new fluid visual borders and ways of learning that contain past-present-future imaginings. The authors use a Deleuzian post-qualitative theory in an arts-based inquiry project in Australia for gifted artists and learners (Grushka et al., 2020). In what they characterize as an art-science interaction with visual artwork and visual diaries, the authors share two of the student participants' visual works in which the students explore their personal meaning-making with the aesthetics of scientific representations. The authors note the difficulty of crossing aesthetic disciplinary borders as mentioned above in the previous section on epistemic diversity. However, I believe the framework of ABR can facilitate interdisciplinary research by incorporating Nail's conception of hybridity in knowledge production (2021).

Leavy (2017) describes ABR as occurring along a continuum of art-science (pp. 196-197). ABR methods are flexible in their use of generative creative practices in research design. These practices create new knowledge and can therefore be used with qualitative and quantitative practices or alone (Barone & Eisner, 2012; Leavy, 2017). ABR methods include a variety of creative practices as viable methods of data and content generation, analysis, and interpretation including but not limited to visual art, video, performance, poetry, and fiction (Leavy, 2017). These research practices include a variety of ways of knowing that rely on imagination and non-verbal, sensory, and kinesthetic ways of knowing, or epistemic pluralism. The effect is the generation of empathy, the disruption of dominant narratives, and the transformation of the audience through emotional experiences of the creative content that shifts their understanding of the topic (Leavy, 2017). I argue that these qualities make ABR methods culturally

responsive (Bloomfield, 2013) and related to the epistemic pluralism research I reviewed above and also fit with neurodivergent ways of being/knowing (Berryman et al., 2015) and calls from the neurodivergent community for new methods in research that includes the narratives and perspectives of the neurodivergent themselves (Chryosochoou et al., 2022; Cuellar et al. 2022; Woods et al., 2018). However, as I came to understand that I was neurodivergent at the end of the study and I never theorized neurodivergence as part of creative materialism, I must further explore these connections and possibilities in future research.

### ***Arts-based Methods Are Culturally Responsive***

Use of and appreciation of the arts, storying, and performance for knowing and communicating differ across communities and social identities. For example, *testimonios* are important processes and products of truth-telling in the Latinx community in which stories are shared that show connections, demonstrate cultural epistemologies, create new knowledge, and can be disruptive social justice pedagogical tools for people of color but particularly members of the Chicana/o and Latinx communities (Bernal et al., 2012). bell hooks (1995) describes the role the arts historically played in the Black and African American communities in her classic *Art on my mind*, but also the role of creativity in her journey as a Black feminist. ABR methods are used by researchers with unique cultural epistemological ways of knowing from various communities for social justice purposes. To better understand BIPOC student experiences, Oliver (2017), for example, uniquely combined arts-based narrative inquiry with hip-hop culture and critical race theory, creating *critical hip-hop storytelling*. This contribution offers a unique arts-based



methodology for educators and researchers from communities of color to explore their own experiences with students. Similarly, Davis (2021) blends hip-hop sampling aesthetics with critical pedagogy and critical race theory to form a methodology for minoritized participants in research that is culturally responsive and allows for protest and counternarratives. Lawrence-Lightfoot and Davis (1997) created *social science portraiture*, which crosses disciplinary boundaries and illuminates the complexity of human experiences with institutions in their cultural contexts, including a narrative portrait of an arts center in a low-income community that acts as a haven for African American children. Myntha Anthym (2018) instrumentalized a Black feminist critical arts-based inquiry methodology and created an autoethnographic poetic narrative in her dissertation about her ordeal with a chronic pain illness that went undertreated. Using the emergent methodologies found in critical arts-based inquiry, the author demonstrated how her lived experience was a source of new knowledge. Anthym (2018) built on Black Feminist autobiography and used poetry to show her experiences as a marginalized person in the U.S. and revealed the subjugated truths that justified her marginalization, including in healthcare.

ABR methods are also suitable for including spiritual and religious revelation as a way of knowing. Sidrah Maysoon Ahmad (2018) used arts-based methods with anti-colonial Muslim feminist theory to create a praxis framework to interview twenty-one Muslim women who survived Islamophobic violence in Toronto. Ahmad notes that faith-based epistemologies were used by a few participants and poetry by six others, which provided the emotional depth to her discourse analysis. Ahmad's findings uncovered a

variety of forms of violence used in Islamophobic attacks and impacts including trauma. But the findings also revealed the participants' strengths and agency.

There are, however, few studies that use ABR for research in higher education that specifically focus on the neurodivergent community. Douglas and colleagues (2021) published an article that shared six short films that were created from the perspective of autistic people that sought to create a new understanding of their experiences. However, the participants were not in higher education and the study relied on family members and caregivers to augment the participation of the autistic participants. Ridout (2014) shared the results of a workshop at the Theorizing Autism Conference that used collage methods to explore the variety of views autistic people hold about autism, but also non-autistic participants; however, the study was not focused on higher education experiences specifically but the development of research methods. In summary, ABR methods are appropriate for my study because they are culturally responsive, have the potential to be neurologically responsive (Berryman et al., 2015), and align with CLO (Nail, 2021) in my conceptual framework.

### ***Arts-based Research Methods in STEM Research***

Researchers in STEM education have used arts-based research methods to help uncover the engineering identities of first-generation engineering students (Ozkan et al., 2018). ABR methods have also been used for storytelling and increasing the researcher's understanding of their own work (Kellam et al., 2015). For example, to better understand the nuances of how engineer identities form in EHED students, Kellam and colleagues

used poetry as a method for content creation in their study (2018). Jacob and colleagues (2020) showed how to cultivate ecologically focused aesthetic learning environments for children through an aesthetic pedagogy of the Little Green Museums (LGM). Using a theoretical combination of artifactual critical literacies and critical pedagogies of place, the authors show how creating the Little Green Museums generated collective material stories from the students of their ecological mindedness that were attentive to interconnectedness, place, and caring and resulted in more equitable learning. The authors' findings (Jacob et al., 2020) were that the Little Green Museums were an aesthetic method that provided agency and voice to participating students about their own lives, important places, and how they know and value things. But the LGMs have also collectively been shown to have the power to disrupt dominant narratives. All these ABR research methodologies I included here provided the local specific stories that might be missed in quantitative approaches, as well as providing detailed understandings of the complexity of the problem being researched, like exploring the experiences of underrepresented engineering students in the culture of EHED.

In summary, ABR methods are varied and applied across disciplines and sectors. ABR methods are used for personal insights but also collaboratively to examine participant and researcher experiences and learning outcomes. ABR methods are culturally responsive and resonate with the epistemic pluralism described in the literature. Importantly, ABR methods often produce shifts in perception and new perspectives previously undetected. With the support of the literature, I believe ABR was a strong fit as a culturally, and possibly neurologically responsive method, for me to collaboratively

explore my research questions with underrepresented students. I now close Chapter Two by bringing my theories and ABR methods together in my conceptual framework of creative materialism.

## **Creative Materialism**

### ***Introduction***

Creative materialism is what I termed my overarching conceptual framework that used arts-based research methods in combination with CRM (Berryman, et al., 2013b) and CLO theory (Nail, 2021). Creative materialism supports my own knowledge-making processes as a neurodivergent artist-scholar, a type of culturally responsive methodology for this artist. Like a/r/tographers (Springgay & Zaliwska, 2015), I exist with interdisciplinary roles in which I attempted to create a hybrid methodological framework that connected the logical analytical Western science-based skills in me as a Ph.D. candidate researcher with my own unique creative neurodivergence through which I come to know the world, or what I call a kinesthetic-onto-epistemology.

### ***Theoretical Connections***

Theoretically, I blended Nail's kinetic-epistemological concept of "know-how" (Nail, 2021) and Barad's (2008) concept of ethico-onto-epistemology as relational material knowing to form my kinesthetic-onto-epistemological process. To create this framework, I generated material patterns of knowledge that emerge during each creative feedback loop with the content, theories, and literature included in my study. That is, I came to know through creating (Robert, 2020). As I showed in my literature review and through the inclusion of CRM principles (Berryman et al., 2015), aesthetic, hands-on,

imaginative, reflective, and creative practices are utilized in a variety of non-Western science-based epistemological traditions and STEM researchers are experimenting with these practices to experience and embrace epistemic pluralism. Berryman, Ford, Nevin, and SooHoo (2015) offer that CRM is indeed intended for research with disabled people by challenging the medical model that dehumanizes rather than acknowledges the range of cognitive differences that human bodies hold.

### *Using Creative Materialism in My Study*

I utilized Nail's (2021) CLO theory to theorize both the professional socialization process and the research process as material, sensory, and relational, but also as unmeasurable, turbulent, and unpredictable processes. For EHED educators to come to know how professional engineering socialization affects students differently, there must be an interdisciplinary, creative, culturally responsive framework in which these student participants could explore and share their experiences. Thus, I created an interdisciplinary space that was appropriate to collaboratively uncover and make visible the participants' experiences of the complex relationships between the kinetic operators in EHED and the students' own multiple social identities. CLO theory (Nail, 2021) provided a framework for me as a White female artist and Ph.D. candidate in higher education to make sense of my own cultural ways of knowing as a neurodivergent artist and researcher while working across disciplines.

## **Chapter Conclusion**

In this chapter, I provided the contexts that my study emerged from and with, but also how I experienced the various theories, methods, and research literature as feedback loops to create this hybrid document that is my dissertation (Nail, 2021). As the literature clearly shows, different methodologies are needed to better understand the personal subjective experiences of underrepresented engineering students as they are socialized into the culture of engineering. The research shows how positivism and its associated concepts like rigor, objectivity, and socio-technical dualisms in engineering culture, create barriers for those experiencing marginalization, exclusions, and oppression based on their social identities. I showed how my combination of culturally responsive methodological principles and Nail's contemporary loop object theory worked together to create an interdisciplinary space for my collaborative study in which to use arts-based methods. But I created this space also as an alternative to the hegemony of positivism in EHED and for me to self-interrogate my own academic and personal agendas that I brought to the research. I showed the historic kinetic operators that affect how different students with different intersecting identities uniquely experience their engineering education. By using the literature to show the historical and cultural relationships between engineering education and how these relationships affect student experiences, the student participants and I were able to collaboratively explore these kinetic operators' agency in the students' experiences of socialization.

## **Chapter 3: Methodology**

### **Introduction**

In this chapter I explain how I conducted my study within the context of my conceptual framework of creative materialism to answer my two research questions:

1. How do underrepresented engineering students experience socialization into the professional engineering culture during their education?
2. How did creative materialism function to answer research question one?

I was guided by research showing that the culture of engineering education is a barrier to increasing diversity and derives from the professional engineering culture (Cech, 2014; Seron et al., 2018). I was interested in exploring how underrepresented engineering students experience the process of becoming engineers and particularly wanted to use alternative methods to explore how they are socialized into the professional culture with its hegemonic positivist perspectives (Adams et al., 2011; Cech, 2013, 2014; Heybach & Pickup, 2017; Seron et al., 2018). As I created my research design, I was also guided by arguments from the STEM education research literature that states that students must be able to frame their engineering identity, problems, solutions, and practices in personal ways that include their own unique embodied experiences (cole & O'Riley, 2017; Kimmerer, 2013). I included the second research question to specifically examine how my approach addressed the gaps in the literature calling for more

interdisciplinary (Baille & Armstrong, 2013; Cech, 2014) and subjective (Moloney et al., 2018) methodologies to uncover the assumptions and habits embedded in EHED culture related to positivism and that provided the opportunity for individual students to share their stories of their experiences in their own voices (Beddoes et al., 2011). This approach was in keeping with culturally responsive methodologies (CRM), which are a component of creative materialism (Berryman et al., 2013a). To this end, I combined arts-based research methods with individual conversational interviews and personal diaries to create a three-method process for the participants to explore their experiences with me as collaborators. Later, I added a focus group in which all the participants met and together we discussed the findings.

Leavy (2017) states that qualitative research methods are valuable for exploring subjective experiences and how people make meaning, which was a good fit for my research aimed at uncovering student experiences of professional socialization during their engineering education. In ABR, the term *content generation* is used (Leavy, 2017, p. 197) to better reflect methodological differences with quantitative methods, which I used in conjunction with the term *data collection* to describe data created through interviews with the participants and their personal diary entries. I chose ABR methods as culturally responsive methods (Berryman et al., 2013b) that allowed the participants to choose the aesthetics, oral stories, poetry, drawing, painting, and photography that fit them best. I used this hybrid form of critical qualitative methods, in which the participants chose their creative processes because I believed it provided the broadest methodological field for



culturally responsive power-sharing with the student participants as co-creators (Nodelman, 2013).

My choice of CRM as a part of my theoretical framework radically influenced my research design and grounded my collaboration with the participants. I theorized the co-creation of the research as a dialogical relationship in which I as the primary researcher was learning about the engineering student experience with the participants themselves (Berryman, et al., 2013b). This approach was a contrast to traditional approaches in which I would think of myself as an outside expert with objectivity. Together, each of the participants and I marked the borders of our collaborative research by creating prompts that were appropriate to the individual participants, rather than using preestablished questions for interviews that were repeated across participants (Bloomfield, 2013). I used the new materialist term *intra-action* (Barad, 2007) instead of interaction to reflect the inseparable quality of the relationships between myself and the student participants, as well as with all the material artifacts entangled with our study; that is, I do not claim objectivity in my framework (Berryman, et al., 2013b).

Importantly for CRM principles (Berryman et al., 2013a), the cultural context of the study was bounded by our interdisciplinary differences as well as our combinations of various identities, some of which we shared. As a disciplinary outsider who is not trained in STEM, I remained aware that I was entering a culture that I was not a part of directly, which I explain more below. Instead, the culture of our small research community was grounded in our search for greater understanding of the larger culture of engineering that we all participate in. In this way, the culture that the research took place in, namely

between the four of us, emerged over time within the larger engineering culture that we were exploring.

As we moved through the research process, we generated content and folded this content back into our process for collaborative and individual reflection, analysis, and interpretation (Nail, 2021). This generated content marked the various points along our research journey, and we looped it back into our analysis process; there was not a linear progression through data collection, analysis, and then interpretation (Bloomfield, 2013). Rather, our generated content and findings were at once both new emerging points in our research while I also constantly analyzed and interpreted the findings as part of the entire process itself, that is, holistically (Nodelman, 2013). I entered these relationships with vigorous (Riley, 2017) respect for the participants' knowledge, experiences, time, and vulnerability. I used the CRM component of my framework to cultivate humility (Valenzuela, 2013) by constantly reflecting on and checking my perspectives, assumptions, biases, power, and knowledge as I moved through the project. Indeed, the CRM component was useful in reminding me I was not attempting any objectivity but was a participant in the study. I was building caring reciprocal relationships with the participants by being responsive to each of them as we moved through the study together (Nodelman, 2013).

### **Chapter Organization**

In the first part of this chapter, I describe my unique creative materialist approach and how I situated the theoretical elements for the creative materialist framework that I

used within traditional qualitative methods of interviews and diaries. That is, I show how my approach is different. I follow this brief overview of my methodological approach with a profile about me with transparent descriptions of my own identities and positionalities, including my identity as a member of the Mines community, which CRM requires (Bloomfield, 2013). As part of this profile, I show the theoretical process by which my conceptual framework of creative materialism emerged, which sets up the findings and discussions about how the methods produced new knowledge in the following chapters. In the second part of this chapter, I describe my research design specifics including explaining the location of the research, the Colorado School of Mines. I also explain how the three participants were recruited and provide detailed profiles of each participant, which have been reviewed, edited, and approved by them. I then describe how my participants and I intra-acted (Barad, 2007) and generated data and content (Nodelman, 2013). In the last part of this chapter, I explain how I analyzed and interpreted the data and content using the unique lens of creative materialism. I end the chapter with unique ethical considerations and the limitations of my project.

### **Creative Materialist Research Design**

#### **Synthesizing Qualitative, Arts-Based, New Materialist, and Culturally Responsive Methodologies**

Because I purposively theorized creative materialism to address gaps in the literature calling for interdisciplinary and subjective methods, which are unfamiliar in EHED research (Riley, 2017), I begin by explaining the theoretical similarities and differences with the qualitative and arts-based research methods literature which

Nodelman (2013) also used in her CRM dissertation project. Creswell and Poth (2018) describe the qualitative research design and the analysis process as a spiral contour (p. 185) which the researcher moves around during the research. They note that the research processes must be customized and that the steps along the spiral are often relational and may occur simultaneously; that is, it is a non-linear process. From conception through the conclusion of the research, they describe the researcher as in a relationship, or “touching” (p. 185) the various strategies of analysis iteratively. I use Creswell and Poth’s (2018) description to describe the motions of my creative materialist process as I sensed resonance between their analysis spiral with Nail’s (2021) CLO theory as a material kinetic and iterative process of knowledge generation. Creswell and Poth’s (2018) steps start with data collection and include:

- Managing and organizing data
- Reading and memo writing of emergent ideas
- Describing and classifying codes into themes
- Developing and evaluating my interpretations of codes and themes
- Representing and visualizing the data and content

Leavy (2017) agrees with Creswell and Poth (2018) that each qualitative research design must be unique to the project being researched, but also that there is a general format that qualitative research takes that includes the points contained in Creswell and Poth’s spiral and listed above. However, for arts-based research, Leavy (2017) offers additions that are not on Creswell and Poth’s spiral. Leavy’s ABR template (2017) also includes theory,

participant selection criteria and methods, and how content is generated as part of the ABR research design. However, according to Leavy, ABR designs typically also describe the creative practices to be used. I took a hybrid (Nail, 2021) approach and described my own creative practices that I used throughout the entire research process, including theorizing the conceptual framework described here. However, I left the student participants to choose their own creative practices, which reflects the inclusive holistic principles in CRM (Berryman et al., 2013a) and the emergent process of CLO theory (Nail, 2021).

Additionally, Leavy's (2017) ABR design template includes describing what form of representation the findings and interpretation will take based on the intended audiences. Based on my framework and that both CRM (Berryman et al., 2013a) and CLO theory (Nail, 2021) reject the concept of objectivity and representation as theoretically possible, I forgo the use of the term representation as Leavy uses it. Theoretically, CRM rejects representation as ideologically driven (Berryman et al., 2013a), while in CLO theory (Nail, 2021), the material looping process itself and the emerging content are not representations of the research, but material artifacts of the very process of coming to know. Because relationality is a grounding concept and material condition in CRM and CLO theory, I believe Leavy's (2017) consideration of the intended audiences during analysis and interpretation is already entangled within our process, not separate.

Both Creswell and Poth (2018), as well as Leavy's (2017) iterative, non-linear process of qualitative and arts-based research, resonate with Nail's (2021) CLO theory of

research as a process of iterative, material, emergent, and hybrid knowledge generation. Leavy (2015) also describes the benefits of this iterative, circular, or spiral approach when this framework is enacted from the beginning of the process, which for me included opportunities for my own self-reflexivity about my own experiences and insights during the research design process. This perspective helped me interrogate my power, agendas, and assumptions about engineering and Mines students before working with each student participant (Nodelman, 2013). Because ABR methods are emergent and open to unexpected surprises (Leavy, 2017), my research design balanced the strict academic requirements for dissertations and methodological standardization while also allowing for flexibility and changes during the research process, which is also reflected in CRM principles (Bloomfield, 2013); this flexibility proved crucial for all three participants as all three required a pause in participation due to their workloads, uncertainties with the subjective methods, and to care for themselves and their mental health during the semester.

My use of culturally responsive methodologies (Valenzuela, 2013) required prior self-reflection concerning the research problem, and the participants, but also my academic power and privileges before beginning the research and intra-actions with participants. But I also continuously returned to this framework through data collection and content generation, analysis, and interpretation. In this way, the ABR benefit of creating opportunities for self-reflection (Leavy, 2017) that is also contained in the iterative spiral motions of qualitative (Creswell & Poth, 2018) methods fit well with CRM (Nodelman, 2013). Like the contemporary loop object (Nail, 2021), the principles

of CRM (Berryman et al., 2015) state that knowledge is created iteratively and collectively through meaning-making with participants as the experts in their own knowledge. Together, we co-created the specifics of the study, meaning the research design was merely a starting invitation for collaboration (Bloomfield, 2013).

Additionally, in this first part of the chapter, I explain and describe the process by which creative materialism emerged and show the analysis process by which I came to understand my conceptual framework as a kinesthetic-onto-epistemology (Bloomfield, 2013).

### **Positionality and Transparency**

In this section, I transparently describe my own identities and how they shaped my conceptual framework of creative materialism, but also the study design, methods, and intra-actions with the participants and the data and content they generated (Denzin et al., 2008). I identify as a middle-aged, cis-gendered, heterosexual White woman from a working-class background, and I am a first-generation student; through the study, I uncovered I am neurodivergent and disabled as well. I hold both an insider and outsider status at Mines; I completed an MS degree in the Humanities, Arts, and Social Sciences (HASS) department at Mines and am currently an adjunct professor in the HASS department where I teach several sections of the required 200 level course Global Studies. An important experience for me was the suicide of a student in one of my Global Studies sections several years ago, which deeply affected me. While I did not know this student personally, as it is a large lecture course with more than sixty students, the roommate of the student who killed himself was also in my class. It was this experience

of accommodating and coaching the roommate through the remainder of the semester to successful completion that further drove me in my dissertation study to better understand how students experience the culture of extreme rigor. Additionally, my experiences as an adjunct professor were salient during data collection as the participants described their classroom experiences and intra-actions with faculty both in STEM classes and in the Humanities, Arts, and Social Sciences (HASS) department. I often interrogated my power as faculty as I intra-acted with the participants and they shared their experiences with faculty that impacted their learning and well-being. I transparently shared during interviews my own experiences and perspectives as faculty with the participants while remaining open and non-judgmental about their data and content that were critical of teaching practices that I employ like using visual presentations.

I am not a professional engineer and therefore can be considered an outsider to the engineering community in this context. Indeed, HASS as a department holds a marginalized status at the institution and is not organized as a separate college and has little autonomy. Along with my Master of Science from HASS, which was in the international political economy of resources, I also had two minors: Mining Engineering and a minor from the business department in Engineering and Technology Management. I applied to Mines after being laid off from a job as I wanted to continue to work in environmental compliance. As someone who loves geology, I have a deep affinity for the school, and because of the knowledge that emerged during my classwork at Mines, I became interested in sustainability. I also was a project manager for a mining engineering safety grant in which I managed the PIs, faculty, and student engineers on the project. My



experiences as a member of the Mines community are diverse, complex, and nuanced despite no formal training as a scientist, engineer, or mathematician. However, while I was not aware of my autism and ADHD until after data collection, I have been aware of my dyscalculia since fifth grade; I knew I could not do mathematics and seem to be unable to conceptualize quantities. However, while I theorized creative materialism and the conceptual framework for this study as epistemologically pluralistic, during the creation of the research proposal I was unaware of my neurodivergence and that all three participants would come to share this identity category as well because of our interactions.

While I shared overlapping identity categories like being female with the participants, my experiences of these identities differed primarily due to age and disciplinary differences; I am in my mid-fifties, and I am not formally trained in STEM but in the fine arts, liberal arts, and social sciences. I also was an outsider concerning some of the identities held by the participants as I sought to learn about and share their stories (Denzin et al., 2008). As a cis-gendered heterosexual woman who has not been required to think about these identities due to being socialized and living in a binary heteronormative society, I was a learner in the research with the two participants who identified as queer/bisexual. In terms of physical and learning abilities, I had my own unique experiences and identifications with these embodied phenomena that I was aware of. I had not been diagnosed with learning disabilities and had been a successful student through several higher education degrees. Identification with my physical abilities intersected with my working-class identity: decades of physical labor working in the

trades, including the professional painting work I describe below, resulted in arthritis and chronic skeletomuscular pain that is aggravated by sitting at the computer for long periods.

My working-class identity also came into play in how I conceived of the work of researching, as well as writing this dissertation, but also my conceptions about professional careers like engineering. I found that I tended to think in terms of labor hours and completing specific tasks, and often experienced imposter syndrome, which was a fear that I was not qualified or ready to do this research (Ramsey & Brown, 2018), despite my professional academic doctoral identity that emerged through completing a Ph.D. I also interrogated my first-generation student identity status during the research with the students as they described their own first-generation experiences. My gender identity as a woman differed from the participants' due to growing up in a conservative Catholic and sexist household with the traditional conceptions of gender norms that were prevalent in the 1970s and 1980s, however, some of the participants' experiences resonated with my own despite the age difference. As I describe below, gender was also salient to my identity as an artist growing up in contrast to my brother who was an engineer.

I now turn to my identity as an artist, which was deeply entangled with my choice of arts-based research methods for this study and my conceptual framework development. I became intrigued by the gender gap in engineering education while learning and teaching at the Mines' campus as I have experienced the social value dichotomy between STEM and fine art careers in which STEM is more highly valued. This socialization

began early. Because of my obvious creative proclivities as a child along with number dyslexia, or dyscalculia, I was funneled into the arts and away from STEM, while the opposite occurred for my brother who became a professional electrical engineer. I developed a mathematics phobia by fifth grade but was socialized to believe I could not do math and could not do science because I was an artist, not because of an undiagnosed learning disability. The research literature (Bix, 2013; Diekman et al., 2017; Leyden & Lucena, 2018) shows that there are historical gender identity entanglements with the disciplinary path students choose, which I suspect were also at play in my socialization.

As a lifelong visual artist, I knew I was primarily a visual learner (Nodelman, 2013). I theorized my experiences as a kinesthetic-onto-epistemological way of knowing and being, which in engineering culture (Riley, 2008; 2017) is not a valid way of knowing. I therefore theorized a supportive space that recruited participants with unique interdisciplinary and neurodivergent ways of knowing and being that allowed them to express and share their experiences (Beddoes et al., 2017; cole & O’Riley, 2017; hook, 1995; Kamali et al., 2016; Kimmerer, 2013, Kinloch & San Pedro, 2014) using qualitative culturally responsive methods (Berryman, et al., 2013b). However, theorizing this difference for the study created a context for me to explore the disciplinary boundaries and silos that are kinetic operators (Nail, 2021) that influence EHED but also support implicit biases against those without STEM degrees who teach and research about the engineering education experience (Riley, 2017).

While theorizing creative materialism and the methodological framework for this study, I reflected on my artist identity as more than a disciplinary or professional career

choice; to understand the world I am experiencing, I must create visual images (Nodelman, 2013). My earliest memories are of creating as a toddler. Before I could even read, I clearly remember coming home on Sunday mornings and immediately cutting the church bulletin up with my blunt safety scissors, then assembling and pasting the pieces of paper down on another piece of paper as collages. My mother enrolled me in private art lessons at the age of ten as I was drawing on the walls at home. In 1990, I earned a Bachelor of Fine Arts in drawing, painting, and photography in which I developed the skills that I learned in private art lessons. After college, for ten years I painted professionally in the interior design and construction sector creating custom residential and commercial murals and faux finishes that expressed my clients' identities and aesthetics. For much of this work experience, I was self-employed and had my own business. Indeed, most of my forty years of working have been outside of higher education.

I chose Mines for my MS to earn professional credentials for sustainability and environmental compliance work in conjunction with my career experience as an occupation safety coordinator. My employment history and experiences are mostly outside of the education sector and include experience in the retail, customer service, interior design, construction, and manufacturing sectors. My choice to pursue a Ph.D. in higher education came from a realization I had during my time working on campus sustainability at Mines that for the U.S. and the world to become truly sustainable, diverse perspectives must be present at the engineering decision-making table.

Additionally, I realized that sustainability also required transforming how engineers, the people who quite literally build our material world, were educated.

However, as a White heterosexual woman I was unable to see the racial, homophobic, disability, and other forms of exclusion in EHED until I purposively chose to do diversity and inclusion coursework during my Ph.D (Berryman, et al., 2013b). I am still coming to know how I benefit from whiteness (Ahmed, 2007) and how I move in and contribute to systemic forms of oppression like racism (Bloomfield, 2013). I also have come to know that this dynamic critical self-reflective practice will continue throughout my lifetime. I am also conscious that I am a White person using Kaupapa Māori, an Indigenous theory, as part of my framework (Bloomfield, 2013). However, I chose CRM because of the balance Kaupapa Māori principles provide to the Western academic theoretical proclivities deeply embedded in me through my extensive education (Berryman et al., 2015) and it was immensely valuable in this way. As I am primarily a disciplinary outsider to EHED, which research shows in a closed system that is often myopic in assessing cultural barriers to diversity (Riley, 2008; 2017), I argue that I offered a different perspective on the continued lack of diversity in EHED. Indeed, my identities, and particularly the discovery that I have autism and ADHD, were kinetic operators that directly affected the study and the participants' understanding of themselves and their experiences (Nail, 2021).

## **Methods**

### ***Location and Time Frame***

The Colorado School of Mines (Mines) is a small public engineering university located in the suburbs of metro Denver. The small campus is snuggled up against the foothills of the Rocky Mountains in Golden, a small historical tourist town. Established in 1864, the campus has a well-established institutional saga (Clark, 1972) as a prestigious and exclusive engineering-focused institution in Colorado, despite recently adding some non-engineering degree programs like biochemistry to especially attract more female students. Mines' reputation within Colorado is that of an extremely difficult school in which students often develop mental health problems. However, the school is relatively unknown in the U.S. outside of Colorado other than in the international and extractive industry professions of petroleum and mining engineering fields in which Mines graduates are highly sought. As part of its prestigious identity, Mines achieved R1 status in 2022 during the data collection period. The timing of the publication of this dissertation coincides with the 150-year celebration on campus in 2024 that the institution has been preparing for.

I chose this location because of my established relationships and my depth of understanding and experience of its ongoing campus diversity, inclusion, and access (DI&A) efforts that made it receptive to this study (Diversity, Inclusion and Access, 2019). During my years as both student and faculty, I built strong relationships across the campus with administrators, HASS and STEM faculty, and students. Mines President Paul Johnson stated at the 2021 CDHE diversity conference in Colorado that their diversity goals include making Mines a more attractive and accessible engineering school for students from diverse backgrounds, but he recognized not all Mines student

experiences are not the same (Equity day of dialogue, 2021). I participated as an adjunct faculty in the early iterations of diversity work on campus from 2016-2017. The campus continues to build its diversity efforts, which include faculty research on engineering education, skill and awareness building for faculty as professional development, themed learning communities that provide a cultural place and fit for underrepresented students, and Mines continues to build on their well-established multicultural engineering program (MEP) (Multicultural Engineering Program, 2022-2023). The Trefny Center (Trefny Center, 2023) offers faculty development workshops that challenge faculty to critically examine pedagogical, epistemological, and cultural assumptions around rigor, which I have attended and found valuable. Ethically from a CRM perspective (Berryman et al., 2013b), I think that Mines provided a setting and culture in which my study and its findings will be appreciated in terms of the insights into student experiences that it provides. My experiences as an adjunct faculty who experienced students with mental health crises also inspired me to conduct my research with Mines students as the school has been implementing mental health support initiatives to better support students who are struggling emotionally.

The timeframe for the study was from December 2021 to March 2023. I recruited participants at the end of the fall 2021 semester, and interviews were conducted from January 2022 through May 2022. I conducted data collection and content creation with the participants primarily during the 2021-2022 academic school year, however, due to my unexpected discovery of my neurodivergence, the research process was extended into the 2022-2023 school year. Both Nodelman (2013) and Bloomfield (2013) noted that

when conducting culturally responsive dissertation research, one should be prepared for the unexpected and that plans may change.

I added a focus group (Chauhan & Sehgal, 2022) method to the data collection based on the emergent insight that the individual participants wanted to meet each other and I wanted to create a community of support for all four of us (Berryman et al., 2013b). About halfway through data collection, I asked each participant if they would want to meet the other participants and all three agreed. We felt that there was value in the participants meeting each other, discussing the findings together, and collaboratively making recommendations. The focus group provided an opportunity to verify and triangulate the results of the study with the participants and add further data to better understand the culture that the participants experienced in their engineering education (Parker & Tritter, 2006). The focus group provided an opportunity for the three participants to interact and generate new knowledge collectively (Chauhan & Sehgal, 2022), which fit with the methodological framework of this dissertation project in which power is shared with the participants (Berryman et al., 2013b). I asked several questions to facilitate the conversation that focused on three goals: getting their collective feedback on the findings for Chapter Four and how they felt about their participation in the study; determining that each participant's privacy was maintained in the findings and that they were not able to identify each other; and providing an opportunity for the participants to make their own recommendations to the school based on the findings.

Through this conversational practice, the focus group provided a new data collection method that complemented and built on the individual data collected earlier.



One participant was able to accurately identify the other two participants, so I further removed identifying details from each of the participants' profile to protect their privacy. We discovered that all three participants knew each other, which affected the dynamics and conversation during the focus group as the participants discussed their pre-existing relationships and knowledge of each other's experiences (Chauhan & Sehgal, 2022). I considered these dynamics as I observed the interactions of the participants during the focus group and acknowledged that each participant had different thresholds for sharing with a group versus in an individual interview. I moderated the focus group with a recognition that consensus was not reached when we discussed specific experiences that the participants shared, like the variety of relationships they had with their male peers and faculty. Instead, I noted that each participant had different interpretations as to why they perceived situations in the culture of engineering differently. I included these differences in the findings in Chapters Four and Five.

However, the duration of the study was extended due to the emotional and psychological impacts of recognizing the emergence of my own neurodivergent identity that resulted from a final interview with one participant who shared her autism diagnosis in late April 2022. Berryman, Ford, Nevin, and SooHoo (2015) noted in their discussion of CRM and neurodivergence education that it is important to resist objectivity and instead establish and develop interdependent relationships and embrace different ways of knowing, including neurodivergence. In this way, my emergent new identity was a kinetic operator (Nail, 2021) that directly shaped the study process and outcomes.

Because of this impact, the analysis and interpretation of the data and content were delayed several months, and the focus group was not held until March of 2023.

### *Recruitment of Participants*

I recruited three undergraduate student participants through the vice president of Student Life who forwarded the study description to students through email (Appendix A). Three students responded to the email, and I recruited all three after conducting a screening (Appendix B) through Zoom with each individually in December 2021 as each met the selection criteria. I limited the participants to three so I could intentionally and ethically develop long-term relationships and a deeper understanding of each student's history, culture, and worldview following CRM principles (Berryman et al., 2013a). I included as potential participants all students from a variety of gender, racial, ethnic, class, sexuality, religious, immigration status, international, and disabled identities. I recognized with this research that all students experience the effects of EHED socialization (Seron et al., 2015), that these students are affected differently (Riley, 2013), and that there was value in seeing these differences (Kinloch & San Pedro, 2014).

### *Participant Selection Criteria*

I provided several criteria (Appendix A) for participants based on the purpose and goal of my study with my culturally responsive methodology. First, I recruited students who were interested in exploring their social identity-based experiences of socialization in EHED. In a pilot study, I found that the intensity and power of the creative materialist approach combined with personal work on social identities can be emotionally rigorous

and, if not prepared, participants can become dislodged and stuck in the liminal space of coming to know. Therefore, I reasoned that potential participants must consciously be ready to take on this challenge. Secondly, I requested students who were comfortable being creative. Given the hegemony of positivism in EHED (Riley, 2017), I reasoned that participants who were not comfortable with creativity could find these methods stressful (Moloney et al., 2018), and indeed, all three participants did question the subjective approach. Another criterion for participation was, given the culture of rigor, that the participants felt they had the time to participate. I financially compensated each of the student participants for their time and personal contributions with \$100 VISA gift cards at the end of data collection during the final interview. I offered this payment as a form of respect and gratitude for their vulnerability, generosity, and sharing, as well as the additional time our study took from their already busy workloads.

### *Participant Profiles*

These profiles were approved by the participants after I made minor revisions. Each profile contains some specific demographic information and the social identities that each participant claimed and explored in the study, however, I left out some details to protect their privacy. The profiles also include information on their families that set up the shared findings in later chapters of how their families shaped their experiences as students at Mines. I also include a brief narrative of how each student arrived at Mines and describe their STEM academic identity. By providing these details about the participants before sharing the overall findings, I hope to set the stage for each participant's story to emerge and to show how their experiences of the culture were

unique to them, while also showing how there were similar patterns of experiences between all three participants.

### *Esperanza*

Esperanza was in her sophomore year at Mines during data collection and content creation in the winter of 2022. She identifies as Christian, female, heterosexual, multiracial, and Hispanic. Racially her family legacy includes her mother who is Swiss/White and her father who is African/Black/Caribbean, and Indigenous/Caribbean, with all her grandparents immigrating to the U.S. from the Caribbean and Europe. She does not speak Spanish, which she shared sometimes creates feelings of marginalization among some Spanish-speaking students. She shared that Spanish was lost as a family language as her immigrant grandmother was advised by educators to not speak Spanish at home, which was intended to help her son assimilate into the U.S. Esperanza participated in several identity-based student organizations on campus. She chose the alias Esperanza, or hope in Spanish, from a favorite childhood book about a Mexican girl who encounters adventure and adversity. When I asked her during the first interview why she choose the name, she said, “[I]t’s like going into the unknown, hoping things will turn out... something good is going to happen, even though you don’t know what it is”. She comes from a creative family of musicians and Esperanza plays multiple instruments and she listens and plays music to help with her anxiety and stress. Esperanza was diagnosed with a physical disability before attending college. This disorder causes nerve pain that impacts her extremities like her hands and feet, which affects her ability to walk, write, and do lab work. Without a break from her busy schedule and stress, she becomes

physically exhausted and needs rest to recuperate. She also is affected by asthma and anxiety. She chose not to disclose any of these traits to the school nor did she seek accommodations as she felt that none could help her with STEM coursework. After the interviews, Esperanza became aware that she might be neurodivergent but did not identify as having learning disabilities during data collection. However, by the focus group, Esperanza had an evaluation appointment for a formal assessment with a neuropsychologist. Esperanza identifies as a first-generation student despite her parents having attended college at two Colorado regional comprehensive universities. She explained that as a minority and first-generation students, her parents received an abundance of guidance and assistance through their college experiences and did not come away fully understanding the higher education systems and bureaucracy, and therefore are limited in their ability to guide her in her experiences at Mines. She is the only person in her family to attend an engineering school. During data collection in the winter of 2022, she worked three different on-campus jobs to help pay for her education.

During the orientation interview, Esperanza described herself as interested in engineering in high school. She shared, “I had a fascination with roads for some reason, I thought roads were really cool”. However, she clearly remembered encountering sexism early in her education and recounted a story that as a child she voiced her desire to be an astronaut at school and was told by a boy that girls cannot be astronauts. This challenge impacted her so much that she set that interest aside and became interested in civil engineering. Esperanza was recruited from her Colorado high school during her junior year to attend Mines’ summer bridge program. Esperanza expressed in the orientation

interview that she has great affection for the Mines community because it included people with similar interests and passion for engineering, especially other women and racial minorities.

### *Creek*

Creek is a cis-gendered female student who was in her senior year during the interviews and data collection period in the spring semester of 2022. She graduated in May of 2022 and went on to graduate school. Creek, who chose her alias from a favorite video game character she created, identifies as queer/bi-sexual and a person of mixed racial ancestry. Her parents are both immigrants to the United States who are now U.S. citizens. Her father is of South Asian and European ancestry and her mother is European. While Creek's parents are college educated, she identifies with first the generation college student issues as her parents were not familiar with the U.S. system of higher education as Creek entered college. However, complicating her experience as an underrepresented student in engineering is the fact that she was socialized since childhood into the culture of engineering as both her parents have engineering degrees and work in engineering education and industry. Creek shared that their expectation was for her to major in a STEM degree in college; other disciplines were not an option despite her love of writing. Creek felt she received more rigorous preparation for college from her parents than her U.S.-born peers and was prepared to work harder to succeed in STEM as a woman of color and child of immigrants. Her parents met at university in Britain and later immigrated to the U.S. where Creek and her younger brother were born. Creek's parents both have advanced STEM degrees from the British education system,

which according to her parents is more rigorous than U.S. schools. Her father is a professor of mechanical engineering and theoretical physics at a rural Colorado institution of higher education. Her mother works in the computer science industry. Creek wants to follow in her dad's footsteps and become a college professor.

Because of her upbringing, during this study, Creek wrestled with how her own experiences at college were similar or different to what her parents prepared her for. She described her relationship with her father as often one of "talking shop" and his influence on her expectations was pronounced in Creek's data and content. Creek is a gifted mathematician and logical thinker with a strong confidence in her mathematical abilities, though she recognized she struggles with memorization and had an aversion to disciplines like history that she perceived required memorization. In the orientation interview, she described her abilities. "I was really good at math in school. It was really something that just clicked for me. It was just easy." Creek was diagnosed with an anxiety disorder that she explored during our research. She also came to identify as neurodivergent after I shared my diagnosis with her though she decided not to get a medical diagnosis due to the stigmas that she felt could negatively affect her future goals. She explained that she was transparent about her mental health experiences with peers and others at Mines as a way of normalizing mental health issues in STEM because she was conscious of the stigma about mental health issues in engineering. Because of her on-campus student job in which she worked with her peers, Creek was aware of the tenuous mental health status of other students, which made mental health an area of advocacy for her. Creek also shared that her gender and her sexual identity as a queer

woman in a relationship with a heterosexual man were also salient as an area of marginalization that she experienced, though her sexual identity is still not completely clear or static for her.

### *Eilidh*

Eilidh identifies as a cis-gendered, queer/bisexual, White woman who grew up in Utah and Colorado. She completed high school in a small rural town just outside the Denver metro area near where her mother and her younger brother currently live. She chose the alias Eilidh (EE-lee) because it was a nickname given to her by her father. Eilidh was in her junior year of college during data collection in the winter and spring of 2022 and turned twenty-one years old during this period; she graduated in the spring of 2023 and was accepted to a master's program. While some of her older relatives attended college, she does not have generational knowledge of institutions of higher education. For this reason, she lived in a first-generation student-themed learning community in the residence halls during her first year at Mines. She is also from a low-income and working-class family. She held multiple on-campus jobs to help pay for school and to provide for herself. Part of Eilidh's stress at Mines included balancing her lack of financial resources with needing formal accommodations from the institution for her disabilities, which required medical documentation she could not afford. Eilidh was diagnosed with ADHD during her freshman year of college, and later a physical disability that causes constant chronic pain and her joints to pop and dislocate. This disorder affects her physical mobility, strength, and endurance. Holding the same position for long periods, whether sitting or standing, causes her pain. She also suffers from swollen and



cold fingers, bruising, and is losing her sight. She shared that often she can barely get out of bed and often needs time to recover from exhaustion. These physical differences are invisible to most people outside her circle of friends who know her and who accommodate and support her. Her physical disability is a degenerative disorder in which her symptoms will worsen over time, which she contemplated during our study as she reflected on the physical inaccessibility of the Mines campus, which is tucked in the foothills of the Rocky Mountains and is extremely hilly. Eilidh was also aware that she has dyscalculia, or number dyslexia, which makes mathematics a challenge for her despite her comprehensive understanding of the associated mathematical concepts and processes. To compensate for errors in her work, which includes transposing numerals, she must spend extra time to confirm her homework and assignments are accurate. She also has memory issues and aphantasia, or the inability to visualize things in her mind. She explained that she does not think in images or words but must think out loud through speaking. Eilidh was the participant who decided to get an autism diagnosis during the data collection period, which she shared with me in her final interview. In response, I read an article about the effects on adult women receiving an autism diagnosis (Zener, 2019) and it was through this process that I came to realize I was also autistic. Eilidh's queer/bisexual identity was salient during her data collection as she explained the various stigmas within the LGBTQA+ community about her currently dating a heterosexual male student. She was a strong advocate for members of this community and women in STEM and was particularly concerned about the safety of transexual students and sexual assault

on women. As a White student from a conservative family, Eilidh was eager to learn and understand the experiences of students of color and to be an ally.

Because of her various disabilities, Eilidh chose to go into STEM so she could research, understand, and treat others with these disorders. She shared during the orientation interview, “I want to know how I can help people.” She stated she has always loved her science classes like geology, biology, and chemistry and learned the subject matter quickly, often confounding her high school teachers who suspected she had ADHD. But she also enjoyed and excelled at her liberal arts courses like history and languages. Due to their low economic status, her mother encouraged her to pursue a STEM degree because it would pay better than her initial interest in becoming a linguist. By middle school she decided to pursue chemical engineering after a high school course in biotechnology, stating in the orientation interview, “I knew I wanted to be in that world”. Eilidh was recruited to Mines when she received an application from the school in the mail due to her strong high school STEM test scores. She explained that with the offer of a financial scholarship, the choice was easy for her to make. Due to her dyscalculia, she never expected to attend a prestigious engineering school like Mines, whose reputation was well-known to her family. Despite her passion, grades, and professional focus, Eilidh admits to experiencing imposter syndrome when she arrived at Mines. However, this imposter syndrome has receded for her through hearing stories from other students about their struggle, particularly with mathematics, and making it to graduation in May of 2023. She felt confident in her STEM identity and that

academically she belongs at Mines, while she also accepted that she would never be the top student due to her neurodivergence.

### ***Early Intra-Actions and Rapport Building***

All three students met the participation criteria, and after conducting individual Zoom interviews with each, I formally invited them to participate in the study. I emailed the informed consent form for them to review (Appendix C), and we schedule each of their individual orientation interviews (Appendix D) in early January at the start of the spring 2022 semester when they signed the consent form. During this orientation meeting, we discussed the prompts and research design for their participation in the study. All the participants chose to meet in person for all four interviews. During the orientation I provided the context of the study with the two research questions, the project's purpose and goals, how and why ABR methods provided a different method for our study, and an easy-to-understand description of my theoretical frameworks of CRM (Berryman et al., 2013a) and CLO theory (Nail, 2021).

To create the orientation protocol, I drew on the CRM principle from Kaupapa Māori called *whakawhanaungatanga*, which I introduced in my theory section of Chapter Two (Berryman et al., 2013a). I relied on this protocol to share my own social identities in relation to each specific participant and explained how my own perspectives might shape the study; the participants were clear that I taught as an adjunct professor in HASS and that I considered myself a disciplinary outsider without experiences of the Mines STEM curriculum they experience. My purpose with this orientation was to intentionally

generate mutual responsibility between the participants and myself. I found these elements from CRM (Berryman et al., 2013b) were crucial for moving out from under the hegemonic pressures associated with positivism's objectivity that loomed in the background of our research in which the participants were unsure of the subjective methods. I reminded myself that building rapport and a relationship was a necessary part of my framework rather than attempting to maintain a sense of distant objectivity (Berryman et al., 2013b), and I actively built a new shared culture of care among us. I also used the orientation to clearly invite collaboration and power sharing in creating the details of the study in ways that were culturally responsive to the individual participant's various identities (Nodelman, 2013). I worked with each participant during their individual orientation interview to collaboratively decide on the focus of their participation and how they preferred to generate content by asking the following questions:

1. What do they hope to gain from the study? What do they want to know about their educational experience?
2. How do they want to intra-act with me to generate content?
  - a. What type of conversation do they feel most comfortable with (i.e., in person, written, online/remote, formal, or casual)?
  - b. How long do they want our intra-actions to last based on their workload?
  - c. Do they desire informal intra-actions outside our schedule, like check-in phone calls when they have something to share or to discuss concerns?

- d. What form of self-reflection do they feel most comfortable with and how often do they want to share these insights?
- e. What type of creative practice do they want to use? Do they need materials? How often do they want to create content and share it with me?

I used their answers to the first question about what they hope to gain from the study to collaboratively create conversational interview prompts with them, which remained flexible as we moved through the process and looped in each round of content, which I describe below.

### ***Organizing and Managing Content***

I managed the data and content both digitally and in material forms, which I realized through the study was necessary due to my neurodivergence (Woods et al., 2018). Within a new digital dissertation research folder, I created individual secure folders to manage all the informed consent forms, literature, recordings, transcripts, creative works, and other forms of content on my OneDrive. I created a folder for each student participant using the alias name they chose when we first met. I kept private identifying information in a separate online storage cloud folder for security. I also created individual folders for my own content, memos, analysis, and interpretative documents that I generated throughout the research process. I created a standardized naming protocol for each document using the date and the method, like diary entries or creative content. I also used a paper artist journal for memo writing but also poetic and self-reflective writing as I managed and analyzed their data and content, and this practice

continued to the very end of writing the final dissertation (Bloomfield, 2013; Nodelman, 2013; Valenzuela, 2013). While writing the various components of the dissertation on the computer, I often would find I hit a wall, meaning I no longer felt that composing digitally was fruitful. At these times, I turned to other methods that I now realize are tied to my ADHD and autism, my kinesthetic-onto-epistemology, or my own hybrid ways of sensing/creating/being/knowing (Taylor et al., 2019).

To this end, I also organized and analyzed the participants' content and data on my office wall visually and in three-ring binders. After the orientation interview, I asked each participant to send me a few photographs of themselves so I could visually see them as I worked with their data/content. I organized the photos they sent into a single digital photo collage which I then printed and pinned to the wall. After I transcribed their interviews using Otter.AI. software, I would transfer the key patterns, phrases, and ideas in their content and data as quotes onto colored index cards and pinned these to my office wall around each of their photocollages. I created a three-ring binder for each participant that was color-coded to match the color of the index cards that I pinned to the wall. I printed each interview transcript and inserted it into the three-ring binder along with printed copies of their poetry, diary entries, and visual artwork.

### ***Data Generation and Content Creation***

The purpose of our study was to collaboratively come to understand how these students experience the culture of engineering while grounding the process with culturally responsive methodological principles that fit each student participant. I relied

on the principles of CRM that balanced the needs for standardized dissertation practices with the individual needs of the participants (Nodelman, 2013). As I covered above, ABR methods (Leavy, 2017) are also open-ended and emergent and resonate with CLO theory's (Nail, 2021) focus on research as a process that is dynamic and intra-active. To this end, I proposed three methods for generating content with the participants that fell along a spectrum from casual and unstructured to formal and structured (Leavy, 2017): conversational interviews, self-reflection in their diaries, and creative practices. Importantly, each participant had the final say on the inclusion of any of their content and how they were portrayed in the dissertation (Berryman et al., 2013b). Cardno, Rosales-Anderson, and McDonald (2017) showed how culturally responsive methodologies can combine and mesh different methods that allow for triangulation and evaluating trustworthiness in qualitative research, which we also used in our process.

#### *Conversational interviews*

Interviews have been used in higher education research to better understand individual and local experiences (Kellam et al., 2018; Kellam et al., 2015; Ozkan et al., 2018). As the purpose of this study was to better understand underrepresented students' experiences, including their inner perceptions and feelings in all their complexity, I chose interviews as an appropriate tool for gathering data (Zhang & Wildemuth, 2009). I used unstructured interview methods for data collection (Jones et al., 2014) as this method was culturally responsive by including the participants in the creation of the interview agenda items as equals (Nodelman, 2013). Our unstructured interviews included open-ended, in-depth, and intensive conversations in which I spontaneously generated questions in

response to the participants' narration (Zhang & Wildemuth, 2009). Unstructured interviews are a dialogic approach (Jones et al., 2014) in which the spaces between listening and speaking generated vulnerabilities for both the participant and me, revealed our feelings, and built a sense of trust and rapport between the student participants and myself (Kinloch & San Pedro, 2014). With this method, I did not impose strict time limits for our meetings, and while I did create documents with prompts, I let the participants lead the conversations with what was salient to them. This emergent quality of unstructured interviews also fits with my theoretical framework of the contemporary loop object (Nail, 2021) in which knowledge is iteratively and relationally generated through the material interactions between me and the participants.

For the initial orientation interviews in early January 2022, Esperanza and Creek chose to meet at the student center on campus in small study rooms on the main floor across from the school's bookstore. As the semester was just starting, there were few people around, which provided privacy. However, the orientation with Eilidh took place when the semester was underway, and the student center became more active, and I was concerned about protecting her privacy. To this end, the Eilidh reserved a small study room in the school's library. All the interviews with each participant took place in small study rooms at the library from that point on, with the participants reserving a room. While initially I indicated each interview would be about an hour in duration, often the interviews lasted longer, with Eilidh's interviews usually lasting over two hours. To balance the opportunity for all three to share equally, I offered Esperanza and Creek that the interviews could be longer, which they accepted. To this end, we generated twenty-



seven hours of interview data collectively, with another two-hour focus group the following March 2023 to collaboratively review the findings. I reserved a classroom in the basement of the HASS building for the focus group to maintain the participants' privacy.

As the interviewer I was a learner (Berryman et al., 2013b) with a sympathetic interest in the participants' lives as underrepresented engineering students and therefore had to be responsive to individual differences between the participants as well as changing situations during the research and interview sessions (Zhang & Wildemuth, 2009), which included our physical surroundings. For example, I struggled to remain focused during an interview with Creek as piano music traveled through the heating system at the library and into our small study room. From a new materialist perspective (Barad, 2007), the building's infrastructure, the piano and sound waves emanating from it, and the person playing the piano were all entangled in our study at that moment (Barad, 2007).

This unstructured approach during interviews required careful listening by me, an ability to let the conversation flow and allow the participants to raise new topics or take the interview in different directions, while I kept the interview focused on the issues under study and maintained an appropriate pace (Zhang & Wildemuth, 2009). As unstructured interviews required me to listen closely and be reflexive and responsive, I used audio recordings to document the conversation (Jones et al., 2014), which I later transcribed after each interview using the Otter.AI online application. I sent copies of the

transcriptions to each of the participants to review for accuracy and their approval after I made minor corrections for accuracy and to maintain their privacy.

Rather than predetermined questions that were used across participants, I created interview prompts based on what the participants had previously shared as guides for our conversation (Berryman et al., 2015). These prompts centered on the participant's unique experiences and their identities, backgrounds, and their goals with their participation. These prompts provided a level of consistency across interview sessions where I built on their previous answers and the participants' stories to find emerging patterns (Zhang & Wildemuth, 2009). I used the agenda to ask open-ended background, descriptive, and probing questions in which I avoided being directive or judgmental. My questions were phrased to consider my power and privileges as an older White heterosexual female and adjunct faculty, as well as the identities of each participant and the influence of their families, which emerged in the data and content (Bloomfield, 2013). For example, while we all identified as female, I sensed my generational differences with the participants' experiences as young females in higher education compared to my experience in the late 1980s in a different discipline, the fine arts.

As a starting point for our culturally responsive interviews, I created a list from my research on the empirical literature on how underrepresented students experience the culture of engineering (Berryman et al., 2013b). I also looped in the cultural kinetic operators I theorized (Nail, 2021) of positivism, extreme rigor, and the socio-technical dualism. I presented this list to the participants during the orientation and explained they were merely launching points for our future unstructured interviews. I then asked each

participant if they wanted to explore any of these elements; each student identified a few items from the list, but not all, as starting points. However, as the interviews progressed, the participants also used these items and the prompts in their diary entries and creative practices. While initially this list was formal, as we moved through the process, we returned to the primary points of each item in less formal ways, such as conversations about classroom experiences and how they learn, where they feel supported and by whom, and where and when discussions about differences like race or gender take place. A particularly salient item was the concept of visibility, which is a theme in the Chapter Four findings. Below is the list I presented to the participants.

1. The culture of rigor and extreme difficulty like the weeding out process and concerns about your competency as an engineer.
2. The narrow focus on technical issues and lack of space and time for political, cultural, and other non-technical aspects of being an engineer, which is referred to as socio-technical dualisms.
3. Learning styles and preferences for how you learn best, but also what you struggle with.
4. Your various identities in relationship to your major and/or department.
5. Your experiences of feeling invisible or hypervisible
6. Your support networks both on and off campus, including family, professional organizations, and mentors.

I included a seventh item that offered an opportunity for the participant to explore any historical aspects of engineering education and professions they had related to the culture;

however, none of the participants had historical interests as they expressed that they did not know the history of engineering.

### *Diaries*

I proposed that each student generate data through the self-reflexive use of diaries in whatever form was appropriate for them; Esperanza and Eilidh opted to keep hand-written diaries, and Creek chose to write on her computer but also to do audio recordings, which she then transcribed using the software. I asked the participants to follow the research (Sheble et al., 2009) that shows that solicited research diary entries used for self-reporting over time, which relies on successive entries, are valuable methods for participants to share their points of view, observations, and reflections. Research shows that one strength of diaries in research is that they provide access to internal and usually invisible or unavailable data to researchers. This invisible data includes ordinary events that may be considered too insignificant to share in interviews; indeed, each participant questioned and asked for confirmation that this subjective data was requested. I informed the participants of the purpose and value of their diaries to the study. Research (Sheble et al., 2009) also shows that the act of sequentially reflecting in a diary stimulates awareness and is well suited to temporal studies that explore phenomena over time, like underrepresented student experiences of their socialization into engineering during the school year. The engineering education research shows that processes of self-reflexivity, which can occur through autoethnography, diaries, and journals (Haverkamp et al, 2019), benefit engineering students by increasing their understanding of how they are socialized into engineering culture (Seron et al., 2015), how their various complex social identities

intersect with the engineering culture (Haverkamp et al, 2019), and by helping them understand their profession better by revealing their assumptions (Moloney et al., 2018). I asked participants to use both interval-contingent, that is weekly entries, and event-contingent diaries entries, which are entries made soon after salient events occur related to the student's participation in the study. To reduce self-censoring and share power, I asked the participants to select which entries they shared with me and how they desired to share their entries (in-person or digitally). We then used these entries to generate agenda items for subsequent unstructured interviews (Zhang & Wildemuth, 2009) in which the participants shared why they chose to share those entries and how these entries related to previous interview sessions, other diary entries, and their creative content. The findings in Chapter Five show how the diaries were used in conjunction with the other methods.

#### *Creative Practices*

In my study, both the participants and I used creative practices. Arts-based research methods are often used in conjunction with qualitative methods like interviews to build understanding and disrupt dominant narratives and uncover biases and assumptions, which was a good methodological fit for my study (Leavy, 2015). Arts-based research methods use aesthetic understanding and multiple ways of knowing (Barone & Eisner, 2012) and therefore provided a culturally responsive method for data collection in addition to unstructured interviews and diaries (Nodelman, 2013). The term content generation is often used in arts-based methods instead of the term data collection (Leavy, 2017). In this study, I generated content in response to my interactions with the students using my own established arts-based methods, but I also used my creative

practices like poetic writing and mind mapping for analysis and interpretation (Leavy, 2015). As a form of power sharing and cultural responsiveness, participants were free to choose whatever creative modalities were comfortable or interesting to them to generate content. All three participants used poetic writing while Eilidh and Esperanza also generated visual works using drawing, painting, and photo elicitation. During the orientation, I explained how I used my arts-based research methods of poetic writing, drawing, photography and collage, and oil painting to generate data/content and for analysis and offered to share these works with the participants; however, none asked to view my work. I also used my own visual practices and poetic writing while interpreting the findings, organizing the dissertation, and identifying new knowledge.

### ***Content Saturation***

Content saturation as qualitative research criteria rest on repetitive patterns that can be generalized as findings across participants (Leavy, 2017). Because of the emergent (Nail, 2021) reflective methods used, in theory, saturation could never be achieved. That is, the transformational insights the participants and I gained are part of a continuum of our growth and self-understanding. Additionally, in my study, each student participant was unique, and therefore a threshold for repetitive patterns as saturation was identified in each student participant's generated content. While I remained open to similarities between each student participant's content, I did not use it as a criterion for saturation. Because of my creative materialist framework and its emergent process, I determined we reached content saturation when each participant's responses confirmed and reiterated previous interview prompts, showing how they developed their own emergent insights

and grasped how they were transformed by their participation. However, the borders of generation-analysis-interpretation were constantly blurred with our iterative process (Leavy, 2015; Nail, 2021) as I looped in previous responses to prompts in the development of new but related prompts, which is evident in the findings.

### *Analysis*

In this section, I describe how I used creative materialism for analyzing the content generated by both me and the participants. I include by what process I uncovered patterns and how I sorted and organized the data and content. In qualitative methods, this is typically done with coding and creating themes that are then interpreted to create meaning in the findings (Creswell & Poth, 2018). While I previously showed the synergy of Creswell and Poth's (2018) analysis spiral and Leavy's (2017) iterative and inductive arts-based methods, I believe Nail's (2021) CLO theory and CRM troubling of Western ways of knowing (Berryman et al., 2013b) required a different theoretical approach to sensing patterns than reductive coding and themes. This included that I continued to work with the individual participants as I generated a summary document of their individual findings and profile, which I emailed to each for review. Subsequently, I met with the participants after they read their findings to get their feedback. After receiving positive feedback from each participant and their approval to use their individual findings, I then analyzed their findings together by looping and folding individual data and content together into Chapters Four and Five. I kept the analysis and interpretation process flexible and allowed participants to ebb and flow in their engagement as they desired or needed.

### *The Emergence of Creative Materialism*

In Nail's (2021) CLO theory, knowledge production through research includes more than just the experiment itself. The carefully cultivated emergence of my framework required over a year of visual creative studio work using photography, painting, and drawing in conjunction with rounds of dissertation literature reviews, memo writing, free writing, poetic writing, and handwritten and drawn journal writing (Nodelman, 2013). It was through this iterative reflective process in which I ritually marked, reflected, and witnessed my creative coming to know (Bloomfield, 2013) using Nail's CLO theory (2021) from which creative materialism emerged. But through this process, I also marked down the insights into my own social identities that I was required to interrogate under CRM (Bloomfield, 2013). As a life-long visual artist since childhood, my creative practices and identities have waxed and waned while taking a variety of forms over the years that, in reflective hindsight, I had to excavate as my framework emerged; I had to know myself before entering the research field with the participants (Berryman et al., 2013b). I used an arts-based research method for my Master of Liberal Studies thesis project on Orientalism (Said, 1978) in U.S. visual culture following 9/11 and have used ABR methods for several research projects related to my Ph.D. coursework and dissertation research (Robert, 2020). Memories of these myriad experiences emerged and blended as I oil painted for the first time in about fifteen years as I theorized creative materialism, and my invisible neurodivergence. While painting, I kept a handwritten journal in which I drew, recorded these insights, did concept mapping, and wrote poetry to help put words with the images, theories, and the various techniques



with which I played (Figures 1 and 2), which is a culturally responsive practice in dissertations (Bloomfield, 2013; Nodelman, 2013, Valenzuela, 2013).



Figure 1: Early Graphite Sketch of Creative Materialism Visual Model 2020



Figure 2: Oil Painting of Nail's Contemporary Loop Object Theory

As one example, I used photography (Figure 3), drawing, and painting to come to understand CLO theory (Nail, 2021) through the scientific theories it is grounded in, like

chaos theory. I painted several iterations of the concept of turbulence that mathematics and science cannot measure and predict (Figure 4).



Figure 3: Photographic Study by Author of Turbulence in the South Platte River



Figure 4: Oil Painting Sketch of Concept of Turbulence by Author

It was through repeated sketching and painting during the ongoing literature review that I came to conceive of professional socialization, and coming to know, as a turbulent liminal process.

*Feedback Looping to Create Hybrid Knowledge*

My analysis process was iterative following CLO theory (Nail, 2021) and I used my own established creative practices that emerged while I was developing the creative materialism framework (Nodelman, 2013) and from pilot studies (Robert, 2020). In fact, I finished several paintings during data collection, analysis, and interpretation that I started during the theorization of creative materialism (Figures 5 and 6). The meaning of these images only emerged as I intra-acted with the participants and we looped together with their data and content. In CLO theory (Nail, 2019), data, or content, is not waiting for analysis; rather it merges with the participants and myself as soon as it is experienced—there is no objectivity. I understood that the content was a material part of the research practice and process that had agency in my understanding of the project.





Figure 5: Oil Painting Conception of Intra-action with Participants During Data Collection





Figure 6: Finished Oil Painting of Creative Materialism Visual Model Interpreted as Neurodivergent Thinking

I wrote words and concepts on notecards that emerged as repeated patterns or that resonated with the research question and literature and pinned them onto walls (Figure 7). I pinned them to the wall so I could constantly re-order and re-view ideas, content, reflective insights, research literature, and any other materials folded into the study to see the intra-active relationships between the various wholes and pieces of this research (Nail, 2021).



Figure 7: Photograph of the Author's Use of Notecards Pinned to the Wall for Analysis

I also kept a new designated dissertation physical paper journal, which I referred to as the pink journal in my memos. I used it specifically for generating content for this study in which I poetically and visually interacted with the participants' content and reflected on my transformation in understanding and coming to know the participants' experiences while wrestling with my humility as a researcher. I also consistently wrote reflective academic memos and analyses on the computer, often daily, to describe my process, what I called "jams". Visually I created iterations of my analysis by drawing images with pencil, pen, oil pastels, and graphite, and painting with watercolor and oil paints. Because I am a visual learner, I printed color versions of the participants' shared creative content using my large format photo printer and hung these images on the wall to

view them with other content, the research question, and the literature. I used my analysis process of creative materialism for self-interrogation as well, which provided insights as the findings emerged.

While the proposal emerged, I interrogated my own identities, power, and agendas following CRM principles (Berryman et al., 2013b). As I worked through understanding my own racial identity and understanding whiteness (Ahmed, 2007), I found poetic writing to be the most insightful process for me to generate a new awareness of my own racial identity, though I choose not to share it here (Bloomfield, 2013). In reflections on this observation, I theorized that I need a non-rational method that moves around and behind the invisibility of whiteness in which I have lived my life so I can see my entanglements with whiteness more clearly. I also found through the analysis and interpretation of the process that I fit the profile for neurodivergent thinking (Zener, 2019) and over the months of compiling the findings, insights continued to emerge (Bloomfield, 2013) about this unique framework I had created. These insights included awareness of how I used movement and other activities to process and analyze the data and content, rather than always working at the computer and on this document. I called it my “walking away” method, when I felt formal writing was not helpful and I would go out into my garden and work, go for a walk, do household chores, or run errands. Often writing by hand in the pink journal facilitated a cascade of insights, theorization, and connections that would not emerge at the computer. I also learned to respect and respond to my intuitive desire to go into my painting studio to oil paint or draw despite not having an intentional, rational reason for doing so. I began to reject the voice in my head, based

on my lifetime of academic training and socialization in the modern U.S. workforce, that these were forms of procrastination; they were not.

### *Interpretation of the Findings*

As described in the literature, interdisciplinary research complicates epistemological interpretations (Baille & Armstrong, 2013). And CRM required that I move in my own ways of knowing (Bloomfield, 2013) but also toward understanding how the student participants come to know through their own newly discovered neurodivergent identities (Cuellar et al., 2022). I used my theoretical framework of CRM (Berryman et al., 2013a), CLO theory (Nail, 2021), and Leavy's (2017) and Barone and Eisner's (2012) criteria for arts-based research methods along with the findings from the research literature for interpreting the content the participants and I created. I focused my interpretations through the lens of my research questions, which I once again share here for convenience.

1. How do underrepresented engineering students experience socialization into the professional engineering culture during their education?
2. How did creative materialism function to answer research question one?

Because my study used CRM principles (Berryman et al., 2013b) to guide the design, which includes me as a learner in the process with the student participants, I interpreted the content relationally and as hybrid knowledge based on Nail's (2021) contemporary loop object theory of how new knowledge emerges. I also invited the student participants into the process of interpretation with me by providing written



documents of their individual findings for them to review, correct, revise, and provide reflection and feedback on their experiences during the study. I then shared the combined findings in a draft of Chapter Four, which we discussed in the focus group together in which the four participants could collaboratively provide feedback to me (Cardno et al., 2017).

As each of the three participants is unique, I interpreted each of their content using CRM principles that required me to learn about them and their cultural history and epistemologies (Berryman et al., 2013b) and I used the research literature to guide me (Cuellar et al., 2022). I did not generalize their experiences as the same or universalize the findings as representing all of the participants' experiences of the research. Additionally, my two research questions were not isolated but connected through the purpose of my study, which was to provide new methodological spaces for students to explore how they experience socialization. As I showed in the literature review, history, EHED culture, and research methodologies are entangled in complicated ways in EHED and informed my interpretations.

As I described above, the qualitative analysis processes described in the literature follow a spiral form in which researchers sort data or content into categories and themes, which they then present as the findings that represent the research (Creswell & Poth, 2018). However, in my study, the interpretation is not a mental or intellectual act of comparisons and sorting a discrete body of collected data (Nail, 2021). Rather, with CLO theory, I moved iteratively with the content which created the new material field of knowledge in this dissertation, which I theorized are like themes of interpretation

(Creswell & Poth, 2018). I theorized knowing as a turbulent motion that becomes ordered through the looping feedback process, so my interpretations show the path of this turbulence toward order through the process of content generation and interpretation.

### *Lenses of Interpretation*

To interpret the students' experiences related to the socialization process, I watched for connections and relationality in each of the student participants' various forms of content but also between their individual content and the findings from the literature that describes some of the kinetic operators at work in the list above, like rigor. Because CLO theory (Nail, 2021) is a kinetic epistemology, my interpretation process uncovered and marked the relationships and motions found in the generated content (Bloomfield, 2013). CLO theory does not provide meaning through interpretation but shows relationships and movements between and with objects as they emerge through repetitive folding, to uncover what has been hidden or ignored. To review, Nail (2021) identifies these motions as *pedesis* or emergence, feedback loops, and hybridity. My interpretation described how the content emerged relationally and I described and showed the relational looping of the feedback process. For example, I showed how terms from the literature, like being invisible or hyper-visible, resonated in the findings in Chapter Four. In this example, the looping occurred with the student as they moved through the research process, but also with me as I looped with the student's content with my knowledge of the literature. The final interpretations are hybrids of all this looping analysis.

Following CRM principles (Nodelman, 2013), I constantly interrogated the power inequities in my relationships with the student participants like being a Ph.D. candidate and adjunct faculty—that is having different academic experiences, along with my age, and my experiences as a teacher. I also used an anti-deficit framework (Harper, 2010) to look for not only the participants’ struggles but also their successes as underrepresented students, like their adaptations and resistance to the cultural aspects they felt harmed them and their initiatives towards self-care and creating a community of support through transparently sharing their struggles.

As for my own content that I generated through self-reflexive practices, I brought different ideological lenses to view how it met the CRM principle of self-interrogation and transparent disclosure of my ideological agendas and power, both known and unknown to me (Berryman et al., 2013b). As an example, I was aware that my academic agenda was to complete my dissertation research, defend it, and graduate, all on a tight timeline. These practical and self-serving agendas were kinetic operators (Nail, 2021) that I identified in my interpretations through transparent narration. For example, I share in Chapter Five how I was impacted by my neurodivergence diagnosis and how that new knowledge delayed the focus group and final writing of the dissertation findings (Nodelman, 2013).

### *Trustworthiness & Aesthetic Quality*

According to Barone and Eisner (2012), arts-based research methods provide empathetic opportunities for audiences of the research to participate in the research

through their own experiences of the expressive forms used by the participants and me. The purpose of my approach in the study was to use epistemic pluralism in ways that other research methods cannot, and thereby reach across disciplinary understandings of these participants' experiences (Barone & Eisner, 2012). However, for arts-based research to be effective at communicating, trustworthiness must be established with the audience. To this end, I used particular arts-based research methods criteria to evaluate the significance of the study and to interpret the findings in my study based on Barone and Eisner (2012). To enhance our own and other's perspectives I juxtaposed the participants' creative content with their diary entries and interview data in Chapters Four and Five in ways that demonstrated the incisive and coherent meanings that arose from our work together, that is, how all the methods, data, and content fit together. For example, I placed quotes from interviews with poems that evocatively illuminated new understandings of how it felt for these participants as they were transformed by their participation in the study, thereby generating new knowledge for me as the researcher, the participant, and the audience. I chose content that was socially impactful because it directly related to the research questions and purpose of the study as well but was also identified directly by the participants themselves as relevant to their own participation goals. I determined this social impact by asking questions about the content during the interviews, thereby triangulating meanings by member checking across the methods.

According to Leavy (2017), aesthetic quality or artfulness (p. 213) is an evaluative criterion for arts-based research methods, though Barone and Eisner (2012) note that there are no universal standards for assessing arts-based research but rather

criteria that apply to the study's intent. However, I echo critical theorists like bell hooks (1995) who recognized that Western aesthetics is culturally based and has political implications. These implications are the results of conceptions about qualities that historically elevated Western art traditions and aesthetics above all other traditions, like the hegemony of positivism in Western research and education (Riley, 2008). Nail's (2019) *Theory of the image*, which is another component of his overarching philosophy of movement, also theorizes that images and material creative artifacts are contingent on specific historical, political, cultural, and economic conditions. I chose to use variations of the term *creative* rather than art making or artwork in this dissertation. I did so to distinguish arts-based research methods from art as a commodity or the perceived universalized Western-based design ideals that are like the culturally assumed universality of Western science that I showed in the literature review (Nail, 2019). The purpose of the creative content was not to sell it or use it for decoration, but to let it emerge as artifacts from the process of generating new knowledge that can be shared. To this end, I selected the participants' content for the final dissertation by evaluating which images and poems communicated trustworthiness to the reader and audience (Barone & Eisner, 2012). I chose content that enhanced my perspective of the participant's experiences in the culture of engineering, resonated with the research literature that grounded our study and created new meanings through the content's evocative qualities and coherence with the larger study and findings.

### ***Presentation of Findings***

Arts-based research methods present complications for dissertations as the content and process may not fit well with the rigid structure of dissertations required by academia (Atkins, 2013). I presented the findings and interpretation of the dissertation in a traditional written form that followed the required format for dissertations. However, I also included relevant examples of the participants' and my creative content as images and as quoted text with my written analysis (Bloomfield, 2013; Nodelman, 2013; Valenzuela, 2013) and based on Barone and Eisner's (2012) criteria that I described above. To aid in trustworthiness (Barone & Eisner, 2012), I transparently described in this chapter how the content was created individually and collectively, including my own looping analysis process with the artifacts of my notetaking, memos, journaling, creative content, and the content provided by the participants.

### *Ethical Considerations*

I used CRM to construct my research design because it is ethically focused on power-sharing during all phases of the research including elevating the participants' cultural values, history, and epistemological ways of knowing before we begin (Berryman et al., 2013b). To ensure that I did not essentialize participants, I learned with the students about each of their intersecting and salient identities, their cultural backgrounds and histories, and then I folded in the critical research related to their communities to inform my intra-actions with the participants (Cuellar et al., 2022). The intentionality and awareness required by me throughout the study to meet this ethical requirement was also an ethical consideration in using only three participants. Because of the turbulence I theorized here, and that the literature describes underrepresented student

experience related to their social identities while during socialization, I encouraged the student participants to intra-act with their various personal, social, and academic networks for support, which the literature describes as important (Cech & Waidzunus, 2011; Rice & Alfred, 2014; Tate & Linn, 2005). I am not a trained or licensed mental health provider and clearly explained these relational boundaries to the student participants. Given the hesitancy engineering students have towards seeking mental health care, as shown in the literature (Coley & Jennings, 2019), I was attentive to signals that they were experiencing forms of mental distress as described in the literature, which indicates engineering students are more likely to seek mental health help if encouraged by those they trust. While I suggested their use of the Mines Counseling Center for (Counseling Center, 2021) mental health services by licensed experienced professionals who can assist the students in resolving issues that emerged during the research, all three participants' data and content showed their criticisms of the school's counseling center and reluctance to use it. I also relied on CRM principles (Berryman et al., 2013b) to develop, grow, nurture, and maintain relationships with each participant, which will continue past the completion of this study. I remain attentive to protecting the participants' privacy and will monitor their well-being in relation to their experiences in this study and the insights they gained about themselves.

### *IRB Approval*

While IRB approval is required in the academic ethical paradigm, IRB criteria are culturally derived and exclusionary by prioritizing academic goals and methods that are believed to be universally accessible and understood, not culturally contingent (Denzin et

al., 2008). Because of this gap in cultural knowledge production, I use CRM (Berryman et al., 2013b) to help ensure that I did not harm the participants with my research. Rather, I worked collaboratively with the participants to decide all aspects of the study (Cardno et al., 2017). Additionally, CRM approaches require additional labor in creating unique responsive research designs (Bloomfield, 2013; Nodelman, 2013). Because of my conceptual framework and my openness to recruiting students with all underrepresented identities, rather than recruiting one specific demographic group, my proposal was general rather than specific. I identified the ethical problems in the circular trap of having to get my committee and IRB approval before contacting potential participants, which provided the specific identities of the participants. I attempted to find a compromise to this dilemma by including culturally specific epistemological research in my literature review with the hope that the review provided enough examples for my committee to imagine possible specifics. However, as happens with CRM research, the unexpected occurred and I had to revise my literature review and other elements of the final dissertation to include neurodivergent research; I also removed large sections of the literature review that did not apply to the actual participants culturally.

I received IRB approval at the University of Denver. However, as Mines is an engineering school, they do not have a human research IRB. After receiving IRB approval from the University of Denver, I formally contacted the Mines Human Subject Research Committee for permission to conduct the study. Dr. Scot Allen who chaired the Committee instructed me to coordinate with Dr. Colin Terry, vice-president of Student



Life, to disseminate my recruitment email (Appendix A) through Student Life in early December 2021 as the semester was concluding.

Another gap between academic IRB protocols and my CRM research design (Berryman et al., 2013b) was issues of privacy. Western academic concerns about privacy and protecting participants' identities have been theorized as colonial (Denzin et al., 2008) and some argue that participants should be allowed to disclose their identities. I discussed this issue continuously with the participants as they waxed and waned on wanting to "come out" as participants as part of their desire to do advocacy work on campus. However, by the focus group, all three participants were more cognizant of their own vulnerability due to the deeply personal contributions they provided in their data and content. All four of us are also aware of the current political climate in the U.S. and the backlash against diversity efforts.

### *Informed Consent*

I introduced the ethical parameters of the project and specifically reviewed, explained, and got participants' written informed consent (Appendix C) during the orientation interview (Appendix D). A subsequent informed consent form for the focus group was submitted and approved by IRB (Appendix E). The participants all signed the focus group consent form digitally before the meeting and then signed paper copies at the meeting for my records. The new informed consent form for the focus group required that they not disclose each other's participation. I also created a focus group protocol

(Appendix F) that received IRB approval from DU along with the focus group consent form.

### ***Dissemination and Sharing the Findings and Interpretations***

As CRM requires a long-term commitment to my relationship with the participants (Cardno et al., 2017), I agreed to contact the participants before any future sharing at conferences or in publications as part of the ongoing looping process of our interactions and collaborations. All the participants approved this final dissertation.

### ***Copyright and Ownership of Content***

The creative content remains the property of each participant. However, I asked each participant to allow me to take digital photographs of the creative content that they agree to share for the dissertation; each person decided what they wanted to contribute to the research and were not required to hand over all that they generated.

### ***Limitations of the Study***

Some of the limitations of the study arose from the culture of engineering itself. Due to their excessive workloads, the participants were limited in their ability to participate in the study as much as they desired. I also discovered limitations with some of the methods based on the identities of the participants themselves and their physical and learning disabilities, like Eilidh misplacing her diary due to her ADHD. Epistemological boundaries in engineering culture (Riley, 2017) initially caused uncertainty for the participants and limited their ability to use arts-based research

methods like poetry or subjective methods like diaries. I elaborated on these limitations in Chapter Five.

Additionally, I brought my subjective material history, culture, and ways of knowing to this study, which both CRM (Berryman et al., 2013b) and CLO theory (Nail, 2021) identify as necessary. A different researcher with a different background, set of skills, and relationship to the campus materially changes the inquiry, as would different participants. It was also important to resist essentializing students and not extrapolate the experiences of the participants of this study to those with similar identities elsewhere. However, given the dearth of research on specific underrepresented students in specific engineering disciplines, our findings could be used to inform or analyze another study elsewhere by others. While my project was narrow in scope with three engineering students as co-researchers at one engineering school campus, the project provided an example of how the creative materialist approach can be utilized. Others in the educational research community will be able to generate their own creative, specific, and culturally responsive research projects to better understand the individual differences in student experiences that have not been visible in other forms of research.

### **Chapter Conclusion**

My dissertation research design was a radical yet vigorous (Riley, 2017) approach within the EHED research to research the problem of why, despite decades of effort to diversify engineering, the results have not been more robust. By using my unique conceptual framework of creative materialism to collaborate with the student participants, I provided an alternative space from which to examine some of the kinetic operators

(Nail, 2021) that I identified in the literature review in Chapter Two. In this chapter, I described how my methods emerged using my theoretical framework and illustrated the ways that the participants and I collaboratively created a research design that was culturally responsive to each person. I also identified the complications that arose by using my unique framework and by not choosing engineering students with specific social identities for the research before the proposal. Lastly, in this chapter, I shared examples of my self-interrogation process of my own intersecting social identities and how they affected my intra-actions with the student participants, the content, and our analysis and interpretations. I also showed how my process uses my theoretical frameworks and the literature as checks to examine how my identities move during the research.

## **Chapter 4: How Did the Participants Experience the Culture of Engineering?**

### **Chapter Introduction**

The participants' data and content findings showed several patterns common between the three students as they interacted with the culture, community members, and the institution itself; that is, as they were socialized through informal and formal interactions (Barad, 2007) designed to indoctrinate them into the culture (Seron et al., 2015). An important finding was how the culture is paradoxically hypervisible around rigor and prestige, but also invisible at times like with the weed-out classes. This theme of visibility also emerged in how the participants' social identities shaped their experiences with the culture, community members, and the institution as well. A clear finding was that family experiences shaped how these participants experienced the culture and process of becoming a professional engineer, which is where differences emerged in their data and content at times despite sharing several identities. Some of their identities like their gender were hypervisible to other community members, while others were invisible like disabilities, being low income and a working student, and racial and sexual ambiguity. This shaping also included the social identities, like race, gender, sexuality, and/or disabilities, of those

members of the community that the participants interacted with whether their peers, faculty, or administrators. This paradoxical hypervisibility/invisibility the participants experienced with the culture and social identities created uncertainty, stress, frustration, sadness, fatigue, suspicions, anger, and resentment in the participants at times. However, the participants also chose when and who they shared some of their invisible identities within the community as a form of agency and self-protection. The findings also indicate how these participants must exert extra unseen hidden labor to persevere, which other community members were often not aware of. This extra labor is entangled with how the participants' experiences and interactions impacted their mental health and well-being as well as their sense of belonging and accessibility. Indeed, the participants expressed that it was increasing their individual understanding of these emotions and how they related to their identities and their interactions with the Mines community and institution that drove their participation in the study. What their data and content also showed is how these participants adapted their behaviors and values to resist the cultural pressure of burning out, which is hyper-visible in the culture and reproduced by students themselves.

I organized the findings below into three main sections: The visibility of culture, the visibility of social identities, and finally I show the participants' adaptations in response to the culture. In this third section, I shared the findings that show how the participants adjusted their expectations of themselves and their community, as well as how they actively adapted to maintain their well-being in response to their experiences with the culture, community, and institution. In short, their experiences and intra-actions reshaped their behaviors, expectations, and values. Importantly, the findings include how

the participants were actively changing the culture by sharing with other community members their stories of suffering and their deliberate choice of self-care. That is, the participants were making their differences visible to others so changes can be made to increase inclusion, access, and belonging for future students who share their social identities.

## **Part I: The Visibility of the Culture of Engineering**

### **Introduction**

The findings of the study show how the culture at Mines shaped the participants' experiences and how the culture was both hypervisible and invisible to them, which created uncertainty, anxiety, and frustration. The participants' data and content showed how there was a cultural hypervisibility of prestige and rigor for both the institution but also for individual students. The participants observed the reproduction of the hypervisible connections between extreme rigor and prestige by the students themselves. However, the culture was also invisible at times to the participants as they struggled to understand the informal practice of weed-out classes and the narrow pedagogical methods that did not work for them, which created a culture of fear for these participants who all identified as "smart kids", or as students who had high grades in high school. In this first section, I share how the participants described similar experiences of the paradoxical hypervisible and invisible aspects of the culture but also how they had different interpretations of these experiences and how their families and precollege experiences influence their interpretations. I edited quotes from the casual conversational

interviews and some diary entries and condensed some quotes for clarity with approval from the participants.

### **The Hypervisibility of Institutional Prestige**

The prestige of the Colorado School of Mines was hypervisible in the participants' data and content. As we explored the participants' experiences and their successes and struggles, they all described their appreciation for attending a prestigious school like Mines. All three students and their families were aware of the extreme rigor and difficulty Mines students must endure; they were also aware of the reputation for poor mental health that the school carried as well. Eilidh explained in her orientation interview how she thinks the rigor at Mines is correlated with the prestige of the school by Coloradans.

I went on a first-gen tour group day with my mom. I remember her kind of looking at the school kind of like whoa, this looks intense. Because everyone has heard the reputation that students at Mines are going to kill themselves. Everyone knows the reputation-- Damn, that's Mines. Its students are depressed, and the students die.

I asked Esperanza what her family thought about her attending Mines during the second interview. "Yeah, they tell everyone, they're like she goes to Mines! Oh, wow, that's amazing, like, congrats, she's gonna be so successful". I asked her how that made her feel, and she replied, "It makes me excited. Like, I'm glad that people are excited for me. And I'm glad that my parents are proud of me too". With a robust interest and passion for engineering Esperanza appreciated mastering her skills at a premier institution. She



shared in an interview that she recognizes the elite opportunities she has access to at Mines.

The connections that I've already made as a sophomore, and the training that I get on equipment I wouldn't usually get until I'm a grad student at other universities. I mean, just the equipment that we have available to us is a lot more than other public universities. Like Design One, we get the opportunity to build a prototype and have it invested through the school, we get to work in all the labs that seniors work in to make our products. So, I definitely think there are lots of good opportunities through Mines.

However, during interviews when I asked the participants why the culture of extreme rigor was maintained despite the reputation for poor mental health outcomes, they were uncertain but identified the school's maintenance of its status as a premier institution of higher education as a possible reason. As Esperanza explained in the second interview,

I wonder, could I get the same education with less taxing academics? Like, I don't know if I could or not. Like, I feel like that's something that Mines students just talk about a lot is like, do we really need to be doing all of this? But I guess it's part of the prestige and all that stuff. Like, you know, oh, you go to Mines, so you've got to work hard, and you have got to be an Oredigger... we're all going through it. So, you've got to go through it as much as the rest of the people who graduated before you kind of deal, because that's what makes you a graduate from Mines.

Because of her early socialization into the culture of engineering and the meritocracy by her parents, Creek admitted in the last interview that she never considered the campus or school culture in her decision to attend Mines because she was coming for the rigor that she and her family assumed was equated to its prestige. "I didn't know anything about the school. But my dad was like, it doesn't really matter what it looks like because you already picked it for the academics". While the prestige and the status of Mines were hypervisible and known to the participants and their families, what was less clear to the participants was the connection between how the prestige was achieved and maintained at an institution that prized its reputation for extreme rigor. This uncertainty created feelings of suspicion in the participants. Eilidh voiced in the second interview how she suspected that much of the practices of extreme rigor were related to the institution maintaining and increasing its elite status as a premier engineering school. She explained the connections she sees with students.

It's unhealthy. Because if the school has an inferiority complex, it's not going to be healthy for the students... If the school feels like it has to constantly compete with the bigger tech institutions -- like if you think about engineering schools, you think MIT and Caltech? So, which means they're competing using us. It's like a very big chessboard, and we're the pawns. And the biggest common chess strategy is you can lose your pawns. So, they want us to have good numbers. They want us to look pretty in a statistics book so that they can compete with the big schools.

However, during the focus group in March 2023, I asked all three participants about this finding in their data that linked prestige and extreme rigor. As all three participants are from Colorado, they noted that Mines' prestige is mostly limited to the state, and the school is not nationally known. They all agree that the school's narrative around why extreme rigor is necessary was that the industry desires Mines graduates. Creek shared,

Everyone's like, everyone wants to hire Mines students. They hear you're a Mines student and you'll get an offer, which is an unnecessary lie. This then stresses people out because it might be true for some people-- some people get job offers immediately. But some people are like, well, I did all this work, and I did all this suffering and I'm not getting immediate job offers. What am I doing wrong?

I followed up by asking which industries seek Mines students above all others, as Mines has many undergraduate degree programs. The participants all agreed that Mines' prestige rests with the extractive industries on which the school was built. Eilidh added, "Fossil fuels majors. Like Petro, mining, mechanical, let's throw in comp science".

Esperanza shared what she knew from her outreach work about why Mines students are desirable by industry and how this narrative of the prestige of Mines graduates is produced. "It's because of the group work aspect where we do a lot more group work and working in teams, working with companies to work on projects and things like that". I responded, "So it has nothing to do with weeding out classes of calc one, physics one. None of that?". All three participants confirmed that they did not see the academic value of the culture of extreme rigor and suffering to the student outcomes that would impact why an employer would hire a Mines student outside these majors. Additionally, Creek

and Eilidh described how their assessments became less rigorous once they reached their upper level and major coursework, which for them included that faculty gave more oral exams and take-home tests and that faculty treated them with more respect. They indicated that once they passed the early core weed-out courses, their fears of being weeded out subsided. They were not clear on why the culture of extreme rigor and suffering during the first two years as a student at Mines was necessary.

### **Hypervisibility of the Prestige of the Engineer Identity**

While the prestige of Mines was hypervisible and known to the participants, they differed in how they perceived the uniqueness of becoming an engineer and the status associated with that identity. These differences were clearly entangled with their socialization by their families. Creek's data and content reflected her socialization into the culture of engineering by her parents and the belief she inherited from them that engineers are special. On the other hand, Esperanza and Eilidh perceived the status of engineering students differently but were aware of the hypervisibility of the cultural status of engineering.

Because of her STEM parents, and particularly her father who is an engineering professor, Creek was socialized to believe in the meritocracy and that engineers are more exceptional than people who are in other fields. Creek wrote in her diary in January:

So, my question is how do you quantify the difference in an engineer? How do you pick one out from a crowd? If we could all do engineering, it wouldn't make for much of a profession... there must be something distinguishable. Or maybe we just want to be special and different?

Creek's experiences with her peers did not always align with what she had been told by her parents. In her February diary entry, Creek remarked "I have an expectation that engineers and scientists conduct themselves in a certain way, but it doesn't seem to be a universal expectation". In the second interview, she shared her thought process as she sorted through her understanding of meritocracy with her interdisciplinary interests and abilities.

I think that there's a separation, right, between engineers and STEM people, and then everyone else. And I think there's a narrative that everyone else is ordinary. Like, if you're not in STEM, you're ordinary. Or maybe there are different kinds of ordinary? But clearly like, presidents and higher politicians are not ordinary people. Because getting to that point means they're not ordinary. So maybe to be ordinary is to lack specialization? And we see engineering is already a form of specialization. So, we're already special because we're like narrowed down and focused... So maybe it's a lack of broadness... But then that devalues people who work in broader fields or interdisciplinary fields as being like... indecisive, which I think is a common narrative.

Esperanza was an engineering major and as shown in her profile, her interest in engineering extends back to her childhood fascination with roads and infrastructure. While Esperanza's purpose for attending Mines was to become an engineer and she understood the prestige associated with that title, she explained in the final interview that she was not seeking a personal identity as an engineer.

For me, I've always grown up where it doesn't matter what degree you have; you earn your standing based on who you are as a person, and how you treat other people. Yes, I'll be an engineer. And that's awesome. Like, it's not important to me that [identity] that comes with engineering, because it's just not who I am as a person, I guess.

Indeed, Esperanza explained in the first interview that her goal was to contribute to her family and community with her salary. “My goal is to make enough money to support myself and my parents. I would love to help my church too... that is the community that has built me into who I am”. For Esperanza, who was not raised by STEM parents but by artists, there was a less disciplinary evaluation of engineering as superior or more special than other disciplines. “Because everyone here is an engineer. Maybe it would be different if I was at a school where there are not all engineering students. And maybe there's that prestige of engineering.” While Creek wrestled with the socialization around the meritocracy she had from her parents that created expectations for her when she arrived at Mines, both Esperanza and Eilidh showed in their data and content that they sensed a connection between the cultural and institutional narrative that engineering is more prestigious than other disciplinary fields but also that this narrative was linked to Mines as a specialty school focused on engineering. Eilidh, who was also not raised in a STEM family, rejected the hypervisible status that engineers claim for themselves culturally. Eilidh chose biochemistry as her major over an engineering program due to her dyscalculia and shared during the second interview how she sees different majors

rank each other but noted that engineering might be less prestigious as a major at a comprehensive university.

But I wouldn't say the engineering focus is the pinnacle of what I've learned here. Because anyone can learn to be an engineer. We like to talk about how engineers are the pinnacle of society, like intellectually. But most people can understand any engineering concept you give them. Yeah, we mock the econ majors. That's because they're the only non-engineering science-based major at the school. It's gonna happen. We kind of go oh, econ is a fake major. But if you look at engineering at like schools that have more majors, engineering doesn't shit talk the other majors. Engineering is the shit-talked major because it's like, oh, I'm in engineering, I got like a 50% of my exam average, right?

Creek also noticed and wrestled with how different disciplines compete and perceive each other, which was a driver of her interest in participating in the study. During the orientation interview, she shared that she was particularly intrigued by how her friends at other universities in non-STEM majors experienced higher education differently than what she experienced at Mines. She was curious how she and her peers are affected by this disciplinary culture she is “forced into”.

We've been going back and forth, sort of discussing how engineers interpret different things. I noticed a lot of hypocrisy happening and how engineers interpreted things so much different than my friends who are in the liberal arts, to

the point where it is like a running joke of being like, oh, you can't say that; you're a liberal arts major. You can't think that; you're an engineering major.

While the participants shared many similar experiences due to their common social identities like being women, their data and content about their families showed how their upbringing shaped how they perceived the status of being an engineer differently, as did their various other identities like being first-generation and low-income students.

### **Devaluing the Humanities, Arts, and Social Sciences (HASS)**

Another common finding among all three of the student participants was that they were interdisciplinary and enjoyed and appreciated their humanities, arts, and social science (HASS) classes. However, all three were clear that HASS was not valued nor respected by the campus community for a variety of reasons. While Creek pursued non-STEM activities and disciplines before college, like creative writing and taking a visual art class, she communicated that based on her upbringing with her STEM immigrant parents, she knew she could only pursue a STEM degree and profession. Through this socialization process, Creek knew that HASS disciplines are lower in value in the culture of engineering, and she shared in interview two that she found this cultural value well entrenched at Mines. “I think that, from a Mines student perspective, we definitely don't value our HASS classes, for sure. So, we see those as not being like part of a valuable education. Which I think I came in with that mindset, but now I've changed my mind on that”. Creek explained how HASS is perceived and devalued by the STEM faculty and



staff and how that lack of value is reproduced through student socialization, which influences students' perceptions and expectations of HASS classes.

The department is not taken seriously from a faculty level or admin level at all when they interact with their peers. They are not giving the same amount of funding. They're not given offices; they're set in random buildings [for classes]. And all those things translate that disrespect to students, and we adopt that. Even other professors in other courses will joke about HASS classes in a negative way. That says, to be part of our group, you know, we don't all like that guy, right? We're all friends here, which means we ALL don't like that person.

As a member of the HASS department, I attempted to listen to their stories about the department without bias and with curiosity about a disciplinary outsider's perspective. What emerged was that all three had a range of disciplinary skills. Esperanza explained that she has limited time and financial resources to participate in extracurricular activities but would appreciate studio art classes for credits. Creek reasoned that there were far more interdisciplinary students at Mines in her experience than the campus narrative that Mines students were a specific type.

### **Hypervisibility of Extreme Rigor**

As shown in the previous section, the value of rigor is deeply entangled in the culture of engineering and institutional prestige at Mines and the expectation of extreme rigor was hypervisible for the participants. However, what emerged in the findings again were the differences between the participants' perceptions of the rigor due to family preparation. Because Creek was socialized into the culture of engineering by her parents,

she explained in interview two how she was prepared by her immigrant parents for the extreme rigor she was told was coming in college.

I was very good at math in school. And my parents then tried to direct that by talking to schoolteachers and being like, oh, more homework, more rigor, things like that. That was an expectation of college that it was supposed to be a lot more work, a lot more time. If anything, it's less time, I think because I've learned to manage my time better. I remember my junior year of high school spending hours and hours studying every single night, I have no clue how I managed eight hours of classes [laughs] and then studying afterward, too. But it was miserable. But I think that was supposed to prepare me for rigor... to be like... even though you're only 11, this isn't enough homework, this isn't enough work, like... there needs to be extra added on so that you can work up to being ready for college.

She explained in the second interview how her parents' experiences as immigrants affected her preparation with an expectation of the mental duress that would result, which she would be expected to endure to succeed, and how majoring in STEM was not negotiable.

I think it's a typical stereotype of immigrants to talk to their 12-year-old and be like, you have to get ready. How will you ever go to college kind of deal? That was definitely accurate from my childhood. I think the idea of being an engineer was first introduced to me when I was 11. And then, this back and forth and of

trying to find a spot. But usually, it was as long as you find a spot within STEM, it's okay.

While college was easier than she expected due to the rigorous preparation by her parents, Creek observed the struggles of her peers with concern and made efforts to support them. She explained across her data and content how she saw how these students were learning to navigate not only college but a school with a culture built on meritocracy that weeds out students who are perceived to not be qualified because they cannot keep up with the intense physical and mental pressures. Creek shared how she understood her father's perception that the meritocracy required suffering based on his own experiences in engineering school in Britain which he would often share with her to prepare her for college.

I remember him telling stories about it. And not necessarily in a somber or positive way, but maybe that [suicide] demonstrated the expectation. Because that to him was a measure of how rigorous and hard the school was. Because if people are killing themselves over it, it must be really hard.

However, Creek shared in the second interview that she learned that there are different cultural expectations for how to experience college and learning.

I saw [an article] that was how underrepresented students and specifically I think Native students, regard fun differently. And that, to them, having enjoyment was an essential part of college, which is not at all what we're being fed here at Mines. Like it's not at all what I would think of as a Mines student.

In contrast to Creek's family preparation for extreme rigor, for Esperanza, who had three jobs, extreme rigor meant limited flexibility for emergencies that arose during the semester, which she brought up in the second interview.

[STEM] classes are not as flexible as we sometimes need them to be. Like, things come up with life. And it almost seems like we just need to prioritize being a student over everything else. It's like, no—academics! We need to stay on schedule, or else we fall behind.

Esperanza explained in the second interview that she noticed how her engineering education was different from her childhood friends attending other schools for engineering, particularly with the constant exam schedule and workload she has at Mines.

It's funny, my friends at other colleges are like, oh, midterms... you know, in March. But we have like, four sets of midterms it feels like. Like, we have some first quarter, second quarter, third quarter, and then the final. And Mines does not do a good job of planning things out. Like, I have friends who have six exams this week-- that is too much. So, I'm lucky I have two exams and two papers. And what else? And a presentation [this week].

During interview two Eilidh described the toll on mental health that the extreme rigor has on students and how she sees it as tied to the prestige of Mines and the quality of their graduates.

We all kind of go through a roller coaster here, kind of every day. I think the school acknowledges that it's hard, but that we'll thank it later when we get a good

job. Because the school always likes to tell us, because we graduate from the School of Mines, [employers] are going to think our applications have higher merit, because of how rigorous the school is. Which is like, yay, I'll get a job. But it's also like, you're fucking me up for four-plus years. Everyone likes to be like, it's a Mines degree. Everyone wants to hire the Mines degree kids and I'm like, do they have health insurance to pay for my therapy afterward? Because no one's happy. And it's exhausting to constantly hear them say you'll value this one day. But you know what I value right now? My health, my sanity, my ability to go to school. It shouldn't get to the point where I let myself miss a day, once a week, because I'm too tired to go.

Esperanza was also not clear on how the extreme rigor was preparing her for her future career. She noted in interview three that the workload at school did not reflect her experiences of workplace expectations.

I don't know, like I've shadowed engineers before. And I know that they have work on their plate, obviously, and a bunch of projects that they're working on at a time. And I just... I don't know... the value of endurance... I don't know that it's preparing you for what a day in the life of an engineer would look like.

And while the rigor was hypervisible at Mines, where it comes from was ambiguous for Esperanza, as she explained in the second interview.

So, I think some of that [rigor] comes from faculty. And I don't know if they intend to put that on students. I really don't know; I haven't talked to professors

about it. But I think some of it comes from that. But I think some of it also does come from your peers.

All three participants were clear across their data and content that students recreate a culture of competition around rigor and suffering, enacting a type of performance that makes their dedication to Mines and being an engineer visible, while also hiding the more impactful mental health outcomes like burn out, which are discussed below.

### **Hypervisible Rigorous Student Dedication**

All three participants explained how they saw the culture of extreme rigor and suffering reproduced and performed by the students themselves which included a narrative of competition between students as to who is suffering more. Creek reflected on this culture of suffering in her February diary entries as she sorted through her experience of the culture on campus.

I feel like there is an expectation at Mines to be stressed. We joke about it, we revel in it, and we relate about it. So maybe I'm more comfortable with being stressed. I still wish I could avoid it, but I don't believe I can live without stress.... How much stress is a good amount of stress? What does it even mean to have stress?

Creek reflected on the mental health implications during our final interview.

I feel like there's an expectation for us all to have like mental health issues, but then it becomes like a normal thing that people disrespect [mental health]. Like, oh, we're all stressed. It's competitive too. One thing that really bothers me and a

lot of my friends about the culture here is that we compete for how sad we are.

We compete over who got less sleep, over who has more exams this week... And being like, oh, well, you think your life's hard? Mine's worse.

Esperanza shared her concerns about student well-being in the hypervisible culture of extreme rigor in the second interview.

And the workload affects people. I saw it somewhere where it's like, got to take a break from my mental health to work on school, where it's like, that's not good. You should be taking care of yourself. Like, you're a human first and then a student and then your work. But I think that Mines just put such an emphasis on academics that it's like... it almost makes it seem that that [academics] is the most important thing when it shouldn't be.

The participants were clear that they had participated in these competition narratives earlier in their education before shifting towards practices of self-care. Despite their attempts to adapt their behaviors towards a more balanced view of their schoolwork, they still felt the cultural pressure to work until they were exhausted. During the first interview, Creek reflected on how she experienced the culture of ranking and measuring herself against others and the implications while also noting that it is through the competitive ranking of GPAs that students are accepted to Mines.

I think that I'm a very competitive person... But if I keep measuring my life that way, it's never gonna stop. And I think that some people here measure their life that way. The "I'm-not-as-good-as" so and so. I'm not doing the best in the class.

You know? We all want to be the smartest person in the room... I mean, it's how we got here. It's a criteria for getting here. I remember coming in freshman year, and people talked about that ranking like it was part of them.

I asked Esperanza where she thinks this belief comes from that if you are not suffering, you are not working hard enough. She replied that working to the point of burning out is not only expected but that new students are prepared for this result during their formal orientation.

It's a hard school.... like you come in and even during orientation week, it's like, how to handle burnout. It's just expected that at some point at Mines, you're going to be burnt out. Like it's kind of part of the culture where, yeah, at some point, you're gonna be burnt out, and this is how you handle it.

Creek described how she sees connections between the culture of engineering and how students may fail to handle their mental health due to expectations about themselves as engineering students and their identity as rational problem-solvers.

There's an expectation-- and I don't know if it's just like an engineering thing, or the way that we're raised as adults-- that we're supposed to be in control now. And so, when we lack control over our emotions or understanding of ourselves, we feel guilty for it. This is abnormal, this is wrong. I should understand what's happening. If I can understand the objectivity of thermodynamics, why can't I understand the objectivity of my own emotions and stress right now?



A poignant example of the hidden connection between the culture of extreme suffering and the resulting mental health impacts in the data was from an interaction with Creek during interview two. We were in a small grey study room at the library. During our conversation, Creek pulled open the top desk drawer of the old metal desk where she was sitting and explained she had opened it while waiting for me to arrive. She shared what she found inside. “It was written in this drawer ‘this school makes me want to die’. And a bunch of other people writing in the margins too”. I was shocked. She continued, “It’s an expectation that we don’t like being here. To a point where if you don’t have something to be upset about its kind of weird.” Creek noted in the final interview, “I think that helps for us to like, bond as a group. And maybe it’s not the best for us to always be like trauma bonding. I think it’s a really useful thing for us as students now. But I kind of wish it wasn’t a situation we were in”. This interview in the library with Creek illustrates the hidden mental health impacts that the students at Mines experience due to the culture in which they must paradoxically show their extreme dedication, but also hide their mental health struggles. The participants’ data clearly showed how prestige and rigor were hypervisible in the culture at Mines, and all three participants shared their own experiences and their observations of their peers’ experiences of extreme rigor and its impacts on student well-being.

### **The Visibility of the Weed-Out Culture**

All three participants’ data and content showed how they knew they were being weeded out in specific low-level classes and that this unofficial school practice was intended to eliminate a portion of students from the program. However, because weeding

out was never something formally explained to them by the school, the reasoning and process were not visible nor understood explicitly. All had heard the term “weed out class” through an informal socialization process in which upper-class students prepared incoming students for the extreme physical and mental rigor that they will endure in specific classes. Even Creek, with her extensive socialization into the culture by her parents, explained that she had learned about weed-out classes at Mines after I asked her where she first heard the term. “Other freshmen, I guess. I don't know where I heard it. I've never heard a TA call it that, or professor call it that. We just started calling it that”. Indeed, Creek brought up the term on her own and described how it she perceived its purpose.

I find it kind of strange because we have freshmen classes called weed-out classes. Their only intention is to be as hard on you as possible, to prepare you to figure out if you're destined for this school, to just beat you into the dirt until you're good enough for us... physics one and two are those classes, for sure.

Those are the biggest weed-out classes we have. And then Programming Concepts is a weed-out class.

The cultural notion and socialization process of “weeding out” troubled Esperanza. When I asked her if she had heard the term, she stated that she had, but she voiced concern and uncertainty over the socialization process that includes failing a specific percentage of students as a form of rigor.

Yeah, I was really upset when I heard that. Because like I heard like, a certain percent has to fail each semester... Like they expect that. And if you don't have that percentage of students fail the class then like, someone talks to you about that? Because you might make it too easy?

Esperanza resented the idea of weed-out classes whose purpose was not clear to her. “It's like what about us? We're doing everything that we can. Or at least in my case, I'm doing everything that I can to succeed”. Additionally, Esperanza shared how she and other students discuss how this policy affects low-income students unfairly as they cannot afford to retake courses.

I was having a conversation the other day about this, we were talking about how expensive it is to come here. And so, when there is an expectation to fail classes, it's like, if I fail this class, I have to pay to take it again. Like that, for me is like a waste of money.

She explained how weeding out could be detrimental for some first-generation and low-income students and how that could affect diversity, inclusion, and access (DI&A) efforts. “So, like, no wonder we don't have a lot of low socio-economic students. Because especially if you weren't given the opportunity to learn how to study, then you're failing more classes, and you have to pay for them again. Like, it's not realistic”. Esperanza explored the connection between rigor, weeding-out, and the school's reputation in the final interview but was still not clear on what the purpose of the extreme rigor was.

I think, even comparing to other schools. Like no matter where you're at, engineering is going to be [tough]. And I think maybe that adds to the prestige of it. Like, you have to go through this process to get there... where it's like, a percent has to fail. And that's the weeding out process versus let's make it really challenging so that if they don't learn how to communicate and reach out for help, then they won't succeed. You know, because I think there's a difference there. [Failing] is part of the prestige of Mines too.

The participants' data showed how the weeding-out practice also generates fear in students, which then impacts their learning. Creek shared in the first interview how despite knowing she is past the weed-out classes and knowing she should ask questions in class, she still hesitates.

I think people are afraid of seeming like they don't get it. They just pretend that they get it and move on... And I've been there my freshman year and I've moved past it, and I will ask questions... I don't think the professor's mind that—but I still feel a sense of, oh no... people know that I just asked a dumb question. I'm the dumb person in the room now. Right? That person, you know?... I have heard comments of like, why would someone have such a silly question or such a dumb question?

Eilidh described her hesitancy to, as she put it, ask faculty to “dumb down” materials for her so she could understand them with her learning disabilities. Like the other participants, Esperanza also expressed uncertainty as she explained that she feels

she has a different learning style, and because she learns differently, asking for help from professors induced anxiety and unease.

Yeah, I think it's part of like the stigma of like, I don't want to need support... even though I need it. And I think that's something that is common here to where it's like, I should be able to handle everything. And so, when I can't, it's almost embarrassing.

Esperanza shared how she also gets intimidated “I don't want to look stupid in front of everyone. So, if I'm not 100% certain that it's right, I'm not going to say anything, or give my answer”. All the participants rejected this cultural feature as not aligning with their values around learning but also as contradicting the school’s stated values around mental health and supporting students. In the first interview, Creek described how she sees the weeding out process creates a sense of survivorship and shared trauma for students who persevere but also causes students to lose confidence and leave, including the underrepresented students the school is actively recruiting.

Most everyone that I met my freshman year, especially those students from minority groups that left because they couldn't hold on... sometimes it's a mental health thing about how this school really wrecks your mental health that first year. And then we went into covid our second semester. So that didn't help either. And it's partly the weed-out classes, too, you know a lot of them left because of those classes.

A clear shared finding was that an outcome of the invisible weed-out culture is that it creates suspicion about the intention of such a program by the institution, especially because it is not an official, explicit, or transparent policy. Creek explained,

And it validated our struggle a bit to be like, they're doing this to us. We're not dumb, they're doing this to us. But then the institution becomes our enemy. And it stops becoming about learning and it starts becoming about beating the people who are trying to make our lives miserable. And we aren't really getting a quality education anymore.

The invisibility of some aspects of the culture created uncertainty and added to the participants' stress but so too do the narrow forms of assessment that rely primarily on testing for accuracy that the culture relies on to determine who is qualified.

### **Invisible Consequences of Pedagogical Rigidity**

Related to the cultural practice of weeding out students is the primary pedagogical emphasis on positivism and memorizing individual information, equations, and theories, and then being tested for accurately using these equations and theories, rather than for comprehension. The narrow assessment and teaching methods were clear in the participants' data as was the connection with being measured for the worthiness of being an engineer; however, the reason for pedagogical rigidity was not evident to the participants. With her early socialization into engineering culture by her parents, and her exceptional mathematical abilities, Creek argued that she perceives the pedagogical methods as tied to a belief that only some people merit being an engineer.

I think the idea for the way that our education is run is that... we're tested through tests, exams, labs, things like that. And... supposedly, the only way to be able to pass those things and pass these more technical requirements is to be able to think like an engineer... I don't think that's the reality of how our education works out... I think that's the ideal. A big part of STEM in general is believing that science and logic are completely unbiased and are just like, The Truth, right? And our job is to uncover the truth and to be these really amazing truth seekers.

Creek was critical of how effectively students' abilities are assessed and measured at Mines through constant testing that does not take differences into account and prioritizes accuracy over the application of knowledge. "I get it for certain courses-- the calculus's, the physics... but I think there comes a point where that kind of examination just isn't really working anymore". Creek described some of the problems she encountered with a class in which she was only assessed through testing for accuracy, despite her being exceptionally skilled with mathematics.

The grades were all exams. And so, you mess up something small... I remember an exam, writing like  $A = 0$ , and leaving  $A$  in my solution because I swapped  $A$  and  $B$  in my brain when I was writing it down, and getting docked three points for that... because I mixed it up later, put them in the wrong spots. But before then, I clearly had the right idea, right? But to say that I am now less qualified feels incorrect. So, I guess either our grades are not a good measure of whether or not we'll be qualified as engineers, which means what's the point of

this institution and GPAs, and grades altogether? Or... something as insignificant as those little mistakes... literally make you less qualified?

Creek described how she values different types of evaluation of her skills and is critical of the overreliance on testing for accuracy over comprehension.

I just think there's no good end result to exams. Most people won't remember after they've taken the exam. I remember every step of that project for that research paper that I wrote, and like all of the things that I had to learn to write that paper. Because you have to-- you can't just spew out, like keywords for 800 words and hope for the best. But you can do it a little bit in an exam, I think.

Pedagogical rigidity also creates extra work for students who think differently. Esperanza explained how she sees connections between information and that she requires context and explanations of how something is used and applied to understand fully, yet this is not how she is taught at Mines. "The how and the why, and like, how did you get here? Like, talk me through your thought process". Esperanza explained how she is taught to merely memorize equations and then answer questions with them.

And it's a lot of just the same thing, where it's like, you just have to go through the process. And I'm like, but I need more than just the process to understand. We're just given so many equations. And I'm like, how do I know when to use which equation? Like, when does it apply to this? Because it's all the same thing. Like, it's just so many different moving parts.



For Esperanza, there were no visible paths to find someone to explain content and materials to her in the way she needed.

The way that she teaches just doesn't always click with my brain. And so, I go into office hours and try and have a conversation with her. But it's very, like, this is how it is, you just need to learn it. And so, I think part of it goes back to like, okay, well, I don't learn that way. And so, I need to figure out how I do learn, I guess? And not every professor can show that. And so like, I've been to other professor's classes, but they teach the same way. So like, whenever I asked a question on a problem, it's like, here's what you do. And I'm like, okay, but how did you get here? What are you trying to do?

Because she is on the autism spectrum, which for her included her ADHD, Eilidh has a range of disciplinary skills and abilities, but is much better at some than others, meaning some types of schoolwork are easier than others. When I asked about her classroom experiences in interview one, she explained,

I am not someone who is really good at communicating how much I know over a piece of paper. Like I can't sit in my head and think of something; I have to say it out loud. Which is fun when I'm doing homework with other people because I just distract the hell out of them. But I had a teacher who would let you do an oral exam instead of a written exam. My grade in that class was great. Because I could sit up there explain the chemistry point and explain my conclusions. As opposed to getting a question on an exam that's like, how does this type of folding work? Explaining in that method, my brain kind of short circuits... how do we explain

this best? How do we make sure they understand what we're saying? Because like, a symptom of ADHD is that you add more words than necessary to every explanation you make. Which means when I'm talking, I'm like covering all my bases, everything sounds really proficient. And it makes it so that people definitely get what I'm trying to say when I'm presenting, which is really good when you're in an oral exam. But when I'm writing, the main thing I'm thinking about is, oh my god, are they going to understand what I'm saying?

Eilidh used terms like anxiety, stress, anger, frustration, exhaustion, burnout, resentment, sadness, and a sense of failing to describe how it feels to be socialized into a pedagogical culture not meant to include her. Eilidh was clear on how misplaced the testing for accuracy was at Mines as this type of assessment resulted in a lower GPA that masks her intelligence, knowledge, and ability to apply knowledge. “I lose points for a lot of things because of number errors. Like I will flip numbers around in the wrong order, even if they were right earlier. Or I will just write down the wrong number”, she said. She shared how her classmates and some faculty who know her were confused by her lower grades versus her deep competency and detailed knowledge of the subject matter that she could express through conversation. In the final interview, Eilidh shared an interaction with a professor that shows how the reliance on one type of testing does not allow faculty to properly assess her abilities.

[S]he goes, you erased the right answer. And I was like, I had extra time, so, I overthought. And she goes, well, that was silly... You're wicked good at all of

this stuff. You understand really well... you've learned something once and I don't see you forget it like other people do.

Eilidh explained her ability to apply knowledge, "If I learn the process for one problem, I can apply it to a different one". She also shared how friends were confused by her grades compared to her verbal ability to explain the subject matter. She told me, "One of my friends asked me why my GPA was so low. And I'm like, I can't communicate that I know it with the way it's measured. Like I can write solid papers and explain it that way. But in the exam, no".

The participants questioned the institutional reliance on memorization and repeated testing for accuracy over comprehension. What is especially noteworthy was that this finding emerged from the two participants with learning disabilities, but also from Creek who was extremely gifted and majoring in mathematics. Eilidh and Esperanza's data and content also showed that they could not identify other pedagogical methods available to them to learn the material differently and in ways that accommodated their neurological differences. Eilidh did note that she had worked with several teaching assistants for one of her classes and they agreed to proofread her homework for dyscalculia errors before submission. She noted that this help was the first time she felt supported and that having her work reviewed, it removed the need for her to follow up and explain her errors to reclaim points and maintain her GPA.

### **The Invisible Impacts of Culture on Students with a Smart Kid Identity**

Another consistent finding related to the weed-out culture and extreme rigor across all the participants' data and content was their concern about the mental health effects of the culture on high-achieving students. The participants shared how they witnessed the impact when their peers, who were top of their class in high school, collided with weed-out culture and pedagogical approaches that intentionally fail a large portion of a class. I termed these students as having a *Smart Kid* identity. All the participants explained how they were socialized throughout their pre-college education to measure their worth with their grades, that is as Smart Kids. Esperanza recognized the predicament of freshman students at Mines who are suddenly confronted with being one of many smart students and perhaps were not prepared for the difficulty of Mines and their STEM majors because high school was easy. She explained, "I feel like that's hard to grasp sometimes, especially when people were the smartest kid in their high school... So that now they get here. And it's like, I don't know how to study because everything just came easy in high school". Esperanza described her perceptions of incoming students who experience these shifts in their identity.

And I think especially first year, what I've seen is a lot of students come in, and they're like, oh, you know, I was valedictorian of my class, and all this stuff. So, at Mines, they kind of face the reality of like, oh, this is a hard school, like, I'm not always gonna do well.

Creek also described how she sees new students struggle with not being the smartest student and how it affects their sense of self-worth, which can spiral out of control into a crisis.

But you come in, you're on top of your class and like you've only ever had immense support from like your parents and your family. And suddenly you're hundreds of miles away from them. I don't think they account for how much families support matters here either, especially for freshmen. Like to be feeding yourself? Crazy. Like so many freshmen struggle with that. And then you get to labs, and someone's doing it faster than you are, someone's getting it faster than you are. You're too afraid to say that you're falling behind. And so, you just let it happen.

### **Section I Conclusion**

The participants clearly were concerned about their mental health and that of their peers and were perceptive of the cultural elements that were harmful to students like extreme interpretations of rigor as physical and mental suffering and how students reproduce these cultural values amongst themselves. Suffering was a visible cultural value at Mines and the participants tied it to the institution's prestige and reputation in Colorado. The participants were also disturbed by the invisible pressures from the culture that impacted their experiences, but they were less clear on why these cultural values and practices existed as they seemed counterproductive to the participants, like invisible weed-out practices and narrow assessments and ways of teaching materials. In the next

section, I show how the specific multiple social identities that the participants held shaped their experiences in the culture specifically.

## **Section II: The Visibility of Social Identities**

### **Introduction**

Having established how the participants experienced the culture on campus, I now turn to how the participants' experiences were shaped by the hypervisibility and invisibility of their multiple overlapping social identities. In this section, I share the data and content that shows how the participants experienced the hypervisibility of being female, or the invisibility of being low-income, first-generation, LGBTQA+, and/or a student with a mixed racial identity, but also their learning and physical disabilities. For example, the concept of visibility resonated with Creek during her orientation in multiple complicated ways, including her ambiguous racialized identity, the invisibility of her queer sexual identity, and her hypervisibility as a woman. She remarked she feels both invisible but also hypervisible depending on the situation. In terms of being racialized as White, "There's a little bit of invisibility of like, you get to sort of like pass along with that. But there's hypervisibility in the fact that I'm a woman." However, importantly, the participants' experiences were also shaped by the social identities of the people they interacted with at Mines as well. The participants also described experiences of microaggressions from their peers towards their hypervisible identities like their gender, which in turn created feelings of not belonging for them. However, the participants also described more subtle forms of aggression and suspicion they felt for invisible differences like disabilities. The participants' data and content also showed the extra

labor they had to exert during their experiences when confronted with microaggressions, ignorance, and a lack of access or accommodations. Additionally, they described the extra labor they must exert to maintain their mental health and well-being with their sense of not belonging.

### **An Invisible Sense of Not Belonging**

The participants all described the various ways they were made to feel unwelcome through microaggressions by their peers that seemed invisibly supported by the culture. Because their academic identities were robust and they maintained good grades, the participants were troubled by the constant challenges to their belonging at Mines. Creek was critical of the campus culture at Mines and during the first interview described aspects of community building as feeling forced, including the school's motto of "Hellava engineer". She said, "It's more a joke than anything to us. The school camaraderie feels forced and disingenuous to most of us. The people I talk to belong to minority groups who recognize that we aren't part of this to some extent". From the start of our research together, Creek sought to better understand what she perceived as an invisible conservative climate. She noted she observed increased and more vitriolic and intimidating political discourse on campus. During the orientation interview in January 2022, she shared her sense that a radical conservative ideological backlash was forming in response to the school diversity initiatives. "I think that there's a lot of radicalism growing in engineering... because when we have diversity initiatives that bring in more people of color, or more women". Creek described how she perceives that inclusion is seen as a threat to some legacy students' sense of their access and opportunity at Mines.

I'm being shoved down. I deserve this opportunity. And someone took it from me... And then they think Black people are taking this from me, women are taking this from me. And then when students here see the success that women are having, or people of color are having, it's oh, you're taking that from me because of your identity.

She shared during the orientation interview that perhaps those community members who resist and actively block DI&A efforts do not seem to understand or appreciate the additional mental, emotional, and ultimately physical labor that underrepresented students must exert to merely access their opportunities in a system and culture never intended for their participation.

So, engineers -- supposed to be all your own effort, all your own hard work, which is not the truth at all. And sometimes they recognize that, but when you get diversity initiatives of bringing in people based on identity, that's not hard work. You didn't work to be Black; you didn't work to be a woman... but they don't recognize that there are already systems in place that are ruining meritocracy from the beginning, and we're trying to help.

Esperanza expressed frustration with people who do not know her and make assumptions about her identities, but she also expressed in the final interview that she understands that they are ignorant and need to be educated.

Yeah, I definitely think it can become burdensome, but I think it's also kind of necessary. Where like, if we want change, then that's something that we have to



get more comfortable doing. Just because there are so many people who don't understand and it's not any fault of their own.

Creek shared in interview two how she experiences the extra labor members of the LGBTQA+ community are required to produce to educate heterosexual peers about their community, particularly when her student employment required her to be responsive to other students.

That's something that is mentioned in our Safe Zone training for queer communities... when people start getting curious about the queer community but don't really know how to navigate that, the best resource is to go talk to a queer person. But that is a burden on queer people. So, I've sort of tried to learn the language of, if you have questions, like you can come to me and I will do my best to represent whatever identities I have, because I'm in this position, and I'm willing to have that burden so that you don't then put it on other people.

During the focus group, the participants discussed the differences in their defensiveness and assumptions about the way they perceive threats from legacy students and particularly men, which showed how pre-college experiences with their families affected how the participants perceived and experienced their campus interactions. All three explained personal experiences of violence and assault before coming to Mines within their families and in their communities. However, while they each shared their stories of violence and oppression, they could not agree on why they would feel more or less threatened by legacy men at Mines. Despite sharing yet another common experience,

unfortunately of violence, all three participants differed in how they interpreted these experiences and carried them into the college experiences.

In their data the participants expressed that they just wanted to be able to be themselves without being challenged, accused of faking disabilities, making up their needs, creating discomfort by their presence, and generally made to feel like they do not belong at Mines. As Esperanza explained in the final interview,

Because I think sometimes that can be how it comes across, oh, you're just here because you're a person of color. Where it's like, we don't want to feel like that because that's not true. We're here for a reason. And we like got here because of our academics and things like that.

For Esperanza, it was not clear why she was made to feel like she did not belong. “I don't know if they're resistant and against [diversity]. Or it's just like, almost threatening, I guess, the more people, whether it's men or women”. However, upon reflection, she added, “Well, no, I guess because most of the time they respond to other men in a different way”. Through her data and content Creek wrestled with her anger and resentment about her experiences of feeling like she does not belong after her intense preparation by her parents and her high grades. Through our research together Creek gained clarity that it was the culture that was the problem for her, not the STEM subject matter. In interview two, she reflected on how frustrating other people’s ignorance of her lived experience is.

Yeah, it's all a cultural problem. I don't find any problem with the actual topics or anything. I really enjoyed them. It's just corrupted by all these people who are using it for other motives or who have other biases. They don't even realize when they are doing these things. I think it gets irritating when they're not willing to change their minds. Because there's a certain level of forgiveness too. They've just never known and that's okay. But if they're not ready to hear it, that's frustrating.

In the following paragraphs, I share the participants' data and content findings that illustrate some of their experiences related to specific social identities. However, the findings show that while one identity may be more salient at one moment, all their identities were entangled together and shaped how they experienced the culture. Additionally, the visibility of the social identities of those they were interacting with also shaped their perceptions of their experiences.

### **The In/Hyper/Visibility of Being Female at Mines**

Because females remain a minority at Mines, despite diversity efforts, all three participants shared similar experiences of marginalization as female students. All three expressed how they sought out solidarity and comfort with other female students on campus and in the classroom. All three also shared their own experiences of marginalization by male peers, faculty, and administrators. Their stories illustrated their complicated experiences of hypervisibility as females but also the consistent invisibility of their experiences for their male peers, faculty, and staff. During the orientation interview, I asked Creek about her experiences as a female at Mines and she shared a

story about feeling hypervisible by a male professor who reckoned with a classroom of only female students for the first time, which was an outcome of intentional recruiting by the institution.

[H]e kept bringing up how we were all women and how cool it was to finally see a classroom of all women. And I went home and talked to my friends that night. It was like, if it was a class of all men, no one would have said anything. No one would have said, how weird that there are only men in this room. For me, it was kind of weird... if you mentioned it once, like, fine, I get it. Like, good job, recognizing that this is a rarity. But I think he was trying so hard to be an ally that [he] just kept bringing it up and looking for it.

The participants described a range of experiences that included seeking and appreciating support and finding a sense of comfort and security with other women. When I asked Eilidh about her experiences as a female at Mines, upon reflection she described how she had a female-centric experience at Mines, and it has been positive and supportive. Her major in biochemistry is predominately female, and she realized during interview one that she mostly has female friends. “If I think about my close friends in my major, I think only two of them are guys. And one is non-binary but they're very female-presenting”. During the orientation meeting, Creek described good relationships with both male and female peers in her academic department of mathematics, saying “I've never really experienced a lot of disparity gender-wise in my department. I've like made a great group of female and male friends who understand my identities and are comfortable with that. And that provides a safe space there”. Esperanza's desire to build community

and connections with other women showed in her diary entries. She shared her excitement at discovering that she had a female professor for a class, which she did not expect. We discussed how important female faculty were to her during the first interview.

[Faculty] are mostly male. I was super excited about [a female professor]. I like went up to her after class and I was like, I just want to introduce myself. You don't see a ton of women in engineering. And so, I think it's just inspiring to see someone like, oh, that could be me kind of thing.

Esperanza also described meeting other female students in classes, at sporting events, and through joining a women's extracurricular sports team and how she hoped to develop ongoing friendships with these women. She also described choosing to sit next to the few female students in classrooms as it makes her more comfortable, which Eilidh also described in her data. However, for Esperanza, it was the combination of being around other women who were interested in engineering that was deeply profound for her to experience, which she explained in the first interview.

[I]t's cool to find other girls who are also interested in engineering. I think, at least in my group of friends, that's kind of a similar experience. And yeah, there are still very few women in STEM now. But living with other females who are interested in engineering, you have that group to hang out with and to relate with as well, which is cool.

While the participants felt an affinity for other females at Mines, there was also uncertainty about their female experience in engineering.

### ***The Invisibility of Female Safety Concerns***

Safety as a female was a topic that Creek and Eilidh often returned to when reflecting on their experiences as females at Mines. During the orientation meeting, Creek shared that she felt a lack of safety at a predominately male institution and this feeling of insecurity shaped how she interacted with other female students in social settings that were mostly composed of men. She reflected that she was unsure of how this sense of possible threats from men impacted her relationships with men and her experiences at Mines.

I think that's one of the places where I felt most like isolated as a woman when you go into frat events and things like that... Well, usually you have this moment of like, you'll spot another woman in the room, and you try to be like, I recognize you. You're alone in this. I'll be at parties, and I'll get adopted by a group of drunk girls who are like ah, a woman who's alone, and they take me in. There's a little bit of guilt that comes with that. I feel like, oh, am I purposefully isolating myself by finding kinship with people I feel safe with?

I asked Creek about what it was she was seeking safety from. She replied, "From men... it's usually harassment, especially because groups of women, whether they're sober or not, will band together to protect those of us who aren't sober". She elaborated on her concerns. "Whether it's sexual assault, harassment, verbal harassment, or like having your drink spiked and things.". Creek and Eilidh both shared how their male peers were unaware of how they as women feel vulnerable and unsafe at times. Eilidh shared in interview two, with some amusement, how her boyfriend was unaware of the lack of security that women feel in public places, particularly at night and when alone. "And he

just does not get it. He tries very hard. And I'm just like, it's never gonna apply... Just the constant threat of being a woman". In the orientation interview, Creek shared how she understands her lack of physical security as a woman while recognizing that most men are completely unaware of the risks women face in terms of safety and that this ignorance can further contribute to harassment and intimidation.

I'm just comfortable with my own un-safeness and comfortable with, like, what measures I have to take because that's just my reality now... I've had a lot of male friends who are like, I didn't realize that that was an experience you were having because they're physically intimidating men. So, they don't get cat-called, they don't get harassed in streets or anything, whether it's someone who's harassing them for their gender or otherwise.

Eilidh expressed in the first interview how she felt intimidated by an aggressive male professor's behavior and demeanor in a course that she soon dropped because of this professor's behavior.

Like his body language! Like this teacher was very active. His body language was just not the greatest. I mean, he gets so engaged in talking, that spit would fly from his mouth and land on the first couple of rows. And he would slam the chalk on the whiteboard when he was doing a period. And it was kind of just terrifying to be in the room and watch and try to do what he was saying because there was so much going on with him. It wasn't easy to pay attention to the content because your brain is just trying to parse all this information that he was throwing at you.

When asked about her experiences with men on campus, Esperanza was quick to not generalize and instead insisted that it depends on the man.

I think it depends on the person, and how they approach situations, for sure.

Because I mean, there have been some interactions where I'm uncomfortable or like made to feel less knowledgeable or things like that, than White men. But I think it really depends, you know, not everyone obviously is like that.

Esperanza's experience of being mentored by a male graduate assistant was one example of a man with whom she felt heard and seen. His caring and kindness increased her comfort in learning. Esperanza shared in the first interview that the biggest issue she experienced with male students was men talking over her and refusing to be corrected by her.

I've definitely had cases where it's like, they're talking down to me or talk over me in certain situations. Especially in small groups, it's easier for people to do that. Because while I'm in the middle of talking, and then you have an idea, and so then you just vocalize it right there. Where it's like, hey, I wasn't finished talking. And I've even felt that in groups with ideas and things like that. I have good knowledge about this, I say something. And then everyone's like, ah maybe. And then a guy says it a different way, and then it's like, that's a beautiful idea. Like, let's do that [laughter]. And I'm like, that's exactly what I just said. Or that kind of mansplaining is a big thing here. I don't want to generalize, but a lot of the time White men will not be able to say that they're wrong if they are. Where it's like,



someone will say something, and I'm like, but what about this? And it's like almost a battle of, no, I wasn't wrong. And in those cases, for me, it's just like choosing your battles. At that point, it's not really worth it to try and show that I'm right, you know. I just let them have whatever they need to be correct or whatever.

The differences between the participants perceptions of their safety as women is again noteworthy and tied to the discussion during the focus group at the end of the study in which they debated what might account for these differences. The participants described two kinds of safety, one physical and one intellectual. Esperanza never brought up feelings of being physically unsafe around male students, faculty, or administrators as Eilidh and Creek had in their data and content. For Esperanza, her experiences of gender were more about seeking camaraderie with other women who shared her interests, while navigating interactions with male peers who talked over her and dominated spaces.

### **The Invisibility of LGBTQA+ Students**

Both Eilidh and Creek identified as bisexual/queer women, and both shared in their data and content how they faced questions about claiming this identity for themselves as they were each dating heterosexual men. Creek explained in her orientation interview,

I identify as someone who's interested in both men and women, regardless of their respective genitalia, and is interested in both romantic and sexual relationships. But I go with queer because I haven't found a word that works for me overall.

And I like the way that it feels to call myself queer or gay, or whatever. But that's another space where I get invalidated. Because I've never openly dated a woman, because that's not something that would have been right in my conservative town. And there are not a lot of gay women here at Mines... So that's something that's invalidated by the same people who say you always pull the race card is, are you really gay if you've never dated women? But we don't say that to young kids who identify as straight and haven't dated the opposite sex yet?

In the final interview Creek also described how students in the LGBTQA+ community use clothing to signal to others in the queer community and applied the concept of hypervisibility to queer joy, in that she felt that being happy as herself is a form of resistance to oppression.

That's part of the hyper visibility too as we become more comfortable in our identities and outwardly coding like that. So, part of that hyper visibility is like signaling to others. That's an internal struggle that I have especially because my partner is a man. And I want to maintain my identity as a queer woman. And so, I do that through my appearance. I get dressed in the mornings; I cuff my jeans. Like someone's gonna know, because it's a joke that all bisexual women cuff their jeans. Or they wear capris, things like that. Or I have earrings that are these like big rainbow pixel hearts. I wear these for the day that everyone knows kind of deal. Or people have pins on their backpacks. And if you're not queer, you don't know about pride flags. Someone might just like even confuse it with a country

flag here. Queer people are like, I see you. I notice you, and you become more visible to them.

For ambiguous identities like their sexuality, the participants chose to make themselves visible at times and to certain groups in order to navigate the culture while also protecting themselves from possible microaggressions or harassment. The participants also described this choice to make their other social identities visible as well, like their race and ethnicity and their disabilities.

### **Ambiguous Racialized Identities Shaped by Whiteness**

Creek and Esperanza identify as women of color, but both admit that they are often presumed to be White due to their light skin complexion. This racial ambiguity resulted in feelings of discomfort for both women as their racialized experiences varied depending on the racialized identity of who they were interacting with. In the final interview Esperanza reflected, “I feel like there are a lot of different communities on campus and how I show up in those spaces is maybe different, or I feel different”. At a predominately White institution, both Esperanza and Creek were aware that their racial ambiguity created a different experience for them compared to other racially minoritized students whose skin tone did not allow for a mistaken assumption about them being White. Both women also recognized that there were benefits for them in terms of the ease and comfort this assumption often provided when they interacted with White staff, faculty, and students. Esperanza shared in the orientation meeting that her racial ambiguity created tensions with some other students at times, which distressed her.

In the multicultural program, some of the struggles that I've had is that I went to a very White dominating school. And so, I conformed based on that. It's funny because, outside the multicultural program, I kind of feel like I have to put on a persona of, you know, a woman in STEM, all that. Versus, in the multicultural program, it's not quite the relaxing place that I would like it to be because there I feel like I have to prove that I'm Hispanic. Versus, you know, prove I'm White over here. So, I think that mix thing comes into play. Like even in the multicultural program, even in the way I talk and dress... I've gotten slack about, you know, oh, you look White, you look rich. You know, things like that, where it's hard to fit in... but it's more comfortable than it is elsewhere.

In the final interview, we discussed a microaggression encounter Esperanza had with a fellow student who commented on her skin tone, which she wrote a poem about in her diary.

I was sitting next to a friend  
When she mentioned my skin  
She told me  
It looked like I got a bad spray tan  
A little bit yellow, a little bit orange  
I didn't know what to say.

What she didn't know was  
I hadn't worn shorts in years

Because I was self-conscious of my blotchy skin  
What she didn't realize was  
How embarrassing it was to be called out in public  
What she didn't realize was how much I am trying to grow.

So inside I was angry  
I was embarrassed  
I was sad  
But on the outside I said  
“That's what it's like to be mixed”  
And when she said  
“It doesn't look good”  
That's when she lost my respect.

We discussed this poem and the incident in the final interview and how it deeply affected her.

I was so like, shocked that she would say something like that because I was like, I don't understand where this is coming from. It was just like we were at a basketball game just hanging out. And I was like, it's called being mixed. Like, I don't know what to tell you. And she was like, it just doesn't look good. And I was like, okay, well, I can't change my skin color. Like... so bad.

Esperanza shared that she followed up with the student to explain how her comments were offensive. However, the student responded that she did not intend to give offense but was merely making comments and observations. Esperanza noted that this White female student feels comfortable commenting on everything and does not seem to know that “comments may not be welcome all the time. She’s just has never experienced the other side of things”. Esperanza noted that the microaggressions she encountered were often with White students and staff who seemed to be unaware of the differences that racialized students experience at Mines.

Race was also highly salient for Creek and her awareness of White privilege complicated her experiences at Mines. While she identifies as Asian-American and White, I asked her during the orientation meeting what race people assume she is. “Usually like White or Hispanic, if they’re gonna guess, they usually think that I’m Latina”. Creek shared that at times she is assumed to be White when among White people and knows there are benefits that she receives with this assumption that her peers of color do not.

With White-passing, you get away with a lot of extra privileges, which makes it harder for people to understand the racism that does happen to you. It’s more microaggression-esque. But with White-passing, when people are more comfortable with you, you have the privilege of being able to fit in those communities, and they can just assume that you’re one of them. Which also means that you experience a lot more secondhand racism because they think they’re in a safe space with White people where they can say these things. But it

also means that you can just like coast by. Because if you are clearly Black in an environment of White people, and someone says a racist thing, you are singled out. Like they see you, they look at you.

Creek remarked that she is often told that she talks about race too much at Mines though usually by White people who assume that she is White. Creek identified that from her perspective as someone who is racially ambiguous, she believes White people are uninformed about how to understand and discuss race.

Creek always brings up the race card—they always say, you just bring up race too often. Because to them, it's not obvious. If a Black person was bringing up race all the time, of course, it's obvious. Of course, it's part of their identity and really important to them. But why is it important to you when you look the same as me? Where I'm at now is I think White people have no idea how to talk about race. And I've talked to other people of color about this, including people who are White-passing, about people making comments of oh, you bring up race too much.

Creek explained during the orientation meeting that she often signals to other people of color that she is of mixed race, thereby making herself visible to that community. She shared how she feels an affinity with other people of color and appreciates when she is recognized as a person of color.

Sometimes I bring up race in a way of hinting to other people that you are a safe space. I like slip in that I was not White. And they went, oh, I thought so. They

didn't want to bring it up or ask me because I was White passing enough. But they were like, oh, I sensed it in you, which is a really validating moment for me that other people of color can recognize me as one of them.

Esperanza also described and shared stories of signaling her racial identities to others because she knew her race is ambiguous to many people including other racial minorities. In the second interview, she reflected, "I feel like that sometimes in Hispanic-focused places—and I think that's mostly because I don't speak Spanish—where it's like, okay, I gotta prove that I belong here even though I can't speak Spanish kind of deal".

Creek explained in the first interview how she struggles with her mixed racial identities and her knowledge of racial privilege, which creates a sense of shame for being part White racially and therefore part of a group who oppresses other communities.

Even though my non-White part of my race is the smaller part, I consider that my race because the whiteness is just a default, even to me. Not that it doesn't matter. But because I think to a certain extent, it's shameful to be for me. Like I of course take advantage of all these privileges because of my skin color and things that give me an advantage. Like, I've had struggles based on my race and my gender, my sexuality, but I don't realize what it could have been.

During the focus group, we discussed the participants' racial experiences, with Eilidh and I both acknowledging our understanding of the racial issues people of color experience was highly limited due to being clearly White. However, as White females, Eilidh and I are also racialized despite not always recognizing this phenomenon in our



own experiences because whiteness is often invisible to White people in the U.S. and in higher education, while being hypervisible for people of color and Indigenous people. As an example, Eilidh reiterated a story in the focus group which she was interacting with male students of color that exemplifies this invisibility and lack of racial awareness for White people. She described being oblivious to these male students' experiences while they walked together until they asked her to stop running and yelling playfully. She shared her shock and embarrassment when they explained to her how her behavior put them at risk as men of color walking with a White woman whose behavior could be interpreted as distress in relationship to them as men of color. In that moment, she was aware of the whiteness she exists in but that usually remains invisible to her.

### **Invisibility of Low-income and Working Students**

A consistent finding from all three participants was the invisibility of economic differences between Mines students and particularly the invisible additional labor that low-income students exert to pay for their education and expenses. This issue was particularly salient for Esperanza who shared in interview one that faculty and staff at Mines voiced both surprise and concern that she was working multiple jobs while going to school full-time. She shared that she has a history of being a busy student going back to high school and that she felt it was manageable. However, she also explained that she did not have a choice as a student from a lower socio-economic background who sends money to her parents to help pay for school and that this fact seems to surprise members of the Mines community.

I have three jobs on campus and so I'm super busy, right? And just talking to people where they're like, oh, why do you work three jobs? And it's like, well, I have to pay for school. I have to help my parents out. So, I need this income and one job might not suffice. Or they're like, you need to focus on school. And I'm like, yeah, I totally get that this is a hard school, but I also have other things that I need to prioritize. But it's just hard to have those conversations with people because they don't understand.

In the final interview, Esperanza shared that she thought economic class was invisible at Mines for low-income students, but that from her perspective, wealthy students were hypervisible through their behaviors and confidence. “I feel privileged students are hypervisible. Because it's almost a character trait that they have. But it's more of how they act. I think that those [wealthy] students are less worried about consequences”. Esperanza described differences she sees in terms of students breaking rules in the dorms around drinking and which students are more concerned about the implications for their scholarships and remaining at Mines.

The students who are super concerned are students who are on scholarship. And they're like, I totally made this mistake. I'm so sorry, am I gonna lose my scholarship? So, it's in the social situations where you can really tell who doesn't care.

Economics was also a concern for Eilidh in terms of the affordability of getting official accommodations for her physical disability. She explained that Disability Student

Services (DSS) required her to have recent documentation of her physical disability to get accommodations, but that she was unable to afford to do so.

### **Invisible Learning Differences**

Both Eilidh and Esperanza shared in their data and content how they struggled with the learning methods used at Mines because they learn differently, however, most of this data and content were prior to all of us recognizing we are on the autism spectrum. In the orientation interview Esperanza explained that while she gets good grades in her classes, she emphasized that math does not come easily for her.

Concepts are difficult and for me, it's hard to conceptualize things. Like I just need concrete things to look at and to figure out. In physics it's hard to see and figure out all these forces you can't see... Whereas with chemistry, it's tangible; I can picture it, I can imagine it, it's been seen. It takes me a long time to get concepts and so a lot of my time is spent studying and doing work... it's very different from my friends who understand concepts... they'll learn it and they're like, okay, I can do that with a couple of hours of practice. For me, it's like I need to spend weeks practicing and learning things so that I can understand. Like when I say that math is easy for me, it's not like something I just get. I work hard.

Eilidh identified as neurodivergent in the form of dyscalculia and ADHD and other comorbidities at the start of our collaboration for the study. She was aware that she was different than other Mines students who do not have disabilities, but she was unsure how her ADHD and later diagnosis of autism affected her experiences. During the first

interview, she described how her difficulties made her feel when she saw other students make learning look effortless.

Yeah, I don't like them. Like no fault against them. They're great people, but I can't not compare myself to them.... It's so bad... It's so shitty. And I know that just mentally, I'm at a disadvantage because I have more to handle within my brain than they do. Logically, I know that; emotionally it stings like a bitch. And it's a super terrible experience. I just-- like it's this big cycle of guilt. I can't do this. I can't start this. I really want to, why can't I? Everyone else can do just fine, even though everyone else is neurotypical and doesn't have a dopamine deficiency in their brain which is what ADHD is.

Because of her ADHD she explained in interview three that she is “not a narrow it down person, I'm a build the web person. And if you flick one string on spiderweb, all the others vibrate. That's what learning is like to me. I can't just like funnel it all down to like a target. I'm building a web”.

What clearly emerged from Esperanza and Eilidh's data and content was the extra work they put in to succeed in the narrow and rigid pedagogies used at Mines, but also the mental health effects of this approach on them. Eilidh expressed in her diary in late January what it felt like to attempt homework when she is exhausted because of her physical disabilities and neurodivergence, “it required some reflection and real analysis but because I was so emotionally drained, I didn't finish it. It felt like trying to catch

smoke with my hands.” Later in February, Eilidh described her frustration in her diary with trying to get her work done due to her disabilities.

I spent a long time really trying to focus and be productive today, but boy did that not happen. I felt like my eyes were getting pulled out of my head every time I tried to really focus and get the assignment done. I wish ADHD didn't come with executive function problems. I wish I could just sit down and get stuff done when I want to get it done. But instead, I sit in front of my computer with a head full of dread because no matter how much I want to finish or even start my assignments I cannot. It's like trying to move a mountain with my mind. It was incredibly disheartening and even heartbreaking to sit here and suffer in my own mind.

Eilidh gets frustrated and offended when people congratulate her for being at Mines despite her differences as she feels these statements are more about the speaker rewarding themselves for being part of an institution that accepts her invisible extra work. Eilidh expressed in the second interview her extra labor and the stress it causes to remind professors of her accommodations for her ADHD.

Part of my accommodations are that I can ask a teacher for an extension. Three of my teachers don't give extensions. So, it's like that weird thing of, hey, if I email them to ask for an extension... Do I just play my hand immediately of hey, yes, that says you have to give me accommodations, and I feel like I'm blackmailing them. Or do I hope that they remember I have that as an accommodation? And that they'll give it to me.

The findings clearly show across the participants how the invisibility of their neurodivergence and the associated mental health impacts that accompany neurodivergence, particularly in adult women, are detrimental to their learning, self-esteem, and requires extra unseen labor. During the focus group, Eilidh stated she was burnt out from advocating for herself and her attempts to educate others in the Mines community about her disabilities.

### **Invisible Physical Disabilities**

Both Eilidh and Esperanza suffered from physical disabilities that were invisible to almost everyone around them. They both shared how while they experienced physical pain on a regular basis as students, they hesitated to seek official accommodations and only shared their diagnosis with those they felt needed to know; that is, they made themselves visible as disabled students when they chose to. At the focus group, we discussed why the participants hesitated to get accommodations from DSS, particularly for physical disabilities. Eilidh expressed that she sees the school has established practices and faculty are trained to handle learning disabilities like ADHD, but she noted they lack experience, awareness, programs, and practices for autism and physical disabilities.

In the last interview, Esperanza shared how her disabilities affect her as a student and her uncertainty whether accommodations could be offered.

Sometimes I'll have flare ups that are just caused by nothing. And like, it hurts to do everything [laughs], to just exist. So, like, I think just, like, if I were able to just be like, hey, like, I'm having a flare up, can I take a break. So it's like, if I

could just have time to rest and recuperate until I feel better, and then go back into school. Like even, I think that goes with anxiety, too, and asthma and all that.

Like, it's all kind of tied together. So, it's like, I can't really not write for a week, you know, if I'm having flare ups... I just think that in STEM, that's not realistic.

Eilidh described her experiences of Mines as a culture that sees accommodations as a form of cheating through getting special treatment, which affected both her learning but also her mental health and self-esteem. By the second interview Eilidh expressed feelings of dehumanization and her uncertainty of how other people perceive her because her disabilities are not visible.

People don't know I'm disabled. They're never gonna know unless I [tell them]. Because if I show up in a knee brace, they're going to assume she's injured. If I show up on crutches, they're going to assume I'm being a wuss about something. Because if they can't see like a brace, you're gonna go, why does she need crutches? Is she faking it? If I show up in a wheelchair all of a sudden, then people are gonna be like, she's doing it for attention. So, I've just kind of really being aware of like, how people view my identities and how I view my identities and how they're very different. Because I'm looking at my identities going, I love that about me. That's me, this makes me, me. But other people don't necessarily go, that's a good thing. A lot of times people figure out, I'm disabled, and they-- their first reaction is pity, like, I'm sorry, that's happening to you. And I'll be like, well, there's no point in being sorry about it. It's genetic. It's not going away.

Eilidh's data collection included extensive discussions about how her physical limitations affected her. In February in her diary, she shared how her disability affects her mobility around campus.

This week was so terribly long and monotonous. My disorder has been flaring up which made getting to my classes miserable and shot my motivation in the ass. I didn't miss any classes so I'm pretty proud of myself for that honestly! The snow is shitty too because Mines is terrible about salting the sidewalks so it's just sheets of ice. You know what's really hard to walk on when you have a mobility disorder? Ice. It's so exhausting.

Later in the month she reflected in her diary about how self-conscious she was in class because of her physical disability as she did a presentation. "Everyone got to watch me limp up to present... which was fun. I wish I could've presented on a stool or something...". Eilidh explained in the first interview how she needs time to rest and recover after long lab periods where she must stand.

Because our lab sections are four hours long. And I'm really short and the fume hoods are really tall. So, I actually usually wear these boots with big heels on them so that I can more easily work in that space. But wearing heels for four hours is not exactly comfy. And by the time I get back to my room, my knees are typically swollen, and my lower back doesn't feel great because I have to keep leaning and like just engaging all my muscles with the heels to interact with everything. So, I'm really sore when I get back.



I asked Eilidh to elaborate about the problems she has in her lab, and she explained that the lab equipment had not been designed for a small woman like herself.

The lab I did yesterday had not so great chemicals. Which means you have to use in the fume hood with the fume hood lowered... [stands up] so if I stand... the fume hood is about here on me. Which means if I really want to see what I'm doing, I have to tiptoe so I can get over it, right? But with the glass down and separating it, I have to put my arms under it like this, which puts a lot of strain on my shoulder because I'm doing this and trying to fiddle with things. Which is not their fault. It's industry's fault, cuz fume hoods kind of come in one size fits all.

I asked her what she needs so she can work comfortably but also safely. “If they could even just have a shorter one. Like oh my god, I would be thrilled! Like if it could raise and lower itself, I would be ecstatic”. While she often was given a stool to rest on by the lab instructor who was sensitive to her disabilities, Eilidh remarked that she felt resentment from other students who had to stand for hours. “She would bring me a bench, like a barstool kind of thing to sit on. I mean, I used to get so many dirty looks from people, because I could sit down, and labs are long and it's cold. It's a hard floor... like everyone's back is hurting by the end, or their feet. Eilidh was not sure if these students knew of her disability. She used her creative practice of poetry to explore these new insights, which she titled “How you see me”.

It's funny, isn't it?

In life we always sit

Thinking about our day

Getting ready to go without delay  
They never wonder, who is she?  
They never take the time to see  
Past the illusion of me  
An illusion of fitness  
You somehow witness  
An illusion of youth  
That hides the truth  
An illusion of energy  
To mask lethargy  
An illusion of power  
That distracts every hour  
A constant drain  
That creates my pain  
A constant stretch  
That leaves a wretch  
A constant ache  
Left in the wake  
Of my invisible  
Somehow divisible  
Disability

Eilidh's poem shows her growing realizations about her experiences as a disabled student and the invisibility of her disorders for others. She noted that her professors assume young students are healthy and do not have chronic conditions that affect their experiences in class.

### *Uncertainty about Accommodations*

Eilidh interacted with the campus Disability Support Services (DSS) to receive accommodations for her ADHD, but not for her physical disabilities or newly diagnosed autism. However, she repeatedly complained that she did not understand the bureaucracy and how and why she had to proactively advocate for accessibility accommodations that she felt merely put her at the same level as able-bodied and neurotypical students. She elaborated in the final interview about her difficulties with not understanding the school's motivations and programs both in terms of disabilities but also diversity.

It's kind of like this with the university like, okay, you're saying you care about these things? Why aren't you investing in them? ... Why do you care about reaching out to underrepresented students when they have lower rates of retention than everybody else? Why do you care about having aid available to students, if you have to jump through three hoops and like fight the tiger to get to it, to get to the meeting to talk about it even.

During this last interview, Eilidh described her uncertainty with DSS and the institutional perspective that was unclear to her.

I think a part of it too, is like, I know where I'm coming from, I don't know where the university is coming from. How are they approaching this? What guidelines do they have that we don't know about? That I might be angry about? Because I feel like it's a barrier. But they have to do this because it's a law or something? So, it's like I understand how I intersect as a person, but I don't understand what they're intersecting from. So, it's like running into an invisible fence, almost like... I know, the barrier is there. I don't know why it's there or I don't know what it's intended for. So, I get all this frustration this. Yeah, kind of just like, why aren't you doing the things I need you to do? Because they've never sat down and taken the time to go, here's what we have to work around. Like you can go to the DSS page, you can look at their requirements, but it doesn't tell you why the requirements.

Eilidh critiqued the school's DI&A initiatives as opaque and explained what she needs.

I think I need the school to be willing to just sit down and explain things, because I can listen to them go, we're working on this initiative. We're working on this and as you know, we're reaching out to these types of people and that's all good. Like it's not a bad thing to be doing any of that. But it's a harmful thing when it's not being done correctly. ... And so, like the school increasing like POC, disability students, not a bad thing. Doing it harmfully, though, for the wrong reasons is. So, what are the reasons you're doing those things?

What emerged in the participants' data was their uncertainty about if they should have accommodations because they were not clear on who should receive accommodations. I asked Esperanza in the second interview if she thought she needed accommodations for her physical disabilities and learning differences and she explained she was uncertain if accommodations would hinder her in the culture of extreme rigor.

I just, like... the accommodations that I need, I don't think are practical, if that makes sense. Like... sometimes I have a flare up and it really hurts to write and that like, will live on for days. But it's not like I can stop taking notes, you know, for a couple days until my neuropathy flares down, you know? So, I don't know. Some of those accommodations, I'm like, yeah, it would be great if I could have them but then I would be put so far behind that it's just not worth it.

Esperanza continued and explained how she felt that accommodations were for other students and that learning to advocate for yourself is necessary at Mines, that is, students must put in the extra labor.

But I definitely am luckier than some other people who have, you know, more serious physical disabilities But I think definitely at Mines, like advocating for yourself, no matter what it is, whether it's physical disability, mental health-- like you need more time on an assignment. Like, I think that is something super important here. It's just advocating, saying what you need and making sure it gets done.

In the final interview I asked Esperanza if she thought her physical disability was visible to other members of the Mines community.

I know that I have a disability, but sometimes I don't feel like it's enough to be considered a disability. Whereas like other people struggle more and need more accommodations and things like that, that they should get the advocacy versus myself. So, I think that invisibility is sometimes my choice, I guess.

While Creek has an anxiety disorder, she described her perception of Disability Student Services (DSS) and the need for accommodations for differences as only for those with severe needs. Like the other participants, in interview two Creek explained she was unsure of the process, who accommodations are intended for, and whether accommodations would be helpful or not for her.

Even just having DSS as small as it is.... that's only for people who are like, bad enough to need accommodations. And not all of us need accommodations or need accommodations bad enough to go through that process... It's not something that I need accommodations for. Or where accommodations would be helpful.

### **Section Conclusion**

The participants experienced their own identities on a continuum of visibility, from invisible, like sexuality, racial ambiguity, and disabilities, but also hypervisible like being female. And often they chose to be visible, hypervisible, or invisible depending on the setting and identities of others they were interacting with, like faculty or peers. This choice was a way for them to manage the harmful potential impacts of sharing in the culture of engineering where these identities were subject to microaggressions, suspicion,

or resentment. At the end of the focus group, Esperanza asked Eilidh and I who she should tell that she is possibly autistic based on fears of the potential backlash this information could create for her. Eilidh responded that she is selective due to the possible stigmas that could alter relationships.

### **Section III: Adaptions and Modifications for Self-Care**

#### **Introduction**

In this last section, I share the common patterns that emerged with all three participants' data and content related to how they adapted to resist the culture and care for themselves. These forms of resistance included regular routines of self-care that included leaving campus and relief from the constant pressure to be a high-achieving student in a culture of extreme rigor and weeding out in which they experienced feelings of not belonging. Their data and content also made visible how their self-care priorities were also necessary to recover from their invisible hidden extra labor they had to continuously exert in the face of additional challenges that other students without their identities might not endure. Next, I share the findings about how the HASS department was valued by the participants in terms of supporting student mental health, neurodivergence, and their interdisciplinary interests and ways of knowing. I end with the findings about the importance of sharing their stories.

#### **Self-Care and Time**

All three participants shared in their data and content how they had intentional self-care routines, which they often invited their peers to participate in. In her diary in

January, Creek answered the prompt from the previous interview about what self-care looks like in the culture of suffering.

For me self-care looks like face masks, long baths, new hair products, doing my nails. Sometimes going out with friends or calls with my partner, but those tend to be more draining. For other Mines students it seems to look like videogames, time with friends, parties, socializing.

Eilidh described in the second interview her commitment to her self-care and how it is scheduled into her week.

I try to give myself an hour and an hour half every day, because otherwise I'm going to be a depressed mess. So, I get out of classes Monday, Wednesday, Friday at two. And I refuse to schedule anything until three so that I have that hour gap, to eat lunch, to read a book, to check my emails and not respond. It's very good for me to not respond [laughs]. Or to just like go to my room and have a little bit of a breakdown, when you need a breakdown. And then... Friday nights I don't let myself do homework unless I have something to due imminently. Like that night or Saturday morning. I don't touch Friday night.

Eilidh explained how she reached burn out the previous school year and realized something needed to change.

I wanted to cry all the time. I was stressed, I was very depressed, I was in an unhealthy place. And this summer I looked at myself, and was like, we are not



doing that again. Thank you very much. And so, I kind of built in like, this is how we're doing things. And then it's a lot easier for me to go okay, now I can do this.

Eilidh explained how the culture shapes how students think about prioritizing their time but also how her neurodivergence affected her ability to do school work.

Because I know a lot of us students try to say, when you're done with something, then you can do a fun thing. Which helps a lot. It's like a reward pathway. But sometimes you can't do that, sometimes you need to be happy before you can do an assignment.

Creek articulated in the final interview that having activities that were unrelated to school and being a student were necessary for her despite the pressure from peers that she should be working constantly.

I think there's also some competition in like self-care, but it becomes a... you can get taken less seriously for it, right? So, I've been reading a lot of books lately... So, I've been talking about this and being like, yeah, like, I started setting aside time, at least three or four days a week to read, to just sit and read these books, because I want it and I need it. And people are like, Wow, that's so great. Like, they're genuinely like, oh, I wish I had time to do that. But there's this underlying like, oh, you have time to do that? I'm so busy with actual things and STEM things. And I'm like, good for you, but I want time to not do certain things.

Creek was clear that taking care of her own well-being was important. “I can still love and support you and prioritize myself right now”. During the orientation interview, Creek described how other students often fail to recognize how to take care of themselves.

We don't value self-care... And then they get so caught up in school that they're like, oh, I forgot the only meal that I've had today is caffeine. No wonder you're not feeling good. No wonder this is difficult for you right now. Take a break and eat.

Repeatedly the participants shared how they had to develop their own self-care routines and practices that ultimately improved their well-being. Creek composed a poem as part of her creative content that explored her experience going to the pharmacy off campus in the small town of Golden.

“You’re going to like it here”

It doesn’t matter that I’ve already lived here for 2 years, I believe her now

“I never liked it back there, people are much nicer here”

It doesn’t matter that I’ve been called more slurs here than back home, I believe her now

She was at the pharmacy

Just offering a smile and pleasant conversation

Not toiling over what comes next, and what decisions have to be made

At least that’s what I believed in her smile

I was changing my address, so she could mail my pills to me

So, I'd never see another pharmacist again  
But in that moment, I liked being there  
Stepping away from my school, even if it took me an hour at least to make the  
walk to the store  
I liked her candor and love of this town  
Loved how welcomed I was then, by a stranger handing me my medication  
I liked talking to someone who didn't know everything about my day  
Nothing about classes, exams, jobs, students  
Just candor and welcoming and nothing in between

She changed my address  
The pills came two weeks late

Creek showed with her poem her desire to escape being a student; that is, she enjoyed having that identity invisible for a time as a respite from the pressures of being a student at a prestigious school. Creek also indicates the importance of community to her both on and off campus with the poem.

### **Building Communities of Care**

A consistent finding in all the participants' data and content was in the importance of community and the ability to relax and be themselves without fear of microaggressions or questioning. While there were differences in their experiences, all the participants valued the support of other students for schoolwork but also the importance of

transparently sharing their own struggles. As Eilidh explained in the first interview when I asked her about when she feels supported.

I was really thinking about it and like the place I feel most empowered on campus is when I'm with my friends. Because they are the people who know, I can't walk today or, yep, you can try explaining it to me but unless I see it, it's not going to work.

Similarly, Esperanza explained in the second interview,

I have a lot of very smart friends who just get things right away. So, when I find friends who you know, have to work harder and struggle with things a little bit, like that is super comforting to me. Like, let's work on this together. Like, we can take the time to do that. So, I think support at Mines at least looks like talking about things and not just bottling it up, which I think has happened a lot in the past.

For Esperanza, her best learning took place when she felt safe to ask questions without appearing inadequate or unqualified and therefore potentially weeded out. She noted that she felt comfortable with the doctoral student who supervises her in her research job. She explained how this grad student was patient answering her questions and how this interaction helped her see her future professional self.

So, I think that's where I was like, I want to be like that. Like, if I go into grad school, I want people to feel comfortable having those conversations with me, and I just want to share that knowledge. And you know, let me help you understand what's going on. And even now, I still don't completely understand. But that

conversation, we ended up talking for the whole time and I walked out knowing so much more than I did walking in. And I felt comfortable, like, it wasn't ever awkward, or, like, I never felt stupid for asking the questions. And he was just explaining it to me. And I also just enjoy hearing people talk about their passions and what they're interested in.

In contrast to the culture at Mines that perpetuates rigor and competition, the participants all clearly described the type of culture and community they desired and were working to create, a community based on sharing, vulnerability, caring and support.

### **Interdisciplinarity and HASS**

All three participants were comfortable in several disciplines besides STEM and all three recognized a role for HASS on campus in terms of supporting mental health but also as necessary for neurodivergent students and for those who are interdisciplinary and have wider interests. I asked Esperanza in the second interview about the HASS department and classes as she is a musician and creative. She explained she would appreciate a break from engineering but also that due to time constraints, she desired having fine and performing arts classes for credit, so she does not have to use her limited free time for the extracurricular clubs, which is where much of the arts are at Mines. “I miss doing theater in high school. And I don't necessarily want to do theater here through the club, you know? But having a class for that would be fun”. Interdisciplinary courses were attractive to Eilidh due to her neurodivergence, and she appreciated her HASS courses.

I feel like ADHD is primed for interdisciplinary approaches to things. Because just like, the way we function is, we don't have enough dopamine, we seek dopamine. Interdisciplinary things are the biggest puzzle possible. I like puzzles. I like figuring out why things work. I get excited to learn new things.

Interdisciplinary is the center of learning lots of new things at once, of applying things, of meeting new people. It's a lot of -- like, it's a constant dopamine trail that I don't have to create for myself. It's already created. And I can learn from it.

During the focus group, we discussed these findings about the HASS department and the participants expanded on these findings by describing how HASS faculty create a safe environment to discuss mental health. They all shared that after a recent lock down on campus due to an armed gunman who was on campus and hunted by the police, their HASS faculty were the only faculty to ask their class how they were feeling and invited students to reach out if they needed to talk about it. The participants clearly understood the marginalized status of the HASS department on campus but also expressed how important those classes and the faculty were to their well-being and broader understanding of the world and their work as STEM professionals in the future. Specifically, Creek's shifting perspective over her time on campus showed how she had been socialized by her family to see STEM as superior to HASS disciplines, but that she came to value and respect these courses but more importantly the faculty who taught them.

### **Sharing Stories for Well-being**

All three participants were clear in their data and content that sharing their stories was important to changing the culture but also for helping their peers' mental health in the culture. In interview two, Esperanza explained why she thinks being open and transparent about her own struggles is necessary.

I think talking about it as students and like really being open about our, our situation and like, what we're going through is super helpful. Because I really try and do that because it's like, [peers] should know that I'm also struggling, like, you're not going through it alone. And yeah, it's gonna be hard and it's okay. Like, no matter the effort you put in some things are just more difficult for you to understand and that's okay.

Creek also voiced in the final interview how important it is for faculty to be caring and human.

I think one of the most important things for students is to see themselves in faculty. And in people of power. The professors that I've enjoyed most and gotten the most emotionally out of class are the ones that are most engaged with students, that actually care about us, and that are open. They're actually transparent about how they're feeling.

Creek also described how faculty sharing their own struggles transforms students' perceptions and treatment of faculty. "... we see them as more human, so we are less critical of them. We're less rude.... But we also go, oh, you're struggling too... it's okay

for me to struggle.” Creek contrasted this open sharing and vulnerability with the cultural value of stoicism she has been socialized into in one of her student jobs in which she responds to students in crisis. She felt while remaining professional in emergencies is important, hiding emotions reproduces a culture devoid of full human experiences as well as comes across as uncaring and insensitive. “It’s okay for people to see you process grief for students we’ve lost or to go through that experience and be like, yeah, this is something people do here.” Creek shared how she was open and honest about her anxiety disorder because she sees how sharing her own struggles normalizes mental health struggles, which she believes is key to changing the culture in STEM. “That’s something that I’m actively trying to be explicit about with people so that I feel more comfortable saying it and so that other people get more used to hearing it”. Creek elaborated in interview two that because of the lack of transparent communication about mental health, she notices that when she does share, people can overreact sometimes.

Because there's definitely a little bit of like, oh, no, why did you say that to me? When you first say that to people. Or are you okay, like, how bad is it? And there's this balance between a healthy level of concern over my mental health and like recognizing, I'm not always the best at recognizing myself when those sorts of things are happening. But when other people can see it that's, that's really helpful and nice. But [it] can also get annoying in being like, no, nothing's happening right now. I am just a person who is allowed to vary and allowed to have different attitudes and different moods over time. That does not mean I'm going into an episode. And it helps a lot of people who are like, oh, I see those



traits in myself, maybe I'll go think about that, or to ask about it and get more comfortable with it. And to even realize that I'm not just like a neurotic ball, who like, just shakes all day. And that's what anxiety is.

Creek shared in the final interview how she was deeply impacted by professors who were transparent and shared their own mental health battles with students in class.

I remember being like, no one's ever done this before here. I've been here two years, and no one has ever openly talked about mental health. And it made me feel more comfortable here. To be like, well if he has power and he gets to do that, I can do that with soft power.

However, in the focus group we discussed the risks of sharing their stories and how, after reflecting on their experiences for over a year during the study, they were burnt out and tired of advocating as well. They described their disillusionment with the institution and new insights that changing the culture to be more inclusive and accessible is more difficult to achieve than they had imagined at the start of the study. All three expressed their excitement and anticipation to see the impact of the final dissertation and declared their participation was beneficial despite the emotional rigor it required.

### **Section Conclusion**

The participants expressed throughout the study that one of the changes they were actively seeking and trying to enact at Mines was to create a caring community of support in which transparently sharing the stories of one's struggles was not competition over who was suffering more, and therefore more rigorous. Instead, they were all building

communities of support, care, inclusion, and accommodation for differences. Kindness, vulnerability, generosity, and patience were the cultural characteristics they were developing and employing including with themselves through self-care and their own mental health and that of other students was paramount across the entire study. All three participants repeatedly shared how they actively challenged their peers' reproduction of the unhealthy aspects of the culture at Mines and despite sometimes being accused of not being serious students, they shared their values, stories, and self-care practices with others to actively change the way students think and behave. A major theme for the participants was taking time off not only from coursework and classes, but also getting away from the campus and from their identities as students at a prestigious institution. They also identified the faculty, graduate students, and teaching assistants that were visible role models for these new cultural behaviors they were seeking, and they recognized in these individuals their own imagined professional roles as educators and researchers. And despite cultural biases on campus that denigrate HASS as a department, all the participants repeatedly shared that they valued the interdisciplinary opportunities HASS provides that offered epistemological and pedagogical variety. They did honestly and transparently share some criticisms of the HASS curriculum and even some faculty, but more so each emphasized how they valued the culture of sharing, caring, ethics, and social focus in the HASS department. Often their descriptions of what they valued in HASS included comparisons that these traits differed from most of the STEM faculty and department cultures they experienced.

## Chapter Conclusion

The findings that answer the first research question of how underrepresented students experience the culture of engineering as they are socialized exhibited a theme of visibility. Our data and content showed that visibility fell across a spectrum for the students in relation to the culture with some features and expectations hypervisible, like the culture of extreme suffering and their peer's performances and reproduction of these harmful elements. Their data and content show that they came to adapt and modify their own expectations and behaviors after feeling the negative mental health impacts of accepting the culture and trying to operate within it. Indeed, their participation in the study was a further effort on this mission to change the culture so that others who come after them do not have the same negative experiences. All three participants were troubled by the invisibility of the weed-out culture and practices of failing large portions of students in their early core STEM courses. They described the impacts on their mental health but also on their learning, like a fear of asking questions in class. A major impact they all described was uncertainty and suspicion of the university's intentions as the weed-out culture was not explicit and this lack of clarity generated resentment towards the institution and faculty. They did not see the value of trauma bonding, as Creek put it, in their education and preferred faculty and staff with whom they felt safe and comfortable being vulnerable while learning. They preferred the joy of learning rather than the fear of failing.

The visibility of their own myriad social identities was salient throughout the data and content. Initially I included the lens of visibility as part of the list of interview

prompts I presented to the participants during the orientation, and all three participants were intrigued by the concept at the beginning despite being uncertain if it was something they experienced or not. However, each participant incorporated a lens of visibility into their own research self-reflexive process and used the idea critically in discussing and describing their own experiences. By the end, Esperanza was aware that she chose to keep her disabilities invisible to others, for example. And Creek and Esperanza both described the selective choices they made to signal their mixed-race identities to other students of color and make themselves visible, while also noting their discomfort with being able to pass as White among White faculty and staff because they each understood the benefits that come with that ability in terms of feeling of belonging. Creek also described how she signals to others that she is part of the LGBTQA+ community in how she dresses while remaining invisible to heterosexual peers to avoid harassment and questioning. For Eilidh, the invisibility of her various disabilities was a source of extra work and stress for her as she navigated her education and interactions with peers and faculty who were unaware of her differences and how they shaped her experiences. The emotional toll of the extra labor on all three participants experienced in the culture was noteworthy and a robust finding across their data and content.

## **Chapter 5: How Did Creative Materialism Function to Answer the First Research Question?**

### **Introduction**

In this chapter, I used the participant generated data and content to show how the creative materialist framework I theorized worked for the participants and me in the study. The primary focus of our collaboration was to answer the first research question, which investigated the participants' experiences of the socialization process. However, I theorized creative materialism as a culturally responsive methodology (CRM) for the study to purposively counter the domination of positivism in the culture of engineering education and research (Berryman et al., 2013b). Below, I show how the relational and responsive approach of entangling ourselves in the research process generated the study's findings, but also how new identities emerged through personal transformations. I include my own voice in this chapter through quotes from my academic research memos, which I used to analyze and interrogate my own experiences of the process. A major and unexpected finding for all three participants and for me was increased awareness of our own neurodivergence and specifically, three of us seeking medical diagnoses for autism. The methods also provided the means for the participants and me to identify and clarify what was invisible in their experiences in the culture, which transformed how they perceived the institution and their relationship with it.

The methods and conceptual framework we used produced collaborative emergent knowledge through our interactions as co-researchers as we repeatedly looped with the prompts separately and together. While the participants built on their insights across their diaries, creative practices, and in our conversational interviews, I organized, analyzed, and interpreted their data and content through a looping process that included writing memos, drawing mind maps in my dissertation journal and on my white board, and by transferring their data and content on to color coded notecards. I pinned these note cards to my office wall and constantly moved them around in relation to each other and as I added more cards after each interaction with the participants' diary entries, creative poetry, photographs, and drawings and paintings. The focus group at the end of the process provided a milestone for the participants to reflect on their own movements in their understanding of their experiences in engineering education but also how they were transformed by their participation in the study and use of creative materialism. I found that the methods presented both barriers and opportunities for the student participants as they experienced the culture of engineering.

### **Transformations**

There were two types of transformation that emerged from the findings of the study on how the creative materialist process worked. One, we all added the identity of being neurodivergent to our current mix of social identities, which was not an expected finding for the study. At the start of the study, Eilidh was the only participant who had a registered learning disability with Disability Support Service (DSS) for ADHD. By the end, Eilidh and I had medically diagnosed autism and Esperanza had scheduled a medical

evaluation for herself to uncover her own suspected neurodivergence. Creek chose not to pursue a formal diagnosis for herself due to the legal and social stigmas and implications that are entangled with autism but acknowledged that most likely she was neurodivergent. The second type of transformation we experienced through the process was our increased understanding of how the three participants experienced the culture of engineering. That is, by answering the first research question we also increased our awareness of the research process itself as we generated new knowledge and insights. In this first part, I share my own experience of coming to know I had autism and ADHD. In the second part, I share short vignettes of each participant's transformation by showing the process of our knowledge creation itself.

### **Coming to Know My Neurodivergence**

Like the participants, my experience of coming to know how I am neurologically different generated a wide range of emotions, which I moved through during the post interview phase of the dissertation research and to the very end as I write this chapter. My own data and content from this period showed the process of coming to know as turbulent, painful, confusing, disorientating, relief, disbelief, exhilaration, calm, and wholeness. I experienced depression, anxiety, uncertainty, anger, resentment, sadness, stubbornness, determination, and resistance to being marginalized due to the stigmas associated with neurodiversity and particularly autism. However, through the process of compiling the findings and writing the final dissertation, I was able to visualize future paths for myself, the participants, and others like us in which not only the education systems but also society and workplaces provide care, connection, reciprocity, and

respect for cognitive diversity. At the end of this process, I felt a mix of emotions including responsibility, confidence, and celebration, while continuing to feel vulnerable yet empowered, scared but also proud. I feel deep gratitude for the transformative knowledge of who I am and pride in what I can contribute through this research and dissertation.

I began this study by theorizing a methodological framework that would be an alternative to the positivism in the culture of engineering education, which also is prevalent in engineering education research as well. Particularly, in my proposal I wrote that my study confronted “the hegemony of positivism in EHED” by filling the methodological gaps in the extant research with culturally responsive approaches, new materialist theories, and arts-based research methods that explicitly reject objectivity in research. Indeed, CRM (Berryman et al., 2013a) provided the support to consistently humanize my interactions with the participants and resist notions of objectivity that permeated my entire educational experience and preparation, and which always crept back in after interviews in which I criticized myself for being too conversational. As I wrestled with my academic training that emphasizes maintaining objective distance in my proposal, I wrote that,

In my study, there is no distance between me as the researcher and the student participants as CRM principles theorizes me as a learner with the students, not an outside expert there to study them objectively. This relational power-sharing requires that I continually conduct self-reflexive critical interrogations of my own



assumptions and my power as the researcher, but also those grounded in my social identities like gender and race.

Notably, I did not include neurodivergence as an identity for myself while theorizing creative materialism, despite creating a conceptual framework that fits with my ways of thinking through creativity. In addition to CRM (Berryman et al., 2013a), my approach relied on new materialist theory. In my proposal, I wrote that in Nail's (2021) contemporary loop object (CLO) theory "scientific labor becomes the very process of knowing materially, relationally, and iteratively... a process of knowing that does not obscure the process itself". I pulled these ideas together and wrote in the proposal "I combine the qualities and principles of CRM, CLO, and arts-based research methods to form my interdisciplinary conceptual framework of creative materialism, or what I theorize as a kinesthetic-onto-epistemology". I also theorized the chaos theory in CLO theory to conceptualize the liminal experience of coming to know as epistemic turbulence. "From a theoretical perspective, chaos theory describes the inability to mathematically predict and model chaotic systems like turbulence". That is, I recognized the lack of clarity that generating new knowledge can create through the process of coming to know itself. I explained in the proposal:

Because I am a learner in the process and must continually reflect and self-interrogate, I am also a beneficiary of the study. I benefit by coming to know myself, my assumptions, and my ideological agendas through my own intersecting identities as I work with the students to come to know their experiences. I benefit from learning how my U.S. academic training and how my

social identities, as a White, cis-gendered, middle-aged, able-bodied, heterosexual woman PhD candidate and EHED adjunct professor, affect the creation, implementation, and experience of this project.

I anticipated that “As an artist, my creative materialist framework provides me an opportunity to enact my unique kinesthetic-onto-epistemology in social science research that emerges through self-reflection”. With this context set up, I now share my own data from my memo writing that illustrates the transformation process and slow realization that I was a member of the neurodivergent community, which initially emerged through my interview interactions with Eilidh.

On a Friday in late April, I wrote a reflective memo about my process of analysis for the participants’ individual data and content. What is evident in this data, from my position now, is how I was still unaware of my neurodivergence despite describing a neurodivergent process that I had created, and which was not only comfortable for me, but joyful.

I am so happy to be back doing theory... def some happy chemicals there, dopamine trails as Eilidh says. It is firming up the new pattern of being, as creative materialism, that was started in 2019 at the old studio. It comes back to me quickly now. And I have a dopamine trail in the office here... documents spread out ordered on the floor in front of the white board, the proposal, and other docs out for access. I summarized my theories to make sense of them again with

the content and it is so exciting to apply it and see what emerges... kind of like magic lol. Creativity is like magic because it is not logically explainable.

I also reflected in my memo on the disciplinary feedback I had gotten over the past few years through conversations with engineering educators and researchers about my use of the disciplinary term arts-based research in EHED research and that there might be push back and a rejection of subjective methods because of the cultural bias towards positivism.

I was told using the term creativity is okay in STEM because there is science about creativity.... But I am finding [the creativity research] is all these quantitative tests that have been created that they think pinpoint the specific behaviors or mindsets that are directly linked or correspond to creativity. Weird. Perhaps my mission is to be a scholar on creativity, interdisciplinary, and innovation.

I also reflected on my reluctance to claim an identity of neurodivergence. As my data shows from journal entries show, it was a process to come to understand, accept, and claim this identity.

I did some research and watched some YouTube videos about autism yesterday and realized that the term neurodiverse is specific to autism and other diagnosed disorders. So, me taking it and expanding on it may be a bit colonial... I will have to do some more research on neurodiversity and creativity, STEAM, etc. to figure out how to define myself. I watched some stuff on autism in women and it is

different than boys/men. But the woman said clearly that we are all NOT on a spectrum. If you have only a few traits of autism, then you are not autistic, but just have those traits. Autism is very specific and comes with its own difficulties in functioning. She brought up Very Sensitive People too, which I identify with. I think my issues are more cultural than biological... first generation, working class, creative and aesthetic, social anxiety and depression over these differences. Interesting... that also may explain my extreme imposter syndrome and why I never feel like I am good enough. Why I overachieve.

Wow, wasn't planning to write or explore any of that. Was thinking about my methods this morning over coffee... how they work and why. How they are different. How I would explain it to a room full of STEM men. Part of me wants to make charts and compare and contrast between points/measures... other parts of me want to loop unstructured and just flow with it and see what bubbles to the top. I want both! I don't need to choose... I just need to know when and how to do each... and endless compilations of mixes.

The following Monday I reflected on the emotional punch I experienced over the weekend as I further investigated and tried on a neurodivergent identity. My memo writing captured not only the transformative process of looping repeatedly with the new knowledge that was emerging, but the turbulent emotional implications of this new knowledge.

I woke up Saturday so sad and troubled I could barely function. Poetry spewed out of me in the pink journal, which helped. But I was so agitated explaining it all to [my husband] that he went back downstairs without a word... I was just too intense and upset. It felt like I needed a break, not to go deeper, so I went outside for a couple of hours. I woke up both mornings with a simple phrase immediately popping in my head as I became conscious: I am scared. I am sad. Just acceptance of those statements.

Actually, on Sunday morning I had a realization that felt very freeing... I am going to get tested for autism. I just need to know. It would explain soooooo much of my struggles. Am I just truly different? Not just quirky, but wired differently? It felt very freeing to think I am, that I can embrace this... that science can explain me! But I cannot claim it without a formal diagnosis. I just did not know that many autistic women are in the arts. The more I watch videos about women and autism, the more it is clicking. The traditional male version is not me. I wonder about the connections between interdisciplinary people like me and disorders like autism or ADHD....?

Later that day I continued to reflect on the implications of this new knowledge in my writing as the realization sunk in that I was autistic as I gathered more data on autism in adult women. I wrote "I decided to look up autism diagnosis in women later in life... makes me want to cry, makes me feel sick and sad. Jesus, that is me!!! So much of it makes sense. I need to find someone who knows this disorder in women! Jesus.... Fuck. Wow".

As my writing below shows, as I looped through the implications of this new identity in relation to my past and my lifelong strained relationship with my late parents, I experienced a range of emotions that came quickly as the new knowledge transformed me. But my reflection also shows my coming to understand the complicated issues around girls and women getting an official diagnosis but also the implications for me that autism in females was not well understood in the 1970s and 1980s.

I emailed my provider that I need testing info ... looks like it can be expensive. Need to find out more. Wow, can't believe this might make sense! And if it doesn't what does that mean??? So sad if my parents just didn't know I was different... and they made me feel shitty, ashamed, rejected because of it... they didn't know. None of us did. The depression makes sense... Not understanding how I fit, not being able to see it. Wow, I just keep moving through this and it is scary but also affirming. Bit excited at possible answers.

Now I am laughing... it has to be this; it all makes sense... I feel so awkward and unsure... not worthy, too weird, not normal. I thought that it is because I am an artist... but I think that is just how I primarily experience the world... Maybe my extreme visual acuity too? And the tactile and sensory stimulation of oil paint on a brush being pushed around on canvas...?

Of constantly seeing connections others just don't!! And the frustration that others can't see!

My family: you're too sensitive; you don't behave properly; why do you have to dress weird? You talk too much yet you don't know what you are talking about; we go one way, you go the other; irresponsible, selfish, failure. Distracted, flighty, weird. Broken, lazy, rebellious.

My parents told stories that I didn't talk until I was almost 3... then I never shut up hahaha. Man, that stings. But yeah, they took me to a doctor. My tactile experience of drawing with sharp pencils on the unprimed drywall after sharpening my pencil in the basement [as a preschooler]... I can still hear it, smell it, feel it. My earliest memories are of creating visually.

It has to be autism... it has to be.

It is so strange to sit here and try on the identity of autism; I am autistic. I feel space moving under me... shifting. Bit scary but also toward the light, toward understanding. I am more afraid that I am not and what that would mean... that I am just a neurotic failure?

Depression and anxiety often form for [autistic] girls at adolescence because we don't get the social shift and cultural changes that are happening. This is when I started to feel very alone... along with being 6'1" at 13 in seventh grade. Started cutting myself with glass I found in a parking lot when I wandered away from the movie theater and friends to cry, to be upset, to fall apart. Was this the suffering I wanted to end with my aborted suicide attempt [in high school]? The loneliness? The constant stress and anxiety to the point of feeling disassociated physically...

hearing and sight altered. Deeply despondent and depressed... everyone else moving in a dream like state while I moved through the shadows around them?

My entire internal and historic narrative about myself is being called into question as I turn this all over... huge. Overwhelming.

My empathy for suffering is just off the charts... how to explain this?

Naps... time outs, and resets. Remove stimulus... decompress... [My husband] is okay with me staring out the window for long periods. He is so accepting of me!

So kind. The noise of the TV and it always being on... felt extremely autistic.

Like I could not deal with it, like everyone is talking in my head... like there are a 100 people in the house.

The next day I continued to write as part of my process of coming to understand what this new identity I was slowly claiming meant, along with my fears about sharing it and claiming it publicly. A major shift had occurred for me during this transformative process of reflective writing, and I described the disorientation that emerged as I saw myself from a new perspective never before available to me.

Read some more on autism in women... it will be very hard to get an official diagnosis but as I think back over my life, not how I want to be or see myself, I see a strong resonance with autism spectrum. High functioning but still it explains so much. Stuff I wasn't even paying attention to.



Not sure how I feel about it today... feel less like celebrating than yesterday. Bit more depressing knowing all this was missed, still feel broken but in a new way.

It explains my anxiety! I'm tired and going to lay down.

Keep thinking about the autism thing... I am afraid to tell [my husband]. Not sure how he is going to feel about it. I think I want to see a psychologist too to get diagnosed but also to help me understand it and how to adapt. So much of my past makes sense now.

The next day I was still working out in my reflective memo writing if I fit on the spectrum, but my thinking had shifted from emotional insights to analysis. "I think I will make a list of the female autism spectrum traits that resonate with me. It will help me make sense and help me explain it to others". The list I made was extensive and helped me to see myself clearly in the data on adult women with autism. By the next day, I was incorporating this new knowledge into my creative materialist methodologies. It was dawning on me that I think differently and that perhaps advice from previous doctoral candidates on how they approached writing their dissertation did not fit me and the way I come to know.

Executive disfunction- it takes me almost an hour to start painting as I circle around it... whole ritual. Wondering if this daily writing is working that way too... to get me "warmed up" for the computer. Also thinking about a friend who was an athlete who approached her dissertation as an athlete pushing herself to complete [her work].

By later in the month, my academic memo shows that I had moved towards acceptance, despite the months of turbulent struggling and emotional stress that were still to come. I wrote, “The autism thing continues to sink in... I still have moments of doubt, but a few minutes of thinking quickly reminds me that nothing captures my life like autism does. It is a unifying concept”. My writing process based on my conceptual framework of creative materialism provided the means to not only be transformed but recorded my transformation for use as data in this final dissertation document, which was not something I had anticipated when designing the study.

I was tested in late August 2022, and had to wait a few weeks to get the results back. I wrote that morning on the day I received the diagnosis in early September and titled the memo “Big autism diagnosis day”. I felt uncertainty, anticipation, and fear. “Well, 45 minutes until I get my results back... feeling nervous—what if I am wrong? What if there is something else wrong with me?”. My diagnosis revealed that I also had ADHD, which had never occurred to me nor had anyone suggested that I had it. “Yup, definitely autistic but also ADHD!! That was a surprise to me... it explains the inability to stick with one thing despite the autism deep focus”. I was also insecure about the IQ portion of the evaluation. I wrote “She could not come up with an IQ number, but I am in the high to superior range. So, I am smart—was a bit insecure that would come out low for some reason, despite people always saying I am smart. My verbal [IQ] is very high”. The doctor explained that due to the dyscalculia and ADHD, there was no way to quantify my intelligence because of the nature of the tests used. In some areas I was superior, while in others I was average and in one case, below average. In hindsight, I

think these fears were related to the stigma of autism and learning disabilities; I was wrestling with the concept of “being disabled”. I was also diagnosed with a chronic anxiety disorder, which I was unaware of, but this new identity allowed me to better understand my physical responses to stress as an autistic person for the remainder of my doctoral journey. That is, my transformation through using the framework of creative materialism, in which I was required to critical self-reflect on my own experiences during the research with the participants, provided new insights and knowledge that improved my mental health. The process moved me from turbulent chaos to new understanding about myself.

As shown in my memo excerpts, my new neurodivergent identities came as a shock and had considerable emotional and psychological impacts, which initially affected my ability to process the data and content after the interviews were done in May. I had intended to share the neurodivergent news with the participants after my medical evaluation and formal diagnosis in person at the focus group, which I had planned on holding at the end of the summer. However, as I struggled through the summer and early fall with compiling individual profiles and summaries of the findings for each participant to review and approve, I kept pushing the focus group meeting date further into the fall. After receiving an email from Eilidh wondering about the schedule, I decided I needed to be transparent and let them know what had happened. I sent a version of this email below to all three participants in early October.

I am so sorry I have not been on schedule. I really underestimated how much effort and time it would take to get back into teaching this fall and am still

struggling to find the time to write up the results, but when I do have time, it is going very well, and I am excited. Also... I was going to share some news with all of you at our focus group meeting, but since that is going to be at least a month or so away, I figured I would share it now.

Part of the reason I am so behind and my spring/summer were a mess is I found out I am on the Autism spectrum and have ADHD! I would never found out if I had not done the dissertation research with one of the participants who is on the spectrum. I came home from the interview with her in April and looked at the literature on women and autism and after reading an article went, oh my god-- that's me!!!! I was tested by a neuropsychologist at the end of August and she diagnosed me with ADHD too, which I had no clue about!

It COMPLETELY rocked my world. In an instant my whole life made sense, but also fell apart. At 55 years old, I had to reevaluate my entire life to understand it through this new lens. I am so happy to know and am proud to be a member of the neurodivergent community-- I even came out to my two Global Studies classes and it has fundamentally changed how I see diversity and inclusion now. So, it has been an interesting six months and very disorienting. I still feel a bit unsteady, but the official diagnosis really helped by confirming that how I am in the world is unique and not a choice. But lots to process so I am just trying to give myself some grace and take it all day by day. So a lot has been going on. I am sorry if my disordered life has negatively impacted you in any way. I am still a few weeks

away from getting you your results so I am thinking we can do the focus group in December after the semester ends since we are all only going to get busier. Let me know your thoughts on our schedule.

All three participants responded with respect, understanding, and patience. Eilidh was stunned that her sharing had affected me so profoundly. She replied to my email,

I am so glad you were able to get that diagnosis and start to learn more about your world. I completely understand what you said about it making everything make sense but then also making it worse somehow. It really changes the world and how we view the world. It's a hell of a process and I am still going through it. I have found that it makes things so much easier in the long run. I am very glad, however, that I was able to help in the process for you. I never thought that I would be an example for someone and help them figure out their diagnosis... Please take as much time as you need for the dissertation and teaching.

Esperanza responded with curiosity about this new identity but had not yet made connections with herself, nor had I, though we would both come to see it clearly in her data and content later at the focus group. This data also shows how our professional relationship was emerging with respect and kindness.

It is so great to hear from you! I am looking forward to reading your dissertation results and completely understand it taking more time, especially with how intentional you are about how you represent us, which is much appreciated!... Thank you so much for sharing this big transition in your life with me! I can

imagine that it would be challenging but also relieving to explore and understand this new side of yourself. I am so happy to hear that you have been taking time to better understand yourself and that this has given you a new lens/passion in the way you look at diversity and inclusion. I have had a lot of shifts in my life recently that has given me a new found passion for DI&A and better understanding how to support the neurodivergent community here at Mines... I would love to talk to you about some of your perspectives, experiences and I would love to hear some of how your perspective has shifted through this new chapter... I do miss our chats on some of these topics and am always interested in hearing some of your new perspectives. If this is too big of an ask or inappropriate based on our relationship, please let me know.

We met for coffee over Thanksgiving break and Esperanza asked me about how I came to understand I was autistic and had ADHD and how the testing worked. My sharing with her had transformed her perspective on herself and created a new orientation toward learning more about neurodivergence and fitting this new information into her understanding about her own experiences as an engineering student who struggled with how she was taught at Mines. Later, she emailed and asked for the name of my neuropsychologist, who is one of the few in Colorado with expertise in diagnosing autism in adult women, which I gave her. By the focus group in early March, Esperanza had done research and was accepting that she was most likely neurodivergent.

Below are excerpts from the focus group meeting transcript in early March of 2023 that show how we intra-acted and discussed this major finding about all of us being

neurodivergent. Esperanza arrived a few minutes late to the meeting because she was making her neurodivergence evaluation appointment.

Esperanza: I got my test scheduled. So, I'll be tested in May. I'm super excited. Because I think for me, it's just like, I found out through you that I have a lot of those characteristics. And I've been doing research for like the past three months. And I'm like, wow, I really identify with this. And I just think it would help me, like in my interactions with others. And I have real learning challenges. So, I'm hoping to better understand how I learn and how that can be more effective.

Katherine: Well, I think it's the method because the creative materialism I made was neurodiverse to fit me because I'm creative. And I had all these adjectives for myself, but it turns out, I'm just autistic and have ADHD.

We discussed how I found out through the research process with them and Eilidh was still sensitive that she was the catalyst for all this new information. I assured her it was a good thing. Creek shared with us that while she was not seeking an official diagnosis, she was accepting this new identity as well. I share this excerpt from the focus group below because it illustrates how each autistic person is unique despite sharing characteristics or traits.

Creek: I'm currently in a spot where I feel incomplete without that descriptor, without being like, you know, I have symptoms of ADHD and I have symptoms of autism. Because like Esperanza was saying, it is a significant thing that

contributes to how I interact with the world.... it's the same way I have physical sensitivities.

Eilidh: I can't touch velvet or corduroy because of that.

Esperanza: Oh my gosh! Hairy leather... [laughter from everyone] is what velvet is.

Eilidh: I describe it as tarantula legs.

Katherine: See and I'm the opposite. I went to the neuro psychologist, and she has these beautiful purple velvet chairs, and I was petting them. And I'm like, there's so pretty! I love texture....

Creek: There's good texture and there's bad texture.

During our meeting, I reflected and shared how I came to see their data differently because of my diagnosis and new knowledge about neurodivergence, particularly Esperanza's.

Katherine: it's funny rereading your [Esperanza's] transcripts, because again, when we were talking about your childhood and all these things. And I was like, oh, that's so interesting. And then I reread it while I was doing the chapter, and I'm like, oh! NOW I see it!

Esperanza: Even just like sharing some of the things that I did as a child with other friends who have autism, they're like, how did your parents not know? But they really just like, weren't educated. You know, like, my, my mom, I'm pretty



sure has autism, but her parents were immigrants, like they had no idea. They didn't even take her to an eye doctor till she was 20 years old.

This focus group exchange shows the transformative power of sharing stories within the creative materialist framework and the process of continuously looping with previous and new information as it emerges within the context of the research project and our goals of increasing understanding of the participants' experiences. I explained how they had transformed me and inspired me to advocacy because of what they had shared through the research process, that their individual motions toward creating new knowledge had changed me as well.

So, it's funny, because the three of you were like, I want to do this research. And I want to be an advocate. I want to make change for other people. And now I feel I've taken that on, because of what I've learned with you, so I'm really happy with the way this has come together as far as like, it feels like a collaboration. I hope it does for you as well.

As our combined looped and entangled data from our intra-actions showed above, it was the conceptual framework that provided the means toward self-awareness and transformation through uncovering new neurodivergent identities that were previously hidden from us. The CRM requirements (Berryman et al., 2013b) of sharing power, transparency, and building trust and rapport as a collaborative research community of co-researchers provided the space and theoretical grounding to build relationships instead of attempting to maintain objectivity and distance between us. My use of Nail's (2021)

contemporary loop object theory and his conception of research as a hybrid emergent looping feedback process allowed us to continuously build new knowledge, loop it back in together and apart through sharing our stories of transformation, from which further new patterns of knowledge emerged. While our culturally responsive collaboration resulted in new neurodivergent identities, in the following sections I show how the various data and content generation methods worked together to produce new transformative insights for each participant in the study related to their answering the first research question about their existing identities that they were aware of at the start of the study and how those identities shaped their experiences in engineering culture.

### **Participant Transformative Learning and Knowing.**

#### ***Introduction***

Because of the unique creative materialist framework and the conceptual foundations of Nail's contemporary loop object (CLO) theory (2021), I designed our data collection and content creation to emerge through our interactions to show how new knowledge was emerging. To this end, I brought in terminology like looping and oscillation (Nail, 2021) to the conversations with the participants to describe our process, which they adopted and used. Below I share short vignettes that illustrate our relational, intra-active process of generating new knowledge using the creative materialist framework and the specific transformations the participants each went through with this process.

#### ***Esperanza's Experience of Burn Out at Mines***

The story of Esperanza's struggle with the culture of burning out manifested during the data collection period and through her interview, diary entries, and creative content as she communicated her concerns and feelings in response to a crisis she experienced in January as we started our collaboration. This crisis triggered a post-traumatic response; however, she was not aware of this as we sat down to talk in the tiny study room at the library in mid-February for interview two. I noticed that Esperanza's energy had changed from earlier in the semester where she expressed excitement and optimism for the new semester. She arrived a few minutes late and was visibly emotionally troubled, which she explained was from concern about a fellow student's mental health crisis. She tearfully indicated she did not want to elaborate, so I did not press the issue. Much of that interview focused on the extreme rigor and weeding out process in the Mines culture and how it affected her ability to handle this unexpected crisis.

Like even with this, asking for an extension on this exam that I have tomorrow, like, I'm really nervous about emailing my professor, because I don't know how they're going to take it. If I have to take the exam tomorrow, I will-- if it's gonna put me behind. But I also would really like that time [to recover].

It was in her diary entries that she sent prior to the final interview in May that she explained it was a fellow student's suicide attempt that had triggered old traumas for her. Below I share my memo from late April that illustrates our relational, looping, and emergent material process of generating new knowledge; this is the same writing session

and memo that I shared first in the previous section in which I was first grappling with my own neurodivergence.

Esperanza sent her content to me, and she is dealing with suicides over at Mines. Gut punch... had to go get a hug from [my husband] in the kitchen after reading her short diary entries. And there is no wiggle room for her to deal with the emotions of it... we postponed [the last interview] until next Friday 5/6. I will stick with Creek today I think... transcribe Eilidh next week too and fold her back in while I prep for Esperanza by re-reading her past content. She asked in her diary who she can turn to and give her emotions to... she takes everyone else's on. I told her she can tell me if she wants. This treads a fine line between therapy and research, but I don't feel like removing emotions is the solution. There seems to be no room for emotions anywhere on that campus... like they are all rational agent robots performing tasks.

I suddenly feel drained and want to walk away from the project for the rest of the day... work in the garden, go for a walk, paint... read. Since I don't need to be ready for Esperanza on Monday, perhaps I will shift to deal with the emotions of care and responsibility to help... all of them, the whole campus. It is a mental health emergency. My gut hurts.

In the final interview Esperanza and I discussed her diary entries that she had shared with me, and she indicated that she was extremely stressed out, fatigued, and worried about her grades.

And it's just like the worry if I miss this day of class, then I'm gonna have so much more to do in the future. And I think when you're in the moment, everything is just so overwhelming, where like, you don't even know how to handle your emotions. It's like, how am I... like, it's hard to think past the next five minutes versus, down the road, how am I going to be feeling? How am I going to be able to do the schoolwork?

Esperanza wrestled with her lack of control over her trauma and emotions around her peer's suicide attempt and how it affected her in the final interview. "I should be over this by now. It's like... it's like, I should be over this by now. Like, why am I not?". She explained that the mental health guidance she had received, which was to take as much time as she needed to recover from the trauma, was unrealistic.

I feel like [the school] has a culture of just go go go. Like, there is no room to be human or to have emotions or to deal with things. And so, like, [from the] Counseling Center, it was good advice. But I wasn't really able to really enact that advice. Life happens. Everyone has emergencies.

For Esperanza, taking any more time off other than a few days meant falling behind on assignments and exams, which created more stress. She explained that the only areas of flexibility for her timewise were in her three on-campus student jobs where she felt like she could ask for time off.

However, Esperanza found the research experience using creative materialism provided her the methods to reflect on her experiences and gain perspective. I asked Esperanza about her participation in the study during interview three and she replied,

“I’m so happy that I did it. I think it was insightful too”. In the final interview we discussed the photos she had taken on a trip to the mountains with friends that she used as part of her creative content for our study and the process by which she looped in new experiences as part of her participation in the study. She explained that she realized leaving campus was necessary for her mental well-and helped her recover from the trauma of the semester. She said, “I had been on campus for like two months. Like I hadn't left and so I went on a weekend trip with a bunch of friends. And it was just so good to get off campus and not worry about school, not worry about responsibilities”. Esperanza took pictures of the winding mountain roads from the front seat of the vehicle and explained that with our research in her mind, she reconnected with her earlier love of roads and infrastructure through taking photos.

So, all these pictures were just kind of like scenic pictures, but it really like represented just a place that I could just like breath and not worry about being on campus and all those responsibilities. And like, I think going back to some of the [interview] questions, I think for me, a lot of my life is school, whether it's work or whether it's academics, it's a lot of just thinking about school and worrying about school. So, like it's really important to get out and take care of yourself and I think I had neglected that for a long time. I took pictures of some of the driving and the roads and going through that it really took me back to like, oh my gosh, I love roads, these are so cool! Where it's like, this is why I got into engineering. So, it was just good for me to kind of go out and be like it's okay.



Figure 8: Photograph by Esperanza of Road and Infrastructure

I gave Esperanza her profile and findings summary in the fall of 2022 for her to review and provide feedback. She responded in late November in an email:

Thank you so much for your patience as I worked through this! It was challenging to read through as it brought up a lot of emotions as I continue to go through my DI&A journey here at Mines. Overall, it was interesting to read about my experience through the research lens and continued to give me good insights the more I read it. I left a few comments in areas where I had questions or thought there may be space for clarification. I did not leave a ton of notes however, so let me know if there are any other questions I can answer. I would still love to grab coffee and chat whenever you are available even if it needs to be later in the semester.

Esperanza's participation in the study allowed her to witness and reflect on her experiences of burning out in the culture while she was experiencing it, which provided a unique vantage point for her to come to understand these experiences. Put another way, her reflection on the culture and how it impacted her was not theoretical or abstract, but material and embodied. It was through her looping the study into her off campus experiences and sharing her reflections on the previous interview conversations and prompts while creating content in the form of photographs that she generated new knowledge about her own lived experience and how to prioritize self-care.

***Eilidh: Coming to Know and Love Herself***

With her learning and physical disabilities, Eilidh confronted her own expectations about her grades and previous academic abilities prior to Mines, which was a deeply transformational and profound experience for her during our collaboration using creative materialism. Eilidh's participation provided her the space to reflectively and collaboratively work through the various entangled experiences and identities related to her disabilities and confront her own feelings of vulnerability. She related in the interviews that because she came from a low-income household, she felt that her good grades in K-12 were one of the few things she owned, that was hers. Because of her learning disabilities, her grades in college consistently did not represent her knowledge and abilities and she had to adjust her own identity in this new rigorous weed-out climate at Mines. During the second interview, Eilidh elaborated on the impact of realizing she was no longer the "smart kid".



Because a lot of us get academic validation, we get told we're smart from the time we were kids and we started doing better than our peers. So, all of our self-worth comes from that little five letter word that we're smart. We get the A's-- we're those kids, right? And then we come here and we're not. And it stings like a bitch. Like last year, sophomore year, I was trying to work to de-connect my self-image for my academic success... I was miserable.

By the final interview Eilidh explained the emotions she experienced as she had to adjust her identity in relation to her now lower grades at Mines as feelings of shame, anxiety, depression, sadness, and a loss of dignity.

It's because my sense of self-worth for years was attached to that good grade. So I got the high on the test, I had the best transcript, all of it, right? I had the whole shebang. And now I'm at a school, everyone's really smart, everyone's really talented, we wouldn't be here if we weren't. And someone's got to be the 50%.

Part of Eilidh's transformation through her participation in the study using creative materialism was a move to self-care and accepting her limitations, which she expressed in a poem she wrote as part of her content creation for the study entitled "Gifted Burnout Kid":

They called me gifted once  
A label for all the A's  
They called me smart once  
A label for setting all the curves

They called me creative once  
A label for different thoughts  
They don't call me that anymore  
They call me lazy now  
A label for an inability  
They call me slow now  
A label for a lack of care  
They call me burnout now  
A label for someone who doesn't care  
Why do they call me that now  
Because the A's turned to B's, turned to D's  
Because I saw the doctor  
Got the words to say how I felt  
Because I'm tired of striving  
Striving for an expectation I set  
That I set when I was still  
Gifted, smart, and creative

Eilidh described in her data and content as we looped together and apart during the study how she was learning to adjust her expectations for herself and learned she could not compare herself to neurotypical students. She described in the last interview her new vantage point and how she was learning to love herself as she is with her unique embodied experiences.

Instead of saying I need to do better than everyone, I started looking at the average. And really just telling myself that my goal for college is to get through college. Because even if I get into a worse than I wanted grad school, I'm still in grad school. I'm still doing the PhD stuff, right?

Eilidh also used her research participation to better understand her physical disabilities as well, which resulted in her increased awareness of her own deteriorating physical body, and she allowed herself to imagine her future self with sight impairment and limited mobility. Her new vision of her future also included her reflecting and imagining on how other students with physical disabilities would experience the Mines campus and culture of extreme rigor. An example of this intra-active insight and new knowledge creation is visible in our interview discussion about the tradition of the M-Climb, which represents the hard work to come as an individual student joining the Mines community. This concept is represented by the individual rock each new student carries up Mount Zion, the large Rocky Mountain foothill that overlooks the campus. Each student then places their rock next to other rocks that previous students have placed in the form of a giant M, which is visible from campus below. The tradition is so important that faculty and staff are encouraged to participate in the event. As Eilidh had physical disabilities that made mobility difficult, I was curious what her experiences were with the M-Climb tradition. During the first interview, I asked Eilidh specifically if she had participated and she lit up at the question and proceeded to describe how much she loved it. She described how she appreciated the welcoming and support of upperclassmen

as they make their way up the winding steep paved road before climbing the side of the hill up to the "M" made of white-washed rocks.

I was not very aware of my disability then. And the fact that I just knew I got hurt all the time. But I hadn't had an official diagnosis. I was so excited to do it-- I just wanted to be cool like everyone else, right? All my friends were pumped. It's an easy hike. It's just hot. Because it's August. You're walking on the blacktop. I quite enjoyed the mild hazing of everyone pouring water and spraying stuff in your face because I cooled down.

I asked her if she thought the tradition was inclusive of difference, and she replied that "They weren't thinking if someone has crutches, this one has a wheelchair, if someone is a woman, if someone has asthma, how they're going to do, right?". I then asked her if she thought it was physically accessible and if she struggled, or if she thought other disabled students would be able to participate. Her demeanor instantly changed as she contemplated not being able to participate in something so crucial to the Mines socialization process. She talked through this shift in perspective during the interview process itself, generating new knowledge with me.

You get your hard hat; you get it spray painted by all the older kids. And then you walk uphill and go for the better part of 3 miles. And then you get whitewashed when you sit on those super uncomfortable rocks for the photo, and then you walk down and go shower and go to rest of fall orientation activities. I would hate to be left out of that. And if you had a physical disability like a wheelchair, you're not

getting up the hill unless they drive you up the hill. And I think about that, no one's gonna want to get driven up it... that's a way to be singled out.... And I can't imagine being permanently wheelchair bound and having to ask for that. I would be very against doing something that required me to do that in the first place.

Eilidh's reflection on the M-Climb as a student with disabilities in this early interview uncovered for both her and me how the different types of abilities students have could impact their experience of joining the community during this important initiation, including make them hypervisible and vulnerable. The result of our intra-action was that Eilidh remained more aware of but also troubled by her growing realization of how physically inaccessible the campus was throughout the rest of the study. In later interviews she shared conversations she was now having with faculty and staff about the lack of physical accessibility on campus. She was continually being transformed in her understanding about herself currently as a student through the creative materialist approach, but also in her understanding of the future. She became more conscious of how she was changing physically due to her disorder, but also how she was viewing herself and her own experiences differently through our collaboration.

Eilidh is a visual artist and used drawing and painting as her creative practice to generate content along with writing poetry. In the interviews she explained that she often draws in class as it helps her focus. In our discussions about her art works she also revealed other cognitive disabilities like her inability to imagine things visually in her mind. She explained that she must copy an image to understand the object, but then could draw it in other ways later without a reference image. Eilidh shared a pencil drawing she

did in class of a conch shell through email, and I asked her in the second interview to explain it to me. She explained how our research together provided her with a chance to explore how her understanding of her disabilities was expanding but also her feelings towards needing accommodations were changing.



Figure 9: Ink Drawing by Eilidh

I asked Eilidh in the interview to explain the drawing to me, and she said,

I saw this photo of a conch shell on the beach. And I was like, I really like seashells. And then I started critically thinking about why I like seashells. And that's because like, ecologically, I understand that they are a part of a creature. It's where it lives. It's its protection, it's pretty. And they change their shells as they grow. I was like, if a snail is okay to change its shell because it has new needs and requirements, it's okay for me to do that, too. And it's also protection for the creature from predators. And it's how I can protect myself. And like, I was almost in tears. Like my two friends sitting next to me, we're like, why is she almost

crying drawing a seashell?... Because no one gets mad when the snail grows, and it's in a shell. And these creatures leave their shells on the ground, and a different snail can come in and grab it too. So, it's kind of this process of, if I start asking for these accommodations, it's easier for someone to ask for them later. Which is a thing a lot of women are focused on is improving things for the people who come after us.

I was profoundly moved by her explanation and told her that her drawing and her explaining what it meant to her helped me to better understand her experience as a disabled student in a new way. Eilidh produced several drip paintings as part of her creative content as well. I printed one of the JPEGs she sent me on my color printer on high quality photography paper and inserted it into the blue binder that was designated for her printed transcripts, diary entries, and poetry that she had sent me. I showed her the binder at the final interview, and I asked her to explain one of her paintings that I described as looking like a bruise or rot.

So, I went back to the painting because I'm so tired of people not seeing [my pain] because I look like I'm not in pain. And I was pissed; I was not making out that I was in a good mood.... And it felt like it when I was making it. I felt like I was getting rid of a bruise. You know how like procedures, when you get really big blood clots, you have to go cut them out and have to be super careful and like tie off all your points; it felt like I was doing that for my emotions. Because I was so pissed that people... didn't see the pain or that if they knew it was there, they didn't care.



Figure 10: Acrylic Drip Painting by Eilidh

By the last interview, when I asked Eilidh if she gained any insights from her participation, she shared that she had; she learned she had to confront her own limitations but also how this new knowledge could be used to help others with disabilities.

How can I help myself? Because like, I love the idea of helping people who come behind me. But to do that I need to know myself. That's a new insight. Because my goal starting was, how can I recognize things to help other people. But now that I'm here, it's like, okay, I recognize these things, and I can use them to help myself. So how do I do that? It's like when you're on the airplane, and they say, put [the mask] on yourself before you put it on others.



Eilidh described how the research framework of creative materialism had provided the space for her to explore her disabilities and better understand herself in relationship to the institution, which was empowering.

I feel like the biggest thing was just... understanding my disabilities more because I felt comfortable researching them, and asking questions, and taking more steps, like actually going to get diagnosed with the autism that I've known about since I was probably in high school, when I would rock back and forth when I kneeled on my feet all the time. And it created a space where I could just question everything. So, I think what really emerged for me was, like, it's not a bad thing to be this way. It's a really good thing. I'm in a system that's bad for me. But no matter what I'm doing, it's okay for me to take up that space and say, I need this, I need that. And I feel more comfortable asking for accommodations.

Eilidh explained how her exploration of her experiences as a disabled student during the study had provided her the confidence to ask for accommodations in the future, something she had been hesitant to do in the past.

Like to actually take up that space. I've seen this space I needed to take up for years, and just haven't wanted to because I felt like I would be making ripples. And you don't want to make a disturbance and things. But now I'm quite confident going, I can do that. It's okay for me to do that.

Eilidh's transformation toward self-care and acceptance were not initially part of her participation goals of increasing her understanding of her experience, which points to the

unique possibilities of the creative materialist framework and approach as a method for generating new knowledge about personal experiences. Our intra-actions and looping during the interviews with her creative content in the form of drawings, paintings, and poetry repeatedly over the months granted us both new insights into her experiences from multiple perspectives. By using a variety of methods, I provided a type of triangulation that demonstrates the trustworthiness of the study's data and content for Eilidh's transformation.

*Creek: Emerging Clarity about Her Experiences in the Culture*

Creek's transformative insights during the research emerged from her combined mathematical and logical deductive reasoning skills with her writing skills, poetry, and interest in storytelling. She often used the interview prompts that I emailed her in her diary entries as a means for reflection. She shared that she appreciated this oscillation back and forth between the various methods and in our interview intra-actions. I explained how I looped in her previous interview data with her diary entries to create new prompts for the next interview. "I like having all the questions to sort of skim over some but point out others to me, and then like that back and forth." In the final interview, I asked Creek about the research process she experienced with me as she had been a social science research assistant as part of her on campus jobs. She reflected on the differences in these experiences.

I think this is just such a different way. I've read interviews transcripts, right? And you ask the same questions again, and again, which is helpful when you're trying

to draw conclusions from it. But the reflowing is so cool. And you get to be more responsive too.

In her diary and in our interviews, Creek often took a mathematical and logical approach to analyze her experiences, attempting to sort and make sense of the gaps and confusion between what she expected at college based on how her parents had socialized her into engineering culture and what she experienced and witnessed with her peers. However, Creek also enjoys creative writing and through her participation in the study using creative materialism she came to appreciate her breadth of knowledge and skills as well as her STEM expertise. She realized through the data collection process that she was attempting to bring these different parts of herself together. This new insight opened up new sources of happiness and satisfaction for Creek in her education but also possible alternative career paths from those her parents prepared her for and that she was not aware of prior to participating in the study. While her parents had prepared her for the difficult work in college and to earn her place in the meritocracy through her skills and abilities, Creek was not prepared for the socio-political impacts of the meritocracy for students with underrepresented identities like her who are made to feel marginalized. She noted that she did not ever consider how the social and cultural aspects of a school would matter when deciding where to go. She explored how these socio-political phenomena that hide invisibly in the cultural myth of the meritocracy impinged on her idealized expectation of college as a place in which student differences were not supposed to matter. Creek's parents prepared her for success in a meritocratic community academically, and for the potential barriers and inequities she might face as a woman. But

her lived experiences at Mines in a culture that inhibited inclusion and access despite technical ability and knowhow disturbed her and was a source of anger that she sorted through her experiences during the research process.

Creek attributed her participation in the study as providing opportunities for self-reflection that were insightful and that aided her in reconciling some of her conflicts about engineering culture and the socialization process on campus and with her family. As an example of how she used the various data collection methods to reach this transformational awareness, in her diary in February, Creek noted some realizations that were occurring through the process.

I'm kind of realizing as I write this. Out in the 'real' world discrimination, hate crimes, etc. are expectations. But here, in engineering, in this spot of logic and pureness, I get mad because the real world comes in. Maybe I was seeking a refuge here in STEM... to try to get away from the frustration I had in the real world. I thought if I just did math well enough or outdid my peers enough, I could exist and not be questioned for it. Like getting an A on an exam gives me the right to wear heels and earrings.... I keep repeating to myself that I'm valid and my existence is valid. Sometimes it is a White guilt thing to reassure myself that I'm allowed space in minority groups despite my privilege. Sometimes it's a justification of my anger or actions. Like I'm not actually valid while dressing a certain way unless I justify it out loud.

Creek's confusion and frustration initially troubled her early in the study and caused her to question why she was pursuing a field in which she is so unhappy.

Why am I doing this if it's not a good thing? Like if I am finding myself frustrated and not enjoying it, why do I keep doing it? I have enjoyed my time at Mines, and I have enjoyed the math and these problems in my classes. And there are some things that I am really curious about. And I'm really excited to keep going and learning in academia. But to then be frustrated with it and to be feeling upset, feels like a betrayal of that excitement.

After our second interview, in her diary Creek explored the tensions in her STEM socialization with her own values and perceptions about the purposes for STEM in society and the cultural emphasis on individual genius, passion, innovation, and status recognition. She turned over how there is an informal narrative that only groundbreaking work based on passion is worthwhile for engineers, or work that leads to monetary compensation and prestigious positions. In contrast to this narrative, Creek reflected in her writing on how she saw her own work as merely a part of something bigger than herself to which she is contributing.

There's something freeing and pleasant in thinking I could just be okay with progress, any progress. Especially in a theoretical or budding field like quantum engineering; I can simply be a rung on the ladder of science and add to the collective journey up and that would be okay... I think this is the positive socialization I was looking for in STEM. The community and collective progress.

The lack of individualism. I think that the individualism and achievement driven aspects are maybe products of a Western society, not STEM specifically. Is STEM ingrained in Western culture or vice versa? There feels like an underlying positivity and community that I've been missing, skating on the surface for too long.

Creek also realized through her participation in the study using the variety of methods for self-reflection that being confident and comfortable as herself in however she chooses to identify would also be success. While her father told her never to admit or share her experiences of anxiety and depression as that would look weak and make her vulnerable to being seen as less capable, she shared in her diary that she believed in being transparent.

A lot of these have to do with actively confronting my own teachings or mental health struggles. They feel insurmountable. They especially did before I came to college, like they would go on forever and forever. But I'm learning that I can become a person who lives outside my family and my disorder and all my labels. That feels like success. Challenging the thinking around me, not necessarily for the sake of being different or separate from it. To understand where my thoughts come from and adjust accordingly, that feels like some sort of success.

As we discussed how we were using the novel approach of creative materialism over several interviews, Creek also came to understand her own interdisciplinary qualities that were marginalized in her preparation for a career in engineering by her parents. As

an example of this process, she explored her different disciplinary interests in her poetry, which she sent to me prior to the final interview.

Quick and churning, like little kids in rows and columns in kindergarten

I try to line up my thoughts like this, in rows and columns

One row for math

One row for coding

One row for arts

The further back the more forgotten

The row of arts is dusty and unclean and riled up

Can't sit still, can't fit into their tiny desk chairs and lined up columns

So eventually it gets forgotten

There is no time for unruly unclean in the day, only colored hour by hour blocks

One hour for math

One hour for coding

One hour for arts

If they would just sit down for long enough

In the final interview Creek shared how she had moved through the difficult emotions she experienced during her participation as she examined her experiences at Mines and that she had reached a sense of closure through the research process, that she had been transformed with the methods.

I think a big thing that came out later was the positivity. So, it came out. And I think the time between the... first like, orientation and the first interview was, I keep focusing on these negative socialization things, these things were being taken away from me or forced on me, but what am I gaining? Right? And that positivity I think helps with the dissonance of, why am I still in STEM if I find it so negative? Because it's not just like, oh, I'm good at math, or I like the work, right? I like solving puzzles. There has to be some like positive social aspect for it. Otherwise, it didn't make sense to me, why be here?

Creek also identified a new identity for herself as an emerging professor through our collaborative sharing across our different data and content generation methods. Through the process, she repeatedly looped through her perceptions and memories of her early socialization experiences with her STEM family. During the study, she reflected on the emotional turbulence she felt with her understanding of her father's experiences, opinions, and guidance to her from his position as current engineering faculty in higher education. Her reflective looping across time as she contemplated her future professional academic career helped her to sort through the differences between her father's experiences and her own. Creek created a new hybrid STEM identity for herself by reflecting on her best experiences with faculty and graduate assistants who enacted the warmth and openness that she wants to emulate as future faculty. Creek, like the other participants, was modifying the culture of STEM for her own health and well-being. By the end of data collection in the last interview, her anger was somewhat resolved, and she



had more clarity about her own experiences and expectations. “I’m like finally reaching the positivity that I wanted in STEM... I’m happy about that”.

Creek was unique among the participants in that she had been socialized since a child into the culture of extreme rigor that is crucial to the culture of engineering. Her participation allowed her the time, space, and methods to explore troubled emotions and confusion about her experiences at Mines based on this early socialization by her parents. While Creek is highly rational and her mathematics and science ways of thinking were clear in her data, what emerged in our collaboration was how interdisciplinary she is and how this new knowledge transformed her visions of her possible futures. The feedback loops we created using the variety of methods also provided her a new vantage point to assess how her identities as a queer mixed-race woman shaped her experiences at Mines here in the U.S. compared to her parent’s experiences in STEM education in Britain in the past.

### **Section Conclusion**

Each participant emerged transformed through their participation in the study using the unique conceptual framework of creative materialism to reflect on their experiences of being socialized into the culture of engineering, which included a variety of data and content generating methods. What emerged as crucial to this process was the sharing and continuous looping of interview prompts, conversations, and insights between each participant and me. However, it was also the continuous process that we employed that allowed us to reflect, analyze, interpret, and then build again into another round of intra-actions both by ourselves but also in partnership. Our data and content

showed how Nails' (2021) contemporary loop object theory provided a theoretical grounding for a process approach to knowledge creation in our research. But it was the combination of CLO with the arts-based research methods' unique evocative qualities to express the participants' subjective emotional insights (Leavy, 2017) along with the culturally responsive methodological principles of sharing power, transparency, and relationship building (Berryman et al., 2013b) that these findings emerged and transformed us.

### **Barriers and Challenges with the Methods**

The participants' data and content showed that while the methods presented opportunities to explore their experiences that were beneficial and unique to the study, there were also barriers. In this section, I share the participants' data in which they agree that the methods were rigorous, but not in the way rigor is defined in engineering culture. For them, it was the emotional nature of the study that required rigor and hard work to confront their own emotions as they came to better see and understand the institution and culture in their experiences. Additionally, all three shared that it was at times difficult to switch their ways of thinking from the memorization and mathematical and technical learning they were doing in classes with the self-reflection required for writing in their diaries and creating poetry and images. However, the methods and study were also designed to be culturally responsive to engineering education and the participants' workloads and mental health needs and therefore I was flexible and accommodating to their needs. The methods also provided a unique opportunity for understanding their own neurodivergence. For example, when I asked Esperanza in the final interview about her

experiences with the methods and what she would change or add, she replied that she desired more frequent in person conversations than the four planned interviews (one orientation meeting and three semi structured interviews about one month apart). She explained how she experienced transformational insights and saw the benefits of oscillating and looping together and apart.

Because I feel like I always walk out of these meetings and I'm like, wow, I learned so much. And then I like, try and go and apply what I've learned almost? And then coming back, you know, a month later. It's like, okay, here's what I did. Here's the new stuff that I got, like, now let's chat and see how I can apply it next. Whereas if it would have been like biweekly or something like that.

### **Emotional Rigor of Creative Materialism**

In their final interview, I asked each participant about their experiences of the methods, and also if they thought there was rigor in the methods. This question was entangled with our ongoing exploration of the cultural trait of extreme rigor, and all three participants answered similarly upon reflection. The methods were emotionally rigorous, but also rigorous because of the extreme workload each participant had that resulted in a lack of time or a feeling they did not have time to write in their diary or create. Additionally, all three shared that it was at times difficult to shift to the different ways of thinking that were involved in the diary entries and creative practices. Eilidh expressed the emotional rigor in the final interview:

It was probably more difficult in the fact that I had to address things I've been putting off for a while... And to look at this stuff and be like yeah, the reason I

don't like asking for help when I'm having a bad day and I'm struggling to get my hair clean. It's because it's dehumanizing. Like, it's hard to admit that to myself that I don't feel fully human, like an adult woman, when I have to ask my partner if he can help me wash my hair, because I'm in too much pain to pick up a bottle of shampoo.

Eilidh described how the arts-based methods worked for her despite the emotional vulnerability, but also how we had built rapport, trust and respect that made her feel safe to share.

Art is the most naked thing in the universe. I was heavily debating on showing [the bruise painting] to you... Because I had to look at myself and be like, I am comfortable being this vulnerable with her. But I don't know if I'm this comfortable being vulnerable with myself and acknowledging how I felt with that. Because a lot of things with ADHD and autism, we just feel. We've just give you all this information. We are hyper vulnerable... with everyone except ourselves. Because [the methods] forced me to be vulnerable with myself, which I'm terrible at doing.

Her quote shows how crucial the culturally responsive methodological principles of building relationships were to the success of the methods (Berryman et al., 2013b).

Without creating relationships of trust, our sharing might have stagnated, and the participants might have remained hesitant to share their vulnerabilities with me, thereby blocking the emergence of the new identities, insights, and personal transformations that occurred. Eilidh described that the reflective writing in her diary was the most difficult

method for her as she allowed herself to explore how her experiences made her feel. But she trusted our methods and process and how it would all fit together and make sense.

I feel like... [pause] the hardest thing for me is the journaling. And I think for me, that's because of the vulnerability of things... It's hard to look at myself and be honest with myself and write in a journal. The way I'm comfortable saying I'm pissed. Maybe not so much writing about why I'm pissed. Because there's lots of stuff in there not related at all to the research. Because I kind of use the journal to rant because I knew the pieces would fall in if I did.

I asked Creek about her experience of rigor in our process in the final interview and she expressed how it was difficult to prioritize the methods given her student workload, which reflected some of the cultural aspects we had discussed and that emerged in the findings. But she also shared that switching to a different way of thinking was difficult.

I think of rigorous being like difficulty and stress. And I think there were times where, like-- with all creative things, including the diary, the poetry, and my own like personal pursuits, those take back seats. Because that's my instinct with school, is that school has to be a priority, and I just need to get this assignment done. And so, in that way, I guess it was rigorous, because sometimes it was difficult to maintain momentum. But it's also rigorous in the sense that I have to think critically, and that takes time and thought and effort.

Esperanza also expressed that time and shifting her thinking was difficult. “The diary came more rigorous as the school year got more rigorous. It was more just when things got busy, it was the first thing to kind of go”. The participants’ feedback on their difficulties with the methods further defined rigor within the culture of extreme stress in which they felt constant pressure to always prioritize academics and being a student over taking the time for self-reflection and personal transformation. However, their insight into the emotional rigor of being vulnerable with themselves in new ways was a unique finding. This finding points towards a pluralistic understanding of rigor outside the concepts of objectivity deeply embedded in the culture of engineering education and research in which qualitative and subjective research methods are rejected (Riley, 2017).

### **Participant Identity Barriers**

Another barrier that emerged through answering the research question about how the methods worked relates to the participants’ unique identities. For example, Esperanza shared more about her physical disability by the end of the study and admitted that at times, it was painful to handwrite in her diary, which she had chosen to do instead of a digital version. In the final interview, she shared a new realization about how she could have adapted the methods by saying “I could have taken like voice notes, and then send those to you. And that would have been an easy way to not have to write, but still get my thoughts out and experiences out”. She shared that there was a difference in effort for her in the two creative methods she chose, poetry and photography. She described the writing of poetry as less familiar than the photo-elicitation method she used later in the semester.

“I had to shift my thinking to focus more when writing poetry, I had to be in the right mindset to do it.” She described the difference with photography,

I was able to just take pictures whenever I was feeling something or, you know, something happened. And it came with a story. I think with writing, it takes more of a mindset to do versus like music and photography, where it's more like a constant.

These findings indicate that the creative methods that each participant chose provided them a variety of ways of reflecting and thinking which produce different experiences, insights, and transformations for the participants. During each interview, I asked the participants about their creative practices and how the process of creative materialism was working for them to be responsive to their changing needs and any barriers they were experiencing. Esperanza expressed her appreciation for the arts-based methods we used along with the diary.

I think it's super helpful. It's another creative outlet, that not only is good for research, but also even just good for like me. Like writing, you know, it was very relaxing and de-stressing, I was able to get everything out. And so, I think having that creative outlet is good.

I found that there were disciplinary issues with the subjective nature of the study, however. All three participants were self-conscious and needed reassurance that they should not censor themselves and that we were not attempting objectivity. While I had explained the methods to the participants during their initial screening for participation

and during the orientation meeting, the participants benefitted from me repeatedly explaining our unique approach throughout the study. Eilidh and Esperanza took my early directions and explanations without difficulty and moved through their concerns about the self-reflective quality of creative materialism almost immediately. What emerged through the study was how Creek was less comfortable with the subjective and creative methods initially due to her socialization into positivism and her STEM conception of research. In one of her early diary entries in January she asked, “How do I do this in a way that doesn’t turn into therapy? Is it that my personal problems are my focus or that engineering is such a focus of my life that it’s inherently intertwined into my personal life?”. Creek struggled with the diary method and sent selections of her digital diary entries in two batches, the first from January and February, and a later batch prior to the final interview in April. She expressed her difficulties with the emotions she was experiencing with the methods in her diary in February.

I find it difficult to journal from a place that isn’t frustration. The primary spikes of wanting to write so far have been from prompts actively given to me, or from frustration with engineering culture. Even while writing my papers, I find myself having this negative outlook on engineering and being angry at it. Which, maybe I have some right. But the clincher is that this frustration doesn’t permeate into other aspects of my life too... which I’m kind of realizing as I write this.

The messiness of the subjective, entangled, and emergent process was confusing and disorientating for Creek, but she continued with the process regardless. Later in a diary entry in March, she described how she was using the interview prompts and



transcriptions with her diary reflections but was self-conscious if she was contributing in the proper way.

I read over the interview transcript between finishing this entry, and it came up in that interview too. I already made a lot of my points there, I think. I feel bad. I feel bad writing about this so much again and again. Maybe it's because I've been shamed against talking about my identity. Maybe it's ¾ White guilt. Maybe I do talk about it too much. I think I'm getting lost in what this project is. Crossing the wires between papers and responsibilities and this journal. I want the things I say in interviews and write down to be meaningful and well thought out and accurate. But really this is just for my truth. And my personal truth doesn't have to be accurate or meaningful. And even my art too!! It doesn't have to be pretty or meaningful. That has been a huge barrier.

Our findings indicate that for participants steeped in objective epistemologies, the methods and framework of creative materialism could be potentially challenging. However, based on Creek's experiences, because of her comfort with writing poetry and stories, she navigated her way through these impasses and uncertainty. I believe her perseverance most likely had to do with the trust and rapport that we built based on the culturally responsive principles in the framework, which allowed her to understand how this interdisciplinary study and methods could provide new knowledge despite never having done this type of work before.

Creek was also hesitant to share the poetry she was writing for the creative content, which I inquired about during the first few months of data collection in an email

after she had not shared any. She explained during the orientation that she used to do slam poetry and felt that would be the best method for her. However, she was self-conscious about quality; I assured her in our email exchange that the methods were a tool and not necessarily intended to create a finished product. When we discussed her concerns during the second interview, she agreed she was intimidated but would continue to work on them. “Yeah, I think I’m just really feeling self-conscious and slow about it. But I need to just like... pull it out and like, actually like do all those things.” Creek used her poetry to explore these barriers she experienced during the study that also reflect the rigor of having to switch between different ways of thinking.

I sit here and start at it, the writing  
Holding off for weeks, the worry  
But then it’s out of me, the words  
And pouring and flowing, the river  
Thought after thought and with it, the light  
Hoping that everyday can feel as loose as this, the writing  
Wishing it could be as easy to flow, the work  
In motion and stays in motion, if only

Eilidh’s cognitive disabilities also provided a challenge to keeping a weekly diary as a method. The main barrier for Eilidh with her diary was that due to her ADHD she lost track of her paper journal she was writing in for several weeks because she had put it on a shelf and could not see it; it was out of sight and therefore out of mind. She sent me a digital document with excerpts from her diary from January through February, but

otherwise did not share her journal writing. However, she shared in each interview what she had been writing about instead.

Clearly there are limitations and difficulties crossing disciplinary borders in engineering student research that are connected to the heavy workload, engineering culture differences with positivism and the legitimacy of subjective methods, but also that the neurodivergence and physical disabilities of the participants must be taken into consideration when designing a project. The incorporation of CRM principles (Berryman et al., 2013b) was crucial for me to be responsive to each participant's unique needs and experiences throughout the entire collaboration.

### **Chapter Conclusion**

In this chapter I used our combined data and content to show how the conceptual framework of creative materialism worked to generate new knowledge that answered the first research question about the student participants' experiences. Indeed, our data and content illustrate the motions of knowledge production that Nail theorizes with his contemporary loop object theory (2021): the emergence of hybrid knowledge through the intra-active feedback loops. By including culturally responsive methodological principles of power sharing, transparency, and community building I was able to build trust and rapport with each participant (Berryman et al., 2013b). Trust between the primary investigator and the participants is key to the transformational process that relies on vulnerability by the participants to explore emotionally difficult experiences as students in the culture. I built this trust by being responsive to their individual needs and experiences as underrepresented student participants in the culture of engineering. I was

responsively flexible to each of their unique but multiple embodied identities, including their neurodivergence and cognitive variations, physical disabilities, and their disciplinary epistemic training that presented barriers to their participation in this interdisciplinary study. Using CRM principles, I also built flexibility into the framework by recognizing their needs as participants in the culture of engineering in which the study took place. I knew from my own empirical experiences as adjunct faculty at Mines but also from my extensive literature review and research on the culture that their extreme workloads might create pressures that required them to pause their participation in the study. Communication was also key when each participant struggled in the study, whether it was their own burn out as with Esperanza or losing track of their diary and keeping up with the methods like Eilidh or recognizing Creek's epistemic hesitancy and uncertainty with the subjective quality of the methods. My findings for the second research question on how the methods worked to generate new knowledge also show that this framework is unpredictable and at times, complicated and messy, which required responsiveness and critical self-reflection on my part as the lead investigator. This finding is in keeping with other doctoral studies using culturally responsive methodologies, which I elaborate on and discuss in the final chapter.

## **Chapter 6: Discussion**

### **Introduction**

The primary purpose of my study was to explore and gain insights into how underrepresented engineering students experience the culture of engineering during their education (Seron et al., 2015) and how their identities shaped these student participants' experiences. However, I intentionally chose not to work with a specific demographic of students based on specific social identities they held. Instead, I recruited participants who were interested in exploring their identities but who also were comfortable with the unique conceptual framework and creative inquiry methods I theorized, which intentionally was an interdisciplinary and subjective approach. Through our collaborative, embodied looping together using creative materialism, we were transformed by gaining new perspectives about our experiences at Mines and within engineering education, but also with our new identities as neurodivergent women. These transformations were possible because of the unique creative materialist approach I used, from which a new research community emerged with a culture of trust, power-sharing, and vulnerability.

In this chapter, I discuss the various implications of my research for higher education, STEM education and specifically engineering education, but also the methodological implications based on the theoretical components of creative materialism.

I begin in the first section of this chapter by discussing how our findings show the complexity of the participants' experiences at Mines and the implications for one-size-fits-all approaches to higher education. I then discuss our findings in relation to some of the engineering culture literature and research on rigor, the socio-technical dualism, and the Mines' historical saga (Clark, 1972). In this section I explore how prestige seeking based on historical narratives created a culture that impacted the participants' mental health. In the next section, I discuss the theoretical implications of my creative materialist approach by exploring how my study incorporated the various elements of the framework of culturally responsive methodologies (Berryman et al., 2013a), contemporary loop object theory (Nail, 2021), and arts-based research methods (Barone & Eisner, 2012; Leavy, 2017). I end the chapter with descriptions of future research and recommendations for higher education and Mines.

### **The Vigor of Creative Materialism**

I offered a different approach to engineering education research that was based on a goal of creating an inclusive research community of care, support, trust, and vulnerability with the participants as collaborators. These cultural values also emerged in the participants' content and data as they actively worked to modify the culture of engineering at Mines by practicing self-care and creating the time and space to be more than engineering students. Engineering education researcher Donna Riley noted in her 2017 essay on rigor how the narrow disciplinary conceptions of rigor in engineering culture are used to police academic boundaries, which in turn limit cultural change and the ability to create new interdisciplinary knowledge. I acknowledge that from the

perspective of those rigidly trapped in their own disciplinary epistemologies, there may be perceived limitations to the generalizability and replicability of my study that seemly reduce its value. However, I counter that those theoretical limitations are based on criteria that do not apply to my approach. I argue instead that my novel approach offers new knowledge using methods that fit with Riley's (2017) call for a conception of vigor rather than rigor. Riley's conception of vigor includes ethics, communication, lifelong learning, and invites different epistemological approaches that include "not objectivity but clarity of expression, not generalizability but specificity of description" (2017, p. 254). Riley's conception of vigor fits well with the principles of creative materialism. With this study I demonstrated research methods that offer multiple perspectives and flexibility in thinking as well as assessments of power. I offer creative materialism as a vigorous framework for expanding the purview of engineering education research, with culturally responsive methodology principles (Berryman et al., 2013b), arts-based and creative inquiry methods (Barone & Eisner, 2012; Leavy, 2017), and Nail's contemporary loop object theory (2021) as the scaffolding on which to design subjective studies that require emotional rigor. By applying vigorous methods using creative materialism, the participants and I were able to uncover the invisible barriers lurking in the meritocratic myths of neutrality in engineering culture. These invisible barriers hide the inequities of the culture as well as the mental toll on underrepresented students.

### **Exposing the One-size-fits-all Education Myth**

Our findings show how each student is unique and that notions that generalize "types" of students in higher education, and in this study particularly in engineering

education, are misplaced; one-size-fits-all models gloss over the depth and degrees of differences between students, even those who claim similar identities such as being female and neurodivergent, like the participants and myself. Notably, our uncovering of our individual neurodivergent identities gestures toward the lack of knowledge and public misinformation about autism and other neurological differences like ADHD, dyslexia, dyscalculia, but also the various ensuing and accompanying mental health conditions like anxiety and depression (Zener, 2019). There is an emerging and growing body of research that rejects the medical deficit-focused approach to neurodivergence and instead utilizes a social model of disabilities, which theorizes that the category of disabled is shaped by society (Chrysochoou et al., 2022; Cuellar et al., 2022). The research is also being transformed by participatory frameworks that includes the voices of neurodivergent researchers and participants. My study provides new stories and perspectives that illuminate the neurodivergent adult female experience of diagnosis, which are needed (Chrysochoou et al., 2022; Cuellar et al., 2022; Milton, 2014; Pesonen et al., 2020; Stenning & Rosqvist, 2021; Taylor et al, 2019; Weinbaum et al., 2023; Woods et al., 2018; Zener, 2019).

One of the problems with maintaining the rigid cultural dogma in higher education institutions is the resistance to change and the impact this resistance has on the people from underrepresented communities who are recruited and invited into postsecondary institutions, like Mines, as these organizations attempt to expand participation across demographics (Riley, 2008; 2017). Ahmed (2007) theorized how people of color who are the new arrivals to an academic organization often experience



being blocked, diminished, objectified, and stopped with questions that challenge their belonging. However, these new arrivals are people who appear visibly different than those comfortable in these spaces due to the legacy of racism and sexism that are traditionally embedded in higher education. In short, Ahmed argues that their visible differences are questioned, and those who look different are often singled out and made to feel as outsiders (2007).

I found that the participants often described encounters like those in Ahmed's phenomenology of whiteness (2007) as they intra-acted and had experiences at Mines, particularly as women, racial minorities, and disabled students seeking accommodations. Ahmed describes how this experience of being made a stranger can create a sense of loss and disorientation in these new arrivals in academia who are deemed different, a sense of loss at what one has never been given in the first place, which is belonging, equity, and access. I think the participants' data and content clearly show they feel a sense of loss much like Ahmed theorizes (2007). This feeling was particularly difficult for Creek to understand due to her early socialization into the meritocratic myth by her parents. Her participation in the study provided her with the tools, time, and space as well as a kinesthetic-onto-epistemological framework to confront and explore her negative emotions that were dominating her educational experiences. Through the transformative process of vigorous self-reflection, Creek emerged from the study with new clarity about her experiences as a student with multiple underrepresented identities in a culture that resists recognizing differences as normal variations across human beings.

However, I think applying Ahmed's phenomenology of whiteness (2007) to my study's findings is also evocative (Barone & Eisner, 2012) in terms of differences that are not visible, such as Creek and Eilidh's queer sexuality, the racial ambiguity of Creek and Esperanza, but also the invisibility of the physical and neurological disabilities of the participants, both to others but also to themselves and me. Creek and Esperanza both recognized that their ability to move invisibly as people of color among White people provided them with a different experience than their peers whose skin tone clearly racializes them as "not White", making them hypervisible. Yet both women also sometime felt invisible to their peers of color who they felt a kinship with and Creek and Esperanza both described signally through speech, dress, or behaviors to indicate to others their ambiguous racial identities that mattered to them and that affected their experiences. A major theme in the findings was how the degree of visibility both in the cultural traits of engineering education but also the participants' various social identities shaped their experiences. Our study showed that hypervisible identities like gender and race often resulted in direct microaggressions like accusations of not belonging and suspicion that women were given special treatment rather than earning their place at Mines through their abilities. However, ambiguous, or invisible identities, like having learning and physical disabilities along with being low-income, created different experiences for the participants. For example, Eilidh struggled with her inability to afford the medical documentation required to get accommodations for her physical disabilities, which made it more difficult for her to ask for assistance that would have made her educational experiences less stressful and harmful to her overall wellbeing.

The invisibility of neurodivergence and lack of awareness and historical under and misdiagnosis of females with autism (Zener, 2019) presents a different type of barrier to entry and belonging in Ahmed's theorization (2007): what if you do not know that you are different when you are entering a room as a new arrival to that institutional space? A shared but unexpected experience for the participants and me through the study was gaining a new identity as neurodivergent, which made our neurological differences visible to us for the first time. While we experienced a range of emotions through the process of coming to know our new identity, overall, we found the scientific and medical categorical knowledge about our embodied cognitive uniqueness empowering in its explanatory ability. Continuing the analogy and application of Ahmed's (2007) concept of new arrivals in academia, we now enter the room with new awareness about ourselves that may not be visible to others. Additionally, according to the research, because of the stigma associated with some autistic and neurodivergent behaviors, neurodivergent girls and women often mask their differences (Chrysochoou et al., 2022), further hiding their cognitive differences and abilities, which like us, they may not even be aware of.

The logical fallacy of *argumentum ad antiquitatem*, or the appeal to history and tradition, rests on arguments against change with versions of "we have always done it this way". The cultural traditions of schools like Mines rest on the continuity of practices of initiation like the M-Climb that are intended to build a sense of community and belonging. However, I showed in the literature review in Chapter Two the research on the exclusionary practices and beliefs in the early professional and educational field of engineering that specifically rejected the participation by people with specific bodies in

engineering: Indigenous, people of color, women, low-income workers, and immigrants (Bix, 2013; Frehill, 2004; Oldenziel, 1999; Slaton, 2010; Stonyer, 2002). Those implementing diversity, inclusion, and access (DI&A) efforts in engineering education must confront the past to change the present. Educators must determine the hidden kinetic operators (Nail, 2021) that lay buried deeply in the cultural myths of neutrality and meritocratic practices. These cultural values support a belief that the meritocratic system can sort quality students from those deemed unworthy because they struggle in the system; however, this system was not designed to include underrepresented students despite the recent emergence of institutional DI&A programs that recruit these students to campuses.

Industry understands the value of diverse workforces. There is growing evidence that all forms of diversity benefit workplaces, science and engineering, and society as cultural and cognitive differences between people provide new perspectives and broader views and possible solutions to problems (Bang & Medin, 2010; Kidwai, 2022; Loop & DeNicola, 2019; Mackie, 2022; Ouimet, 2018; Oyana et al., 2015; Pearl, 2020; Pietri et al., 2018; Sanchez et al., 2019; Walker, 2015; Weinbaum et al., 2023; White, 2014). Engineering educators must incorporate Riley's (2017) conception of vigor to create learning spaces that are respectful and promote inclusive community engagement, which are the values that the participants articulated in their data and content. Schools like Mines must replace the cultural and historical reliance on narrow and self-serving disciplinary definitions of rigor so that underrepresented students on campus never question if they belong because of their personal identities.

As one example of the shift in recognizing the benefits of diversity, the Rand Corporation published a report in 2023 (Weinbaum et al., 2023) that highlighted the unique contributions neurodivergent people bring to the military and national security sectors, which includes engineers and scientists. The report also argues that due to the associated stigmas with disabilities, many current national security workers who are neurodivergent mask their differences out of fear of discrimination and biases. The participants and I also wrestled with the decision to make ourselves visible in the academy due to these stigmas and risks. However, making ourselves visible is required to remove these stigmas by educating others on our differences, a dilemma the participants understood when they joined the study. When those of us who are neurodivergent are hidden, our potential contributions may remain unfulfilled as well. Indeed, the authors of the Rand Corporation report shared that the experts they interviewed argued that some missions “are too important and too difficult to be left to those who use their brains only in *typical ways*” [italics in original text] (Weinbaum et al., 2023). The key findings from the report included that the abilities many neurodivergent individuals hold strengthen national security, like pattern recognition, visualization, and hyperfocus.

However, the broad medical category of disabled does not differentiate the different needs and skills among disabled individuals. Due to this lack of nuanced understanding of disabilities, along with the negative implications of assuming this identity because of co-worker assumptions about disabilities, the report (Weinbaum et al., 2023) found that many disabled employees forgo accommodations and choose to remain invisible, like the study’s participants. The report authors argue that accommodations

could alleviate the extra stress and mental exhaustion that results from working in environments not intended for neurodivergent bodies, which would also improve their job performance; the same can be said for neurodivergent students and faculty who remain hidden and masked. Organizationally, the authors argue that the invisibility of this population and ignorance of how differences matter keeps neurodivergent people hidden and perpetuates the belief that there are not systemic oppression and exclusions in the U.S. security sector (Weinbaum et al., 2023). I argue the same is true of higher education and engineering education.

Clearly, based on the Rand report, and despite the mounting research and calls to embrace neurodivergence in STEM education and professions (Chrysochoou et al., 2022; Cuellar et al., 2022), barriers remain that impact society in undetected and unknown ways. Yet our research findings show that EHED students bring multiple identities to campus, which theoretically cannot be neatly separated because they were not experienced separately by the participants (Cech, 2022). The participants' gender identities as women were entangled with their other racialized, cognitive, physical, socio-economic class, and sexuality identities, identities that were compounded as the participants intersected with other members of the Mines community and the institutional bureaucracy.

The participants' desire to participate in the study arose from their general feeling that because of who they are, they encounter difficulties and barriers at Mines, which resonates with Cech's (2022) quantitative findings that White able-bodied, heterosexual men (WAHM) in engineering derive benefits that those with multiple underrepresented

identities do not. Through our collaboration and creation of a caring culture for research, the participants in the study were able to better understand their own experiences with the institution and with other community members. While all three participants shared some common experiences, their findings show that they are each unique. Our study clearly shows that one-size-fits-all models of higher education are based on assumptions and myths that not only generalize students as all the same, but also works to keep the differences among students invisible while negatively affecting the student's well-being and mental health. However, our study also shows how the participants' experiences of their own identities were shaped by the culture of engineering.

### **The Culture of Engineering and Socialization**

Cech's (2014) research showed that there is an isomorphic quality to the culture of engineering, meaning that there are similar cultural traits—and problems—across engineering education departments regardless of the location or type of institution in the U.S. Cech attributes this isomorphism to accreditation standards and the need to indicate legitimacy as knowledge producers. However, research on the culture of engineering internationally also shows an isomorphic quality (Faulkner, 2007; Godfrey & Parker, 2010). Because of this isomorphism, my discussion of the findings from the three student participants at Mines may be applicable to other engineering education institutions. The purpose and findings from this deeply personal and subjective study should be interpreted as providing an opportunity for educators and researchers to shift their perspective on how they define and conceptualize the problem of diversity, inclusion, and equitable access in higher education. I argue that a shift in understanding is necessary to find

solutions that address the harmful impacts that the participants described in their data and content like feelings of not belonging. In my framework, I did not pose the research questions with an intention to seek specific answers, solutions, or best practices, but as guides to the research design, process, and interpretation. The data and content that we produced provide depth and details of these participants' individualized experiences of how it feels to be socialized at Mines, but also how it feels to uncover through the research process that we are neurodivergent. Our work supports Eisner's arguments that arts education (Eisner, 2008) and arts based research (Barone & Eisner, 2012) may build empathy in students and audiences, which can then shift a person's perspective on an issue to see it in a new way, while also developing compassion for other people's suffering. Our research findings uncovered how diversity, inclusion, and access (DI&A) programs on engineering education campuses, however imperfect, may provide avenues for underrepresented students to gain insights into their own experiences of marginalization. By using vigorous methods like creative materialism in their research, DI&A programs can further their own goals by better understanding the experiences of individual students beyond traditional reliance on quantitative methods (Riley, 2017).

The socialization process is a prime location of where changes should be initiated, and more research conducted. Seron and colleagues research (2016; 2018) on the factors that cause women to leave engineering revealed that the culture shaped female student outcomes. However, a major difference between Seron and colleagues' study (2016; 2018) and ours was that the three participants in my study were actively involved in formal diversity, inclusion, and access (DI&A) and mental health programs and



initiatives at Mines. Their involvement was both personal in terms of participation in identity-based student groups for professional and academic assistance, but also in some of their on-campus student jobs in which they were trained to assist and educate other students about DI&A. Seron and colleagues (2016; 2018) did not describe these conditions in their study. I believe that this difference in the settings in which our research took place is notable. While research shows that diversity programs can create and maintain barriers to the very goals they espouse (Ahmed, 2012), our study shows that these programs can also provide a means for students to assess their own experiences in relation to the stated institutional goals; this intersection is ripe with possibilities if institutions are open to using a variety of research methods like creative materialism. The participants were steeped in Mines' DI&A goals through their student employment. Their participation in the study helped them identify the shortcomings in their own experiences compared to the ideals espoused by the institution. While their explorations of their emotions using creative materialism were at times painful and difficult emotionally, all three participants emerged from the study with more clarity as to how the institution functions but also what avenues are open to them for making change based on these programs. Higher education DI&A workers and leaders should incorporate more vigorous, subjective, culturally responsive, and critical research methods that elevate underrepresented student voices but also staff and faculty in the campus community to better understand the dynamics and real-world impacts of their programs.

I also must note other differences with Seron and colleagues' findings (2016; 2018) when comparing my study's new knowledge about females' socialization into the

culture of engineering. My unique approach was an emergent process that was rooted in the material and historical conditions and relationships that affect us today. Namely, the socio-political events around sex, gender, sexuality, and race that have occurred in the U.S. since Seron and colleagues' study (2016; 2018) matter in this comparison. They compiled their data from 2003-2007 and completed the research in 2015. The "me too" movement in 2016 and the 2022 Dodd decision that overturned Roe vs. Wade at the U.S. Supreme Court were both under currents in my study with the participants as was the murder of George Floyd and the rise of the Black Lives Matter (BLM) movement in 2020. Indeed, as we share our stories here, we are also aware that politicians and media figures are using anti-diversity political rhetoric and legislation to curtail DI&A programs at schools like Mines as well research investigating how different students experience engineering education (Curran, 2023). The vigorous components (Riley, 2017) of creative materialism require looping in the social, political, and economic conditions in which this study took place.

In terms of accepting the culture, rituals, and values in engineering education that Seron and colleagues (2016; 2018) found that female engineering students must do to succeed, I think the complexity of the participants' myriad social identities complicate comparing our findings as well. Cech's 2022 study also revealed real world differences in experience for those in engineering who hold multiple underrepresented identities. The purpose of my study was to explore how multiple underrepresented identities affect an engineering student's experiences of socialization. And the participants described this complexity and the resulting uncertainty and emotions that emerged for them as they

interacted with an institution and community whose cultural beliefs perpetuate a myth that there is one type of engineering student. What our study shows instead is the full spectrum of differences that students arrive with to college and that there is a need to better understand the pluralistic dynamics students with multiple underrepresented identities experience at college. Mines' DI&A efforts, at the time of writing, were still developing and emerging. Yet the existence of these programs created a platform on which these participants could stand, voice their stories, and push back against the school culture, policies, and leadership. The existence of the DI&A programs also offered the participants the ability to recognize how to modify the campus toward inclusivity and well-being for underrepresented students, faculty, and staff. However, at times, all the participants expressed frustration, exhaustion, and resentment at how inconsistent and disjunctive DI&A efforts are at Mines, in their experience. By using a vigorous creative materialism approach to generate data and content, our findings offer DI&A practitioners and researchers a new framework to uncover specific experiences that might be missed using more generalizable research methods. This approach also offers a means to identify the gaps in the institutional programs that are intended to support students and expose the mental health impacts of these shortcomings in programs.

Indeed, through the study the participants identified gaps between school's rhetoric, DI&A and mental health discourse and behaviors, and what they and other underrepresented students experienced during their time at Mines. Our findings again resonate with Sara Ahmed's research, this time on diversity programs in higher education (2012), in which a paradox occurs: the very diversity programs meant to bring about

change may create barriers to making change. Ahmed (2012) argues that these barriers arise in DI&A programs that are merely performative measures that attempt to transform how whiteness is perceived, rather than making the exclusionary structural barriers visible and removing them. Again, my study complicates Ahmed's phenomenological work that focused on the racialized structures embedded in higher education (2007) by adding more visible and invisible identities. But my study also supports her argument that the practices and behaviors of attempting transformations in institutions creates new knowledge by those diversity workers who attempt to identify barriers, or the "brick walls" as Ahmed (2012, p. 174) characterizes them. "For those who do not come up against [the brick wall], the wall does not appear" (p. 174) and the emotional and physical labor of continuously "'banging your head against a brick wall'" (Ahmed, 2012, p. 174) is not experienced. Importantly, through our study as the participants reflected on their experiences in relationship to the DI&A structures at Mines, they began to question if the motivations and goals of Mines aligned with their own personal values and DI&A and mental well-being goals. That is, the invisible walls became more visible to them as they attempted to modify the culture toward their own values of self-care and supporting their peers.

### **Uncovering the Socio-technical Dualism at Mines**

Much has been written about how the culture of STEM rests on a myth based in positivist epistemologies that engineering, math, science, and technology exist in a vacuum separate from society, politics, and economics (Cech, 2013, 2014; Baber, 2015; Frehill, 2004; Godfrey & Parker, 2010; Harper, 2012; Haverkamp et al., 2019; Leydens

& Lucena, 2018; Riley, 2017; Seron et al., 2018). This research also shows this myth can stifle and limit DI&A discourses and efforts at STEM institutions. The participants' constant feelings that they did not belong at Mines despite their strong STEM identities reveals that this myth is at work at Mines as well. And our research supports previous research that these experiences in the culture are detrimental to student mental health (Jenson & Cross, 2021; Lord & Camacho, 2013). The socio-technical dualism and invisible political ideologies at Mines create an environment for accusations against the participants as women, racialized students, and disabled students that they received special treatment, were at Mines only because of affirmative action, and that accommodations are a form of cheating. In turn, this socio-technical dualism created a culture in which the participants never quite felt like they belonged, which also required extra labor from these students to persevere through the emotional and mental trauma of experiencing hostility and suspicion. Put another way, the participants continuously hit Ahmed's metaphoric invisible brick wall (2012), which exacts a mental and physical toll. I argue that this hidden extra labor must be made visible for other community members to understand that differences matter in how different members of the Mines community are experiencing campus life. This educational effort is also crucial for removing stigmas around accommodations for disabilities and learning differences. Faculty and administrators who are unaware that some of their students experience chronic pain or are exhausted from working several jobs to pay for school and their daily expenses cannot effectively accommodate or help these students learn, despite their best intentions and formal DI&A programs.

## **The Impacts of the Fetishization of Extreme Rigor as Suffering**

I theorized that the fetishizing of extreme rigor and suffering is a historical kinetic operator (Nail, 2021) that underpins engineering culture and the associated epistemological and pedagogical assumptions about the meritocracy's effectiveness in sorting and identifying quality engineers from unqualified students. Some of this myth is grounded in a belief that some people are "naturally" engineers (Riley, 2017), which Creek had been socialized into by her parents. However, my study showed that the historical entanglements from which these beliefs emerge were hidden for the participants by the socio-technical dualism in the Mines culture, which rests on assumptions about positivist objectivity and a belief that STEM education and professions are removed from history and politics (Riley, 2008; 2017). Engineering education subject matter, like physics, calculus, and differential equations, are difficult to learn; that is, the subject matter is rigorous. In the culture of engineering at Mines, however, rigor has clearly become associated with suffering and enduring extreme physical and mental stress, which resonated with previous research on rigor (Godfrey & Parker, 2010; Riley, 2008; 2017). In our study, we showed the paradox of students performing rigor through demonstrating and even bragging about their suffering and how this performance combined with the need to hide vulnerabilities and a lack of understanding concepts and materials, out of fear of being weeded out. With our findings we clearly showed that this invisible tension was detrimental to the mental health and wellbeing of the participants and their peers, even contributing to experiences of burn-out and exhaustion.

Currently, the accurate quantity of disabled and neurodivergent students in higher education and engineering education are unknown as these identity remains hidden for several reasons including the stigma associated with autism and disabilities (Chrysochoou et al., 2022; Cuellar et al., 2022; Taylor et al., 2019). This invisibility contributes to beliefs among many EHED educators that all students are the same when it comes to their embodied experiences while sitting in a classroom, lab, or studying. Girls and women are significantly under and mis-diagnosed with neurodivergence (Zener, 2019), which our study also illustrated, meaning that faculty are unaware of the potential variations in their students' classroom experiences. However, the students and faculty themselves may also be unaware of their own neurological differences. Studies also clearly show racial and low-income differences with student diagnoses of learning disabilities (Leonardo & Broderick, 2011), with a disproportionate difference in the racial makeup of gifted programs versus special and remedial education programs; White student are more common in gifted programs while students of color are disproportionately represented in special education programs. Research also shows that there are structural issues with legal and privacy implications as disability services at schools remain solidly in a medical model of approaching disabilities and learning and physical differences in students, which can perpetuate a deficit approach to these students rather than finding their strengths (Chrysochoou et al., 2022; Cuellar et al., 2022). Disability research has shown how the hegemonic medical deficit-based model creates stigmas that also shape the invisibility of disabilities (Chrysochoou et al., 2022; Cuellar et al., 2022; Taylor et al., 2019, Woods et al., 2018; Weinbaum et al., 2023), which was

evident in our research as well. All three participants were not clear on who disability support services (DSS) are for, seemed conscious of the stigmas that claiming a disability would bring, and anticipated difficulties with the implementation of accommodations. These factors, in their minds, outweighed the benefits of seeking formal accommodations to help with mental/emotional, cognitive, and physical impairments that affected their education.

Again, Ahmed's invisible brick wall is salient (2012); Mines and other postsecondary institutions have DSS programs. Yet due to the cultural myth that all students are the same, and that only weeding out and extreme suffering produces qualified engineers, which rests on a belief that there is a "natural" type of engineer (Riley, 2008; 2017), the participants were blocked from even seeing how to get help to reduce their suffering while they learned. The socio-technical dualism is an invisible brick wall embedded in the culture at Mines, and in the isomorphic culture of EHED (Cech, 2014) generally, which the participants kept smacking their bodies against. This intra-action produced fatigue, mistrust, resentment, fear, anxiety, confusion, and exhaustion for the participants, as well as requiring extra labor that many in the community remain unaware of. And continuing with Ahmed's brick wall metaphor (2012), the participants and I only became aware of the socio-technical dualism at Mines through the research process and searching for where we felt we experienced things differently; that is, we found the wall in our search for understanding through the research process using creative materialism.



Based on our study's findings, I argue that the continued cultural reliance on unquestioned positivist-based pedagogies, relentless testing for accuracy over comprehension, emphasis on extreme physical and mental suffering, and weeding out, particularly when argued from the fallacy that this is how it has always been done, removes qualified students who could offer new perspectives and cognitive and cultural diversity to industry and communities. Ethically, it is extremely questionable that it is appropriate to actively recruit underrepresented students from low-income, first generation, and racialized communities, and particularly students who have disabilities, and invite them in as members of the Mines community while not transparently sharing the weed-out policy, which is hidden in the meritocratic myths in the culture. However, besides the socio-technical dualism at play in the culture at Mines and in engineering education more broadly, our study uncovered the role that prestige also plays in student experiences.

### **The Hidden Impact of Institutional Status Seeking on Student Experiences**

Our findings that the leaders and some members of the Mines community seek prestige for their institution fits with the higher education literature on the effects of knowledge capitalism (Olssen & Peters, 2005), which identifies the impact of neoliberal ideology in U.S. colleges and universities, but also postsecondary institutions across the world (Gonzales & Nunez, 2021). Mines' leaders are merely following the pressures and rewards in the higher education fiscal system, which is based on rankings that have emerged in the last few decades, which impacts institutional policies but also the work of faculty. Leaders at Mines and in higher education globally must therefore critically

interrogate how their prestige seeking affects student well-being, particularly when these same leaders claim to support DI&A and mental health initiatives on their campuses. This investigation requires critical historical reflection. I showed in the historical literature review in Chapter Two how engineering education emerged relatively recently as a formal discipline distinct from science education (Seeley, 1999). The historical research illustrates the changing status of engineers in U.S. society and how the professional field emerged (Oldenziel, 1997). This research also shows how engineering education in the U.S. was shaped by the geopolitics of the Cold War and globalization economic pressures to compete internationally with technology development (Downey, 2007). However, Mines prestige and oral saga predate the Cold War era.

Higher education historians Cohen and Kisker (2010) laid out the ways that the industrial revolution in the United States shaped higher education in what they term the “University Transformation Era” (p. 106) from 1870-1944. Mines emerged as an institution of higher education in this era soon after the Civil War while Colorado was still a territory, and interestingly the school was created under the Episcopal Church in 1874 (Mines history and traditions, 2023). This timeframe notably coincided with the new era in higher education that Cohen and Kisker (2010) identified. Early courses included “chemistry, metallurgy, mineralogy, mining engineering, geology, botany, math and drawing” (Mines history and traditions, 2023) in response to the Colorado gold rush that began in 1858 and continued until statehood in 1876 (The Colorado Gold Rush, 2020). The institution’s culture is deeply entangled with this mining history including the school mascot Blaster the burro and the term Orediggers for athletic teams and students.

Indeed, the school's website formally claims and defines the uniqueness of the institution to this history and claims that since 1874, "Not much has changed in the nearly 150 years since" (A unique name for a unique university, 2023). The site also displays the school's ranking as number one in mineral and mining engineering globally.

Cohen and Kisker (2010) explain how the post World War II era in U.S. higher education was transformed from 1945 to 1975 as enrollment in postsecondary education accelerated as the Cold War heated up and government funding of weapons research transformed how STEM programs were funded. As demand for graduates in STEM disciplines increased to fill technical positions in the workforce, so did the prestige of STEM over the liberal arts. Debates continued during this period, as they do today, as to whether the purpose of higher education was the promotion of democratic public goods and the search for knowledge, or career development, competition, and individualism. I believe this is a false choice as higher education institutions' missions are complicated and complex and are deeply entangled with historic precedents as well as current and future needs. Cohen and Kisker (2010) argue that by 1975 higher education curriculums had become vocationally focused as the neoliberalist economic paradigm emerged and students came to be seen as consumers and a college degree a commodity in which institutions competed for students. Accreditation agencies emerged in this period and influenced the standardization of curriculums and shaped institutional policies and governance, which created a new focus on managing schools for efficiency and effectiveness through quantitative assessment. However, the authors (Cohen & Kisker, 2010) argue that the biggest impact on engineering education's prestige was the

disproportional government funding of research and development for weaponry, which was awarded to STEM programs and outpaced funding for all other disciplines.

This funding preference also accelerated the growth and prestige of technology research in specialized centers connected to STEM institutions like the Massachusetts Institute of Technology (MIT) and the California Institute of Technology (Cal Tech). In their integrative analytical literature review to uncover the impact the “ranking regime” (p. 76) has on the production of knowledge in academia, Gonzales and Nunez (2021) explain how these trends continued as four main practices and values across higher education internationally: individualism, standardization, commodification, and homogenization. Indeed, commercial rankings organizations emerged in the 1980s and focused on the domestic markets of parents and potential students (Gonzales & Nunez, 2021). The authors explain how faculty work, including classroom instruction, was impacted by this transformation of higher education into a capitalist market system, in which institutions globally compete to be “world class” institutions (p. 79). The market system of prestige and rankings based on neoliberal ideologies is now normalized, yet the public remains unaware of the effects this ideological structure has on teaching students. Faculty compete as individuals within a tenure and promotion structure that prioritizes attaining research grants and publishing their research in top tier academic journals; teaching at prestigious institutions is often not a priority for faculty or administrators, a reality which is invisible to most potential students and their parents.

Gonzales and Nunez (2021) argue that this pressure to climb in status skews school policies and values away from student instruction. In their research, they found

that despite the increase in pedagogical standardization and overreliance on quantitative rankings in relation to the commodification of higher education, there is no known reliable tool for measuring the impacts of culture, politics, and resource allocation on teaching or for the “dynamic, rich, and engaging knowledge production” in the classroom that is required for student learning (p. 90). The impact of these trends on Mines policymaking and curriculum and pedagogical development are outside the scope of my research project. However, our findings indicate that Mines policy makers, leaders, and members of the community who uncritically pursue institutional prestige may be creating unintended negative effects on student well-being and learning. There is scant research on how status seeking affects students however (Gonzales & Nunez, 2021), and I could find no research that explicitly explored the entanglements of the engineering cultural conceptions of extreme rigor and weeding out with institutional prestige seeking and how these dynamics affect engineering student mental health, particularly among underrepresented students. Clearly, more research is needed.

In her theorization of the phenomenology of whiteness, Ahmed (2007) asked what happens if the hidden habits and marks of privilege in institutions are revealed and brought to the surface? My study with the participants showed that prestige and rigor are deeply entangled with Mines’ oral saga in which members of the community form and maintain a common identity based on overcoming adversity during their student experiences (Clark, 1972). However, we also showed that the forms of adversity that the underrepresented participants experienced in the culture are invisible in this saga. Instead, the Mines saga is an economic story of achievement. The participants all shared how they

have been socialized to believe that by overcoming the adversity they experience in their education, employers will be eager to hire them as Mines graduates. However, the participants acknowledged that this prestige narrative remains connected with a few specific industries like mining and petroleum engineering that were the foundations of the school. Socialization that perpetuates a saga that the extreme suffering will benefit the students because employers appreciate the extreme rigor, group work, and research in the classroom, as advertised on the Mines website (A unique name for a unique university, 2023), is a bit misleading if a student is not in one of these majors. In fact, I argue that the extreme suffering and weeding out agenda do not create the interdisciplinary, creative, and cognitively diverse engineer that the broader technology workforce requires and desires (Taylor et al., 2019; Weinbaum et al., 2023). In fact, these traits and skills are the purview of the humanities, arts, and social sciences disciplines, which are marginalized in the Mines oral saga and campus culture.

The humanities, arts, and social sciences (HASS) department at Mines is unique for two reasons. First, we are not a separate college on campus with the autonomy and power that status provides, but merely a department. Second, the dozens of faculty members in HASS are from a variety of disciplines making the department completely interdisciplinary. Many of us enjoy teaching our disciplines to the STEM students because of the challenge that the interdisciplinary quality of the work provides. However, in my nine years on campus, I am aware that it is a common and well-known narrative that our department is a sort of necessary evil that is required by accreditation, and our contributions to engineering education are not clear to the rest of the campus community,

nor appreciated. The participants' data and content verified this narrative. As adjunct faculty, and therefore part-time and temporary, I have limited insights into the functioning of the department and the HASS faculty members' experiences with the rest of the campus community, so I will not generalize my experience or perceptions as universal. But my sense that I must justify the disciplinary value to some of the students in the required entry level HASS courses I teach was clearly reflected to me in my interactions with the participants and their sharing of their experiences and perceptions of the disciplinary differences they perceive at Mines.

I believe this marginalizing narrative about HASS is counterproductive to creating the professional engineers that industry and government seek, namely, engineers who are culturally and neurologically diverse and responsive to differences, and who are creative, ethical, and thoughtful (ABET, 2022; Chrysochoou, et al., 2022; Taylor et al., 2019; Weinbaum et al., 2023). Additionally, this marginalizing disciplinary narrative is harmful to the students who are socialized to resist these required courses because it can affect their academic outcomes. It is also derogatory to the many interdisciplinary students at Mines who value a full disciplinary college experience while maintaining a STEM focus, including the participants of this study. I believe this damaging narrative, which is based in the culture that elevates engineering disciplines and epistemologies as superior to all others (Riley, 2008; 2017), must be made visible and transformed to improve student well-being at Mines. HASS must be incorporated into the oral saga at Mines as a crucial and valued part of the Mines community just as the stories from underrepresented communities on campus must also be included and deemed a part of the saga.

### **Creating an Inclusive Mines Oral Saga**

As I showed above, Mines' oral saga (Clark, 1972) is robust and has been painstakingly curated across decades. Anecdotally, I have been told repeatedly in my nine years on campus that Mines is a conservative school that is slow to change, with this resistance to change even being a point of pride. The past is ever present at Mines, which the participants' data also showed; they must go through the same experience as the students who have come before them. Mines has included gender differences as part of its saga for decades through highlighting its first female graduate in 1898, Florence Caldwell Jones. The school also boasts a female student population of 31% that is above the national average (Women in science, engineering, mathematics program (WISEM), 2023). Female student associations, sororities, programs, and initiatives are visible on campus, some of which I have participated in. However, despite these efforts, the participants all described microaggressions from male students that included assumptions and accusations that these women were at Mines merely due to affirmative action. And while females are part of the oral saga at Mines, the narrative is still one of elevating female students as remarkable for persevering in an engineering culture that perceives females as outsiders (Heybach & Pickup, 2017). Additionally, other identities based on race, sexuality, gender, ethnicity, disabilities, and socio-economic levels are not visible in the overall Mines saga, which I argue is mostly likely due to socio-technical dualist assumptions that differences do not matter and the one-size-fits-all model that remains prevalent across higher education.



The interview prompt list that I created from the literature included a seventh item that asked if the participants were interested in exploring any of their experiences that were related to the history of engineering; strikingly, none of them chose to discuss this item on the list. While the participants reported that they were at times exposed to the history of the technological aspects of their specific majors in some classes, the social, political, and economic history of engineering was invisible for them. In short, they had no idea of how history has shaped engineering professions and education. However, historical stories about Mines as an institution were prominent and visible both formally, as in the M-Climb, but also informally in the campus narratives about following in the footsteps of previous Mines students. The oral saga of Mines socializes the students into the lineage of those who have come before them. However, as was shown in the findings, the participants were aware of this socialization but sensed that those who came before were different than these three participants with their multiple identities.

### **Student Mental Health in Engineering Education**

The medical community and educators are recognizing the growing mental health crisis among students of all ages and in all disciplines (Greenburg, 2022). In engineering education specifically in 2022, Worcester Polytechnic Institute (WPI) reported seven student suicides in eight months (Moody, 2022). Unfortunately, research on mental health in engineering education specifically is still nascent and limited to quantitative studies (Cross & Jensen, 2018; Danowitz & Beddoes, 2020; Jensen & Cross, 2021). Additionally, given the recent experiences related to the Covid-19 global pandemic from 2020 and into the present, simple identification of causes for these phenomena and trends

are not clear (Moody, 2022). However, our research resonates with the extant research in EHED that implicates the culture, history, and pedagogic approaches as negatively impacting student well-being and academic success (Allen, 2017; Blosser, 2017; Cech, 2013, 2014, 2022; Cech & Waidzuanas, 2011; Beddoes & Danowitz, 2022; Godfrey, 2007; Godfrey & Parker, 2010; Haverkamp et al., 2019; Heybach & Pickup, 2017; Jensen & Cross, 2018; Leydens & Lucena, 2018; Liptow et al, 2016; Lord & Camacho, 2013; Mayes, 2014; Riley, 2008, 2017; Seron et al., 2015, 2018; Slaton, 2013; Stonyer, 2002; Tate & Linn, 2005). Indeed, I argue that our study provides much needed details about how it feels to experience the culture from the three different perspectives of the participants and that our study's findings compliment the few quantitative studies (Cross & Jensen, 2018; Danowitz & Beddoes, 2020; Jensen & Cross, 2021) on student mental health in engineering.

The participants' data and content clearly showed their awareness that student mental health at Mines was problematic. Indeed, it was another student's suicide attempt that triggered Esperanza's PTSD, and the mental health impact emerged clearly in her data and content. Despite being given professional mental health advice from the school's counseling center to take time off, her feeling that she could not take time off points to a barrier to supporting students when they are impacted by mental health crisis of their own or their peers. I did not include any interview prompts about mental health; the emphasis on the mental health impacts of the culture emerged from the participants themselves. Their data and content showed their concerns for both their own well-being but also that of their peers. This concern was evident in the findings that showed how they were

resisting the damaging aspects of the culture of extreme suffering and instead creating practices of self-care that they proactively shared with peers despite accusations that somehow the participants were less serious as students because they took time off.

Additionally, the participants clearly showed the mental health impacts that come with microaggressions. These microaggressions created barriers to their sense of belonging at Mine based on hypervisible identities like their sex but also toward them for their more ambiguous identities like being mixed-race and queer. But our study also showed the mental health impacts of their invisible identities as well, like neurodivergence and physical disabilities. Indeed, what emerged was their resistance to sharing these vulnerable identities with peers, faculty, and staff at Mines for fear of stigmatization and marginalization, which is consistent with previous research (Chrysochoou et al, 2022; Cuellar et al., 2022; Pesonen et al., 2020; Taylor et al., 2019; Weinbaum et al., 2023). Mines, as well as other institutions of higher education, and especially engineering education, cannot address mental health issues with students without examining the cultural features that contribute to marginalization both in and out of the classroom.

### **Section Conclusion**

Industries, workplaces, and the broader world need engineers to solve critical global and local problems. However, they need engineers who are not exhausted and mentally drained from their learning experiences due to invisible weeding out processes that undermine student self-confidence in their own abilities and damage the student's mental well-being. My research and others (Cech, 2013, 2014; Leydens & Lucena, 2018;

Maloney et al., 2018; Seron et al, 2015; Riley, 2008; 2017) continue to show that educators and administrators in engineering education isolate themselves within higher education as somehow different and removed. I have shown how this socio-technical dualist cultural belief of being removed from the rest of society and academia is historically and politically entangled with the emergence of the engineering professions and postsecondary education. Creators of this early culture of engineering intentionally excluded women, racialized minorities, and rested on assumptions about masculinity and changing perceptions about engineering and technology (Bix, 2013; Frehill, 2004; Oldenziel, 1997, 1999; Slaton, 2010; Svyantek, 2016). I have also shown the political and economic changes over time that influenced engineering education culture and created a sense of prestige over other disciplines (Cohen & Kisker, 2010; Seeley, 1999), but also the unknown impacts on students related to the ranking regime and status seeking in the era of neoliberal higher education (Gonzales & Nunez, 2021). My collaboration with three Mines students with multiple underrepresented identities made the socio-technical dualism and its associated values of extreme rigor and over reliance on positivism visible for the participants, me, and now the Mines community. By sharing their stories, the participants found the invisible walls and barriers that still reside at Mines despite efforts, initiatives, policies, and programs aimed at increasing the diversity of Mines students. There is further work to do. Most importantly, we have shown that the myth that there is a one-size-fits-all model that is effective for all students is detrimental to student well-being. I now turn to the theoretical implications of my creative materialist framework.

## **Theoretical Implications of Creative Materialism**

I theorized a neurodivergent conceptual framework that appears to have attracted neurodivergent participants, but who did not know this at the time they joined the study. Nor did I know this was an identity I held when creating my framework and proposal. Through our research entanglement using creative materialism, the four of us were transformed and informed through our intra-actions and continuous looping together (Nail, 2021). However, here is where one part of the journey ends and the next begins; because creative materialism is a subjective, material, relationship-based, and emergent framework, all four of us will continue our own, and possibly shared, journeys of further coming to understand and make meaning about our neurodivergent ways of being and knowing in the world. There was no objectivity claimed in this study as culturally responsive methodologies (CRM) (Berryman et al., 2013a), new materialist theory (Barad, 2007; Nail, 2021), and arts-based research methods (ABR) (Barone & Eisner, 2012) offer different kinds of research approaches that illuminate problems in a new light. And researchers in engineering education recognize the need for different approaches despite the cultural and institutional resistance to interdisciplinarity and epistemological inclusion (Beddoes et al., 2017; Chrysochoou et al., 2022; Cuellar et al., 2022; Douglas et al., 2010; Kellam et al., 2015; Maloney et al., 2018; Riley, 2017; Taylor, 2019)

I anticipate that this alternative to positivism and objectivity for my study may be difficult for engineering education practitioners and researchers to appreciate and accept (Riley, 2017) because of the deeply embedded epistemic values that permeate the culture

and pedagogic practices (Bucciarelli, 2009), like weeding out (Godfrey & Parker, 2010). In fact, I had to reassure all three participants at least once that we were not seeking objectivity, as well reassure myself that my framework required me to build a culture and community with the participants, not keep my distance from them. Yet it was my transparent, self-reflective, honest, and vulnerable ways in which I intra-acted (Barad, 2007) with the participants that built rapport and trust, and the depth of the participants experiences emerged in detail as they shared their stories with me. While the participants sought to build a community of care at Mines, we built a community and culture of care over the months of the research, which grounded our research endeavors. It is this type of engagement and participatory relational research paradigm being called for in neurodiversity literature and research (Cuellar et al., 2022). Researchers continue to call for a strengths-based approach to pedagogy that incorporates Universal Design for Learning (UDL) that normalizes neurological differences and transforms perceptions about cognitive pluralism (Chrysochoou et al., 2022), which overlaps with the goals of culturally responsive pedagogies for cultural and neurological differences in learning (Berryman et al., 2015). These paradigm shifts require normalizing and appreciating the development of creativity in neurodivergent students and valuing this creative divergent thinking as contributing to the overall creativity of the professional workforce, and particularly in engineering fields that value innovation (Chrysochoou et al., 2022; Taylor et al., 2019; Weinbaum, 2023). Indeed, research shows that the standardization, commodification, and neo liberalization of higher education is a barrier to developing creativity in students (Gonzales & Nunez, 2021). And as Eisner argued repeatedly

(2008), all disciplines use creativity. The evidence is that the integration of creative arts education provides the disciplinary know-how to teach and develop the skills of divergent thinking, pattern recognition, and taking feedback and incorporating it into new iterations of projects (Marshall, 2014). The arts also celebrate multiple perspectives and ways of knowing (Barone & Eisner, 2012), which fits well with neurodiverse education as well (Berryman et al., 2015). In this next section, I discuss the theoretical implications of my study for new materialisms, culturally responsive methodologies, and arts-based research methods.

### **New Materialist and Culturally Responsive Interpretations**

Barad's (2007) concept of ethico-onto-epistemology was foundational to my creative materialism framework. She theorized using quantum mechanics that reality is created through our intra-actions as material beings, and therefore we affect each other in material ways, which is the basis of her ethical argument in agential realism (Barad, 2007). Her ethical phrase "marks on bodies" (Barad, 2007) haunted me through my doctoral process as I built my framework and situated my study in the literature, but also during this dissertation research with the participants. As the participants shared their experiences in the classroom, I continually asked myself, what marks are we as educators leaving on student bodies? But I now also believe that we as educators must critically interrogate how we are shaped by these factors as well. What marks is the culture of engineering leaving on faculty bodies that in turn affect our intra-actions with our students? Uncovering answers to this question requires research that folds in the higher education pressures of neoliberal prestige seeking (Gonzales & Nunez, 2021) with critical

examinations of the engineering culture and its pedagogies that are historically entangled with the prestige system and a one-size-fits-all approach to students (Riley, 2017), research beyond the scope of this study.

Research intra-actions also leave marks on the bodies of all the participants and researchers alike, which resonates with the ethical imperatives in CRM of respect, participation, trust, and humility in research (Berryman et al., 2013b). Through this process, a new culture developed for the participants and me in our tiny research community. My experience in creating and implementing a CRM framework resonates with the literature that describes other CRM based doctoral research (Bloomfield, 2013; Nodelman, 2013; Valenzuela, 2013) in two ways: the unexpected will happen and affect the research, and these types of frameworks require substantially more effort and emotional investment and risk than so-called objective and traditional approaches that conceptually maintain the distance between researcher and subjects (Riley, 2017). Indeed, there is nothing neoliberal about using culturally responsive methodologies. Given the uniqueness of my study's framework, I cannot generalize or speculate beyond the data and content created by the participants at our location. However, I think there are interesting connections around power that emerged in the study between the neoliberalist prestige seeking pressures at Mines (Gonzales & Nunez, 2021) and the engineering cultural attachments to rigor, positivism, and notions of objectivity (Riley, 2017) that are perhaps related to using CRM in my framework (Berryman et al., 2013a), with its goal of exposing power inequities. I chose these elements to construct my creative materialism framework and used them to counter the cultural hegemony of positivism by using



subjective, creative, and responsive methods. I repeatedly reminded myself that I was not seeking objectivity, but merely the stories from these participants' perspectives with a goal of sharing them to show how their individual differences matter in their education. I believe that creative materialism is a vigorous (Riley, 2017) novel interdisciplinary approach to examining the culture of engineering for those seeking a different perspective.

Nail's kinetic new materialist theory (2021) is premised on making the research process and knowledge production visible. Perhaps there is a connection here with neurodivergent ways of knowing, but I can only speculate on that as it was not the purpose of the study, nor what I directly theorized. Rather, this connection became visible through the contingent, emergent, transparent research process in which we shared and were vulnerable and trusting; that is, it was the unique combination of theory and methods and an emergent culture of care and epistemic pluralism that produced the findings. Further research focused on this connection is needed. I believe that Nail's contemporary loop object theory offers a robust interdisciplinary framework for new vigorous (Riley, 2017) research in STEM education because of its grounding in quantum field theory, mathematical category theory, and chaos theory. Nail's theory fits well with Riley's (2017) call to replace the disciplinary borders in engineering education and research based on outdated conceptions of rigor and objectivity because of his use of more contemporary conceptualizations of reality and research as an entangled, contingent, relational, and emergent.

Based on my extensive research on the culture of engineering as I conceptualized and designed this study, I used Nail's concept of kinetic operators (2021) in my theorization for this research and identified three that shaped the study context and methods: the fetishization of extreme rigor, overreliance on positivism, and the socio-technical dualism in which engineering education and practices are devoid of any social, political, historical, or economic entanglements. I used these three kinetic operators to create some of the initial interview prompts for the participants to identify a place to start our collaboration and to customize their interview questions to their unique combinations of their social and embodied identities as well as their personal goals for participation. Based on the findings, all three of these kinetic operators emerged repeatedly and robustly in the data and content. The participants described their experiences of these kinetic operators and how they shaped their experiences in the culture despite not comprehending their theoretical role in the study, making these kinetic operators salient. I think our study shows the potential contribution of using Nail's (2021) concept of kinetic operators in the research design to show what is hidden in participants' experiences.

The unique combination of theories and methods I utilized uncovered new stories to add to the Mines oral saga, and to the growing body of research on how the culture of engineering shapes underrepresented student experiences (Allen, 2017; Blosser, 2017; Cech, 2013, 2014, 2022; Cech & Waidzuanas, 2011; Beddoes & Danowitz, 2022; Godfrey, 2007; Godfrey & Parker, 2010; Haverkamp et al., 2019; Heybach & Pickup, 2017; Jensen & Cross, 2018; Leydens & Lucena, 2018; Liptow et al, 2016; Lord & Camacho, 2013; Mayes, 2014; Riley, 2008, 2017; Seron et al., 2015, 2018; Slaton, 2013;

Stonyer, 2002; Tate & Linn, 2005), including their mental health and well-being (Cross & Jensen, 2018; Jensen & Cross, 2021). I showed in the findings in Chapter Five how these new stories are emergent contemporary loop objects of new knowledge (Nail, 2021) that can be shared to transform other people's perspectives on higher education and how one size does not fit all. I also theorized learning and gaining new knowledge as a form of epistemic turbulence using Nail's theory (2021). I think that this turbulence was particularly evident in the findings in Chapter Five that illustrated the difficult process of coming to know I was neurodivergent. While medical and scientific testing provided me new insights that helped me make sense of my experiences in the world, the integration of that new information occurred as a process within the creative materialist framework and the community of trust and care that the participants and I built. By discovering this new identity my perspective was shifted permanently, both about myself but also the participants and my conceptualization of diversity, inclusion, and access in higher education more broadly. This shift in my perspective was contingent, hybrid, and an emergent process of coming to know myself differently that was relational to the participants and only occurred because we were willing to be transparent and vulnerable with each other but also ourselves. I think that my inclusion of culturally responsive methodology principles that emphasize creating community and trust were necessary for this transformation to take place (Berryman et al., 2013b). So, while the participants and I left marks on each other's bodies through our sharing, and while this new knowledge created onto-epistemological turbulence in us, the vigor (Riley, 2017) of our methods,

which included culturally responsive methods (Berryman et al., 2013b), allowed those marks to be healed together and was ultimately empowering and transformational.

The contemporary loop objects as stories in this dissertation will also leave marks on bodies (Barad, 2007) as readers intra-act with the document, theorization, findings, and interpretations. New knowledge is transformational. Additionally, students as they are socialized into their disciplines are marked by the culture, the institution, and in the process of learning through pedagogies and intra-actions with faculty and peers. The same occurred and continues to occur in the final writing of this dissertation and the looping in of my committee members by incorporating their feedback from my oral defense of the research from which these contemporary loop objects emerged.

### **Future Research**

Others who wish to use creative materialism for their research studies can learn from our study and experiment in similar ways. The benefit of continued research using creative materialism, whether in engineering education or higher education or not, would be the addition of more stories that provide the depth of student experience in addition to the generalizations derived by quantitative methods. Differences matter and more stories that show these differences will benefit our understanding as educators of the unique ways that our students embody their learning and experiences on campuses. Future research using creative materialism could focus on specific demographics to explore differences within those communities and add to our understanding of differences to counter the one-size-fits-all model. Creative materialism projects can also be used in

conjunction with other traditional quantitative and qualitative methods to triangulate findings and interpretations as well.

Generally related to the study, further research is also needed to better understand the connections and effects of the higher education international prestige system on students from all backgrounds, but particularly underrepresented students and those with disabilities who experience marginalization. Additionally, research should be conducted with the public to determine their understanding of neoliberal impacts on higher education and how it affects student learning; admittance to the most prestigious institutions may not benefit students who desire or require faculty whose primary role is teaching rather than research. Relatedly, engineering education researchers should specifically examine how prestige and cultural manifestations of rigor as extreme suffering intersect and affect engineering student well-being. However, these future studies must also identify and explore how various historical entanglements are woven into the cultures they study if we are to better understand cultures that are harmful to students.

I did not start my study with knowledge of my disability but rather uncovered it through the research process. This realization occurred because of my intra-actions with the participants who identified as disabled as we explored how their disabilities shaped their experiences as students at Mines. From these findings, I believe that related to disabilities, further research is needed on higher education disability services and how they function. The impact of legal and medical requirements on the process of providing accommodations for students needs in depth examination from the student perspective.

The economic implications for low-income students with disabilities must also be examined for the impact of the DSS medical approach that requires documentation that some students may not be able to afford. There is also room to examine the fiscal costs for low-income students with disabilities in a weed-out culture that may require them to pay for the same class several times.

My study also generated new knowledge about the impacts of culture on the participants' mental health. However, in terms of research on student mental health in engineering education, there is a dearth of qualitative studies that include the student's voice, and specifically the voices of underrepresented students. Further qualitative research is needed. Specifically, more qualitative research is needed that examines the policies and legal framework that are barriers to the campus counseling centers offering ongoing chronic care in addition to acute care; future students will come with diagnosed conditions that need ongoing support. My study showed how one student's mental health crisis affected the mental health of their peers. The diversity of counselors at counseling centers on campuses should be examined for gaps in representation of various identities, including neurodivergence and cultural differences, and how this affects underrepresented students use of these resources. Qualitative research should also be conducted with faculty to uncover different generational understandings of mental health and research is needed on how faculty understand cultural and other differences in underrepresented students' experience. I think that more qualitative research methods in engineering education are needed to clarify the impacts of the culture on a variety of student experiences and should include the student perspective. In short, more qualitative,

and responsive research is needed to generate new stories that can transform higher education cultures of exclusion.

Research should also be done that makes the lived experiences of students with invisible identities more accessible to campus community members, so they understand differences in experiences. Gathering data from the student body on diagnosed learning and physical disabilities as well as mental health conditions like anxiety and depression must be prioritized to make this population visible. However, it is imperative that this research also respects privacy and avoids tokenizing these underrepresented students; care, respect, and responsive methods must be used that focus on improving the students' experiences instead of prioritizing inclusion efforts as an element of institutional prestige. Additionally, further data is needed on the experiences of low socio-economic students and the stresses related to paying for school as well as working multiple jobs as a student.

In terms of the culture of engineering and related to prestige and rigor, further research is needed to understand the experience of students with the “smart kid” identity, which our study showed can be detrimental for students attending prestigious institutions with weed-out programs intended to eliminate a portion of the student body in their first few years on campus. More data is needed to understand the harmful outcomes of invisible weeding out policies on students who assume they are qualified because they have been accepted at these institutions. Ethically, I argue that invisible policies like this need to be clearly and transparently shared with potential students and parents if they remain part of the pedagogical framework and expectations of any school. Relatedly, research is needed in engineering education to critically examine the pedagogical

differences between teaching and learning difficult STEM concepts—that is rigorous subject matter—and the cultural and institutional practices that force students to choose keeping up with their schoolwork over their health, both physical and mental. There are historical ties to the military and gender conceptions in early twentieth-century formulations of engineering (Riley, 2008; 2017) that seem entangled with current cultural practices that focus on workload endurance rather than effectively teaching difficult subject matter to a variety of students, which is what current students and the workforce require.

### **Recommendations**

My recommendations include some for Mines specifically, but these recommendations also apply to other engineering education programs because of the shared culture that extends internationally. I believe these recommendations also apply more broadly to higher education in terms of creating inclusive and accessible campuses for underrepresented students. While these recommendations are based on my research, the participants also offered their own recommendation at the focus group that I incorporate here.

Specifically, based on my study, I encourage Mines to examine how to transform the continuous unending culture of exams that are uncoordinated across faculty and that wear students out. The Trefny Center for faculty professional development at Mines (Trefny Center, 2023) should continue to work with faculty to increase their class organization, communication, rapport building, and ability to use a variety of culturally and neurologically responsive methods to communicate and teach theories, topics, and



concepts to the ever-growing diverse student population. As Disability Support Services (DSS) are not clearly understood by students, further work needs to be done to better explain the process and make it more accessible to students and parents. Additionally, professional development for faculty and staff should include training and research to ensure they understand DSS and accommodations, so they do not contribute to the stigmatization of disabilities of students or fellow faculty. These types of efforts in higher education would also benefit engineering and other workplaces by normalizing cognitive differences among all students so when they arrive in their professions, they are able to work respectfully and collaboratively across differences (ABET, 2022). The research also shows the strong impact disabled faculty have on their students' perceptions when faculty share their own disabled identities and stories (Chrysochoou et al., 2022), so I encourage Mines faculty to be transparent about their own neurodivergence and other disabilities to help normalize differences. Sharing one's own story can create understanding and empathy for non-disabled students but also provides affirmation and can increase the confidence of disabled students. However, I recognize that many stigmas exist and that making oneself visible as a neurodivergent role model comes with risks for faculty and that these decisions are personal despite the evidence that visibility normalizes differences for the larger community. Therefore, creating a campus culture of care and support for vulnerable sharing is crucial and must happen simultaneously with individual underrepresented faculty sharing their own struggles.

The Trefny Center (Trefny Center, 2023) should also continue their professional development of Mines faculty to challenge the veracity of cultural conceptions of

extreme rigor and the weed-out culture through faculty workshops that provide supportive spaces for sharing, vulnerable exploration, and self-reflection and that incorporate different research methods that are culturally responsive. I strongly encourage Mines' leadership to continue their work to remove the entire concept of "weeding out" new and low-level students; why invite students to campus and then purposively make them fail at least one course? The weeding out culture makes the school the enemy of students and creates distrust and suspicion about the institution's motives and intentions and is counterproductive to student learning. The leaders at Mines should continue to support research on campus that elevates the students' experiences of the culture to provide specific insights that then can be used to address harmful cultural practices like weeding out students. The Trefny Center and other programs and initiatives at Mines that research and explore alternatives to traditional rigor-as-suffering pedagogies should also continue to receive resources and support, and findings and new insights should be communicated across the campus for other faculty to develop. Additionally, because of their influence there is a need to educate Mines alumni about current underrepresented student experiences, current mental health challenges, and the resulting required changes to pedagogies and culture. Alumni are influential culturally and financially at Mines and must be included as stakeholders if the culture is to be transformed toward inclusion and access for all the varieties of students Mines recruits. That is, the entire Mines campus community must be transformed through hearing evocative new stories that expand their understanding of the current Mines students, not those of the past.

I also recommend that Mines leadership examine how DI&A news, initiatives, hires, and issues are communicated throughout the entire campus and how to specifically reach underrepresented students, faculty, and staff, which affects these community members' feelings of belonging. By elevating DI&A news to the entire campus, these new developments and contributions to the Mines story will become part of the inclusive saga that recognizes a changing world and that a greater variety of communities are now part of the Mines story. To make the campus truly inclusive requires that DI&A become fully integrated into the Mines culture. When leaders marginalize DI&A efforts rather than elevating and centralizing them in the campus culture, it creates the perception for some community members that these initiatives are merely an obligated addition required for maintaining prestige, which affects underrepresented students' sense of belonging. The DI&A programs at Mines are continuing to grow and many community members are passionate about their work. However, the initiatives remain ineffective, inconsistent, and uncoordinated based on our study.

Research shows that diversity programs at predominately White and exclusive institutions are an emergent process that requires changes over time (Ahmed, 2012). Currently, through design, Mines lacks a strong centralized leadership position that can coordinate and provide resources for initiatives across the campus related to community, culture, and the ethics of inclusion and access. Implementing a high-level leadership position related to inclusivity and access that can shepherd the changing culture at Mines into the future also visibly signals to the community members the importance of inclusion and accessibility for differences; that is, new arrivals are welcome and belong at Mines

and should not be treated with suspicion but with respect and dignity. In a community of care, those who struggle should be helped, not weeded out. However, this cultural change requires buy-in at all levels of leadership and across programs and disciplines. The creation of a culture, community, and ethics leadership position at the highest levels also counters the traditional cultural view that one-size-fits-all and that there is one “type” of engineering or Mines student. Meaning this person could lead the transformation of the culture from one of unnecessary suffering to one of caring and support while learning. The participants specifically recommended that Mines hire professionals with specialized degrees for DI&A positions. That is, they want the school to hire specialists with the training, skills, and knowledge from academic disciplines like higher education, disability studies, and other social sciences. Currently, to fill DI&A positions, Mines often prioritizes current community members with STEM degrees instead of DI&A specialists and experts. With these choices campus leadership expects that STEM faculty continue to teach while holding DI&A leadership positions.

When Mines leaders prioritize elevating faculty and staff with STEM degrees to DI&A leadership positions rather than hiring specialists with the skills and knowledge to address cultural change, it perpetuates a cultural belief that engineering education is somehow removed from the larger higher education environment (Riley, 2017). Leadership’s choices to prioritize those with STEM education and knowledge over experts with the specialized knowledge from other fields related to DI&A indicates that engineering educators do not respect different disciplinary know-how and skills, which further contributes the marginalization of HASS faculty and creates resistance to HASS

courses. Mines and engineering education face many of the same issues as other postsecondary institutions regardless of the disciplinary focus of the schools themselves. By walling themselves off as removed from higher education broadly, I agree with Riley (2017) that engineering education faculty and staff limit their own perspectives and their ability to reach their stated goals. As shown by my review and contextualization of the research and literature on the benefits of diversity and interdisciplinarity in higher education, those in engineering education who remain conceptually and disciplinarily isolated not only miss these benefits, but so do their students and ultimately, the workforce and engineering industries.

As previously stated above, I recommend that Mines community members utilize the remarkable oral saga at Mines with a view to the future rather than the past. Including the stories of new arrivals at Mines and elaborating on the unique benefits that each different generation of students brings to campus and the story of Mines creates inclusion and a sense of belonging. However, these stories need to be shared to increase inclusion in the culture by showing the variety of students who are part of the Oredigger saga, not to tokenize underrepresented students' identities in performative ways that are then geared towards marketing Mines as diverse to add to the institution's prestige. By contextualizing these new stories in the current events and changes taking place in the U.S. and globally, the Mines saga will include change as part of its culture and a future focus for the institution rather than prioritizing the past. As our study showed, sharing stories of differences provides a variety of vantage points from which to view campus culture problems. And stories have the potential to create empathy and understanding that

can then improve the campus climate for inclusion and access, rather than maintain exclusions and suspicions about who belongs. While the campus prepares to celebrate Mines at 150 years in 2024, new and different stories must be regularly included in all aspects of the campus experience for students, faculty, and staff for the next 150 years. In short, changes are required to the culture and oral saga at Mines to meet their stated goals of DI&A, DSS, and mental health initiatives and programs.

Related to increasing the variety of stories included in the Mines community, as I mentioned above, disability support services are not well understood on campus. I recommend investigating the perceptions and assumptions around DSS and disabilities in the campus community to uncover and make visible the barriers for students seeking the accommodations they need, but also to uncover and make visible the ways that disability stigmas are perpetuated on campus. Physical accessibility is of paramount importance for the safety and well-being of students, faculty, and staff with physical disabilities, and operations should be included as a stakeholder in any of these efforts. I also recommend that community members continue to develop and advance narratives of self-care for students, much like the three participants chose to do with their peers. While the oral saga of Mines is one of extreme rigor tied to the physicality of its earliest degree programs and historical ties to the military, the students attending currently do not all hold identities that fit and belong in that narrative. Mines is pursuing diversity, inclusion and access which requires that additional narratives be added to the school's saga to generate the cultural shifts that are required to support the range of differences that students bring to the campus, including physical disabilities, learning disabilities, mental health issues. It is

important to recognize the other forms of endurance underrepresented students experience like financially supporting themselves and working multiple jobs while attending, or the invisible extra labor they exert in a system not designed with them in mind in terms of disabilities for example. However, these stories should not tokenize these community members for prestige and pats on leadership's back for successful DI&A efforts; rather the focus of these efforts must be on creating access and inclusivity for these students in the culture, identifying and developing these students' unique strengths and abilities, and educating the campus community on the variety of experiences that engineering students have on campus to remove stigmas.

Lastly, I recommend that Mines implement additional credited electives in the creative, performing, and visual arts program in the HASS department. I showed in the findings that the marginalization of HASS was visible to the participants and contributed to the dichotomy between STEM disciplines and all other ways of knowing and generating knowledge, which is a barrier to increasing diversity to those students who are interdisciplinary. The research shows the unique role that these disciplines play in educating engineers (Aguilera & Ortiz-Revilla, 2021; Costantino, 2020; Katz-Buonincontro, 2018; Madden et al., 2013; Payton et al., 2017; Perignat & Katz-Buonincontro, 2019) but also how they provide mental health relaxation and reflection space (Constantino, 2020; Guyotte, 2020; Payton et al., 2017). Arts education that is integrated into STEM curriculums can accommodate other ways of knowing including those of underrepresented communities (Payton et al., 2017), which often culturally prize creative and hands-on learning as well as the variety of cognitive differences students

bring (Berryman et al., 2015; Bang & Medin, 2010; Black & Hachkowski, 2019; Castegno & Brayboy, 2008; Zhu, 2020). The arts also provide other epistemological experiences for STEM students to increase their understanding of the variety of ways people think and learn (Madden et al., 2013). Implementing arts education integration frameworks provides unique pedagogies that can increase student comfort with risk taking, failure, and problem solving by using a pedagogy of feedback through critiques, which are foundational to arts education (Constantino, 2020; Madden et al., 2013; Payton et al., 2017). Arts education also teaches how to communicate abstract concepts and ideas visually and through storytelling (Constantino, 2020; Guyotte, 2020). Rather than detracting from engineering education, I argue that the creative arts further develop these attributes in engineering students, attributes that are desired by industry and those supporting innovation (Madden et al., 2013). Engineering maker spaces, while creative, are not grounded in creative pedagogies, which are the disciplinary focus of the arts.

## **Conclusion**

This study's unique contributions provide a different avenue for understanding the experiences of underrepresented students' experiences in engineering education. Given the isomorphic quality of engineering education, particularly globally with the pressures of the ranking regime, the insights we generated should provide new perspective across engineering education based on depth and details we provided. These subjective details are a valuable addition that emerged from using alternative methods than are typically used in engineering education research. I argue that the one-size-fits-all culture of higher education, regardless of disciplinary focus, is a myth that should be identified and studied



with self-reflexivity by those in higher education. I advise that these misguided approaches be made visible so they can be removed and replaced with inclusive and responsive paradigms that acknowledge all students, faculty, and staff, let alone people, are different and unique. Importantly, my theorization of creative materialism proved to be valuable in providing an example of a culturally responsive framework that elevated the voices of the participants by creating a research community with an emergent culture of care, trust, power-sharing, and vulnerability. Our study showed the myriad complexity of participants' experiences because of their identities, both visible and invisible. Furthermore, creative materialism provides a methodology that offers an alternative to the hegemony of positivism and associated beliefs that researchers are removed and distant from their research subjects. Instead, I showed in my dissertation research that research intra-actions as well as educational intra-actions leave marks on bodies that can be transformative and empowering, rather than exploitive, marginalizing, and diminishing of participants.

As I reflect on my purpose for not only this doctoral dissertation, but the focus of all my coursework on investigating why increasing diversity remains a challenge in engineering education, despite decades of outreach, research, recruiting, and program development, I am amazed at the personally transformative journey it has been. Given this original intent of my enterprise, I never expected to discover a new identity as a disabled neurodivergent woman. However, when reflecting on my theorization of creative materialism, the path I took is now visible to me because of this very framework.

While self-discovery was never an intentional research question or goal, I think it is important to communicate that my research framework is neither efficient nor easy and is in fact unpredictable, which makes sense as I chose a subjective interdisciplinary methodology and never sought to validate a hypothesis. My intent was to collaborate and listen to the stories of these three generous and remarkable participants. This intent arose from my research for this dissertation because there was a noticeable gap in the engineering education research on diversity that described the need for new approaches. These gaps described a conceptual framework that made sense to me and made use of my unique cognitive abilities and ways of creating-being-knowing, my kinesthetic-onto-epistemology.

The participants and I shared the outcomes of our intra-actions with all our vulnerabilities to move others empathetically to new understandings of the complexity of the problem of continued lack of diversity in engineering education and relatedly, the professions. The culture of engineering, which is well researched as a barrier to increasing participation in engineering (Blosser, 2017; Cech, 2013, 2014; Foor & Walden, 2009; Riley, 2017; Seron et al., 2015), presented a variety of hypervisible and invisible barriers for the participants during their education but also for our interdisciplinary study. Our collaboration allowed the participants to explore, reflect, and describe these experiences with subtlety and nuance, which also demonstrated how each participant, despite sharing some identity categories, each had their own unique experiences. However, given the interdisciplinary construct of my creative materialism, I also uncovered the marginalization of my disciplinary differences at Mines. As a member

of the Mines community with a complex insider/outsider positionality, my experience with my research at Mines has been enlightening. I hope that this effort in some way contributes to the continuous improvement of Mines in its ongoing mission to recruit and graduate a variety of students while also providing every community member with a sense of belonging on a safe and inclusive campus that offers support and care.

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## Appendix A: Study Description for Potential Participants

Dear Student

You have been identified as a potential participant in my doctoral dissertation research. The purpose of the study is to understand how engineering students with underrepresented social identities experience the culture of engineering during their education. The term underrepresented refers to a group having fewer participants in engineering education in relationship to their overall U.S. population.

To participate you must:

- Be a Colorado School of Mines engineering student.
- Identify as having at least one underrepresented social identity like your race, ethnicity, sexuality, gender, disability, etc.
- Have interest in exploring your social identities in relation to your identity as an engineering student.
- Be comfortable with creativity and making art.
- Have time to participate in the study during the Spring 2022 semester.

Participation in the study involves:

- Participating in 3 one-hour interviews conducted monthly.
- Keeping a weekly diary
- Using your creativity to explore your experiences using the methods of your choice (i.e., photography, drawing, music, writing poetry, etc.)
- A \$100 VISA gift card at the end of the study for your contribution

For more information on this study, please contact the primary investigator, Katherine Robert at [Katherine.robert@du.edu](mailto:Katherine.robert@du.edu) or by phone at 970-779-7073.

Thank you,  
Katherine Robert  
University of Denver Higher Education Department

Dissertation Advisor: Dr. Cecilia Orphan 303-871-3619

Study Title: Exploring Underrepresented Engineering Student Experiences of Professional Socialization

## Appendix B: Script for pre-screening potential participants

Student name \_\_\_\_\_ Date \_\_\_\_\_

### Type of meeting (online or phone)

Hello and thank you for meeting with me to learn more about my dissertation research project. The purpose of the study is to understand how engineering students with underrepresented social identities experience the culture of engineering during their education. The term underrepresented refers to a group having fewer participants in engineering education in relationship to their overall U.S. population. I would like to go over the inclusion criteria with you to confirm you are a good fit, and then explain the study in more detail if you are still interested. If you decide you want to participate, I will go over the Informed Consent document with you that you will need to sign before participating.

I am going to ask you a few questions. Please ask me about anything you do not understand. Feel free to share as much as you want, or you can refuse to answer. You can decide to end this conversation at any time for no reason. Just tell me you want to stop and not participate in the study.

### Selection criteria confirmation

Criteria	YES	NO
Are you a Colorado School of Mines engineering student?		
Do you identify as having at least one underrepresented social identity like your race, ethnicity, sexuality, gender, disability, etc.?		
Do you have interest in exploring your social identities in relation to your identity as an engineering student and your experiences of the culture at Mines?		
Are you comfortable with creativity and making art?		
Are you willing to participate in 3 one-hour interviews conducted monthly?		
Are you willing to keep a weekly diary from January through March 2022?		
Do you have time to participate in the study during the Spring 2022 semester?		



Are you willing to collaborate with me in designing the interview agendas to fit you as an individual?		
--	--	--

**Student is interested in the study and meets inclusion criteria?                      YES    NO**

If YES, continue with explanation of the study in more detail.

**Focus and Purpose of the Study**

As I said, the purpose of my study is to better understand the experiences of students like yourself that identify as having at least one social identity that is underrepresented in engineering. I found while preparing for this study that the professional culture of engineering influences how you are taught to be an engineer and that there are historical trends in the culture of excluding women, Black, Indigenous, and People of Color (BIPOC), LGBTQ, and disabled students. The research shows that the culture of engineering can affect how students with underrepresented social identities experience their education. So, the purpose of my study is to provide you with the space, time, and support to explore your experiences of being socialized into the professional engineering culture during your education.

The goal will be to share your story, while protecting your identity, with the larger engineering education community so they can improve their own diversity efforts. The results of the study may be of interest to CSM as well so they can improve their diversity efforts.

***QUESTION: Do you have any questions about the purpose of the study? Are you interested in exploring these topics with me? What social identities are you interested in exploring? [stay open to conversation and listening to build rapport]***

**Student understands and is interested in the focus of the study on socialization and exploration of their social identities (yes or no)**

**Explaining the Theories and Methods**

Now I would like to explain the unique way I propose we do this study together, which requires explaining the theories and methods. I chose two theories to guide the study that I think offer a different way of approaching research than you are trained in as an engineering student, which is intentional on my part.

One theory, called culturally responsive methodologies, is the framework that requires collaboration between us to create the study. This theory requires that I transparently share everything about the study with you, including my own research agenda, my social identities, and the purpose and processes for the study. A possible outcome of your participation will be to transform how you understand your experiences by examining your various social identities in relationship to your education experiences. You are the expert about your own experiences and my goal is to learn from you and collaboratively

analyze and interpret the data you create to tell your story from your own perspective but also in relationship to the research literature.

***QUESTION: Do you have any questions about the first theory we will use to guide us in the research?***

The second theory I chose interprets quantum field theory and chaos theory as frameworks for research, called contemporary loop object theory. This approach is different than traditional scientific and mathematical based methods that you are probably familiar with where objectivity is a goal. In contemporary loop object theory, we instead focus on your sensory experiences as a student and the relationships between things, for example, how your social identities intersect with your experiences with your department, faculty, and other students. We also look at how your experiences today are influenced and connected to the history of engineering in the US. We will use this theory to analyze and interpret the data we create as we move through the research.

***QUESTION: Do you have any questions about this second theory or how these two theories will work together to guide us? [Listen and be open to the student's interest and own knowledge about these theories and to build rapport through conversation; explain enough that the student acknowledges understanding of how the research is framed].***

#### **Student understands theoretical framework and shows interest (yes or no)**

Now let us discuss what we will do during the research. I propose we use three methods to create data together. I suggest we do three interviews during the spring semester that will be like free-flowing conversations. The purpose of the interviews is to explore your experiences through agenda items that we create together based on your interests and the research literature. I also suggest keeping a diary to reflect on your own experiences with at least one entry per week. You will have control over what you share with me—you do not have to share your entire diary, only what you think is important. Another way I would like to learn about your experiences is through what is called arts-based research methods. The engineering education research literature shows that there is a need for subjective research by engineering students themselves to tell their own story in their own voices. Arts-based research methods use any creative practice. For example, I use drawing, painting, and photography but also poetry to understand an issue I am studying. During the research, I would like you to explore your experiences in some creative way that feels comfortable for you. For example, you could write fictional stories or plays about your experiences or write poetry to help you understand your own experiences and maybe uncover things you were not aware of. I am open to whatever creative method you want to use, and you will choose what to share with me and will have control over any content you create.

***QUESTION: Does this make sense? Do you have any questions or concerns? [watch and listen for the student's comprehension; remain open to their own knowledge as I build rapport; share and describe my own creative process if they want to know more].***

***QUESTION: What creative practices are you interested in using during our research? [conversation about their experiences and preferences with creative practices; goal is to learn and uncover what methods and mediums are best for the student].***

My second research question for the study is about how we do the research based on these theories and methods. So, as we work together over the coming months, I would like us to reflect on and share our experiences of how we are doing this work as well as exploring your experiences of what it feels like to become a professional engineer as you move through your education.

***QUESTION: Does that make sense? Any questions about what I have explained so far? You are my partner in this process. I am merely providing the framework and borders of our process [Build rapport and partnership by working through any power issues that feel out of balance].***

**Student understands and is interested in the methods proposed (Yes or No)**

### **Time Commitments & Workloads**

I recognize as an engineering student you have a stressful workload and limited time, so it is important that we create a balance between my desire to learn about your experiences, and your need to do your own schoolwork. And I am committed to being flexible with you so if things come up, know that we can pause or delay some of our work; I do not want to add to your stress, but instead hopefully provide you with an opportunity to understand it better yourself. The interviews will be about an hour each and we will schedule them about a month apart. I anticipate the diary entry will require about 30 minutes at a minimum each week, but you can do more if you desire. And for your creative practices, it is up to you how much time you want to put in and it will depend on what you pick as an artistic practice. So, I think the overall time commitment will be a few hours per month.

***QUESTIONS: Does this make sense? Do you have any questions or concerns? [listen and watch for their interest and excitement and rapport building]. What concerns do you have about your workload and participating in this study, if any? [determine if participation could cause harm by increasing their stress, or if they see it as an opportunity].***

**Student's workload is manageable, and they have time to commit to the study (yes or no)**

**[Collaboratively discuss with the student if they are a good fit for the study and transparently share any concerns about their participation. If we decide they should not participate, thank them for their time and interest.]**

**For students who are a good fit for the study:**

***QUESTIONS: Does this study sound like something you want to participate in? Do you have any questions or concerns? [Use my awareness of our rapport building and the student's enthusiasm during the discussion so far, but also any hesitation, to formally decide if they want to commit].***

**Student wants to participate:        YES    NO**

**Informed Consent Form Review**

Before you participate, you must review the Informed Consent document. I am going to review it with you now and answer any questions you have. If you still want to participate, I will email you a copy for you to read more closely. If you participate, we will begin our research with an orientation that will help us design the specifics of the study together. I will need you to sign the Informed Consent document at the start of the orientation. **[verbal reading of Informed Consent document with participant]**

**Creation of an alias for privacy**

If you choose to participate, you will choose an alias for me to use in the data and in the written dissertation and your name will not be used in any reports or publications that result from this research study. Please think about and choose an alias name before we do the orientation.

**Wrap up**

Do you have any questions for me?

We need to schedule an in-person orientation that will take about an hour. We can meet on the Mines campus or off campus, although with Covid I cannot come to your home.

When do you want to meet?

Where do you want to meet?

Contact information:

Phone \_\_\_\_\_ Email \_\_\_\_\_

## **Appendix C: Consent to Participate in Research**

**Study Title:** Exploring Underrepresented Engineering Student Experiences of Professional Socialization Using Culturally Responsive, Arts-Based, and New Materialist Methodologies

**IRBNet #:**

**Principal Investigator:** Katherine A. Robert, doctoral candidate

**Faculty Sponsor:** Dr. Cecilia Orphan, Assistant Professor Morgridge College of Education

**Study Site:** Colorado School of Mines campus and off-site locations

**You are being invited to participate in a research study.** Your participation in this dissertation research study is voluntary and you do not have to participate. This document contains important information about this study and what to expect if you decide to participate. Please consider the information carefully as you read it. Feel free to ask me any questions before making your decision on whether to participate. If you decide to be involved in this study, this form will be used to record your permission.

### **Purpose**

If you participate in this doctoral dissertation research study, you will be invited to share your experiences of being an engineering student who identifies as having at least one social identity that is underrepresented in engineering. The term underrepresented refers to a group having fewer participants in engineering education in relationship to their overall U.S. population. The purpose of the study is to collaborate with you to generate personal stories from your perspective as a student to better understand how the culture of engineering affects students during their education. The study will take place during the 2021-2022 academic year. Together we will design the study to be flexible to accommodate your busy schedule and workload. I propose 3 methods for gathering data that will occur during the Spring 2022 semester. I would like to do 3 unstructured one-hour interviews once a month that you will help design. I also would like you to take at least 30 minutes a week to do a diary entry. The last method is using art to reflect on your experiences, and you will choose what creative practice(s) you want to do and how much time you put in. All time commitments are flexible, and you can contribute as much as you desire or have time for. The data collection methods are intended to explore your personal experiences and will require sharing sensitive information, such as your personal history in relationship to your social identities and your choice of engineering as a major.

### **Risks or Discomforts**

Potential risks, stress and/or discomforts of participation may include emotional and psychological stress and anxiety and the sharing of confidential information about yourself and others. To mitigate these risks, you will choose an alias name for the study to guard your identity and the names and details of others contained in your information will be changed to protect your and their privacy. You will be provided opportunities to review any information you share as well as how that information is interpreted and represented. Once approved, your non-identifying information will be shared with the dissertation committee and used in the final dissertation presentation and written document, which will be published. All further uses of your information will require consultation with you prior to sharing. You will choose what parts of your diary entries and artworks are shared with me and retain ownership of these materials. Audio recordings will be made of the unstructured interviews and will be kept secure and confidential as part of the study's records until the end of the study.

For support during the research the Mines Counseling Center provides mental health services to Mines students. It is staffed by licensed and experienced professionals and services are confidential, voluntary, and covered by student fees.

Student Wellness Center  
1770 Elm Street, 2nd floor Golden, CO 80401  
Phone: 303-273-3377  
Hours: Monday-Friday 8:00 am-5:00 pm

Additional resources include the Colorado Crisis Services at 1-844-493-8255 or text TALK to 38255. Outside of Colorado call the National Suicide Prevention Lifeline at 1-800-273-8255.

### **Benefits**

The benefits which you may reasonably expect to result from your participation in this study are an increased understanding of your social identities in relationship to your identity as an engineering student. Previous research shows that providing the space and time to you as an engineering student to critically reflect on your experiences may increase your understanding of your own assumptions about your profession and is an opportunity for personal growth and to gain insights into your purpose as a future engineer. Benefits may also result for the communities that you identify with through sharing the outcomes of the study. Because your campus is the location of the study, the published dissertation may contribute specific insights and stories about the school that can be utilized by them to improve their diversity, inclusivity, and equity efforts. Other possible benefits include aiding the broader engineering education community's

understanding of how to make their programs more inclusive and equitable to different students to increase diversity. However, I cannot and do not guarantee or promise that you will receive any benefits from this study.

### **Confidentiality of Information**

#### **Limits to confidentiality**

All of the information you provide will be confidential. However, if I learn that you intend to harm yourself or others, including, but not limited to suicide ideation or threats against others, I must report that to the authorities as required by law. Know that if you choose to participate remotely through the internet that the data you provide may be collected and used by the online system of your choice as per its privacy agreement. Please be mindful to respond in private and through a secured Internet connection for your privacy. Your confidentiality will be maintained to the degree permitted by the technology used. Specifically, no guarantees can be made regarding the interception of data sent via the Internet by any third parties. Your name will not be used in any report. Your responses in the interviews and the diary entries and artworks you share will be assigned to your alias name. The documents connecting your name to your alias will be kept in an encrypted password protected file. Only I will have access to the file. When the study is completed and the data has been analyzed, the document with your identifiable information will be destroyed if you choose to end our relationship. With your permission, I would like to audiotape the interviews so that I can make accurate transcriptions that I will share with you to review for accuracy. The audio recordings will be destroyed at the end of the study. Your name will not be in the transcript or my notes.

### **Use of your information for future research**

All identifiable information like your name will be removed from the data collected in this project and in the final written dissertation. However, know that the information in the published dissertation may be used for future research by other researchers without your additional informed consent. At the end of the study, you will have a choice on whether you want to continue our relationship or not for future collaborative research. I will not use your data from this study in any future research or publications without your consent.

### **Incentives to participate**

As an incentive to participate and as a form of appreciation for your time and sharing your personal stories, you will be paid \$100 in the form of a VISA gift card at the end of the data collection period.

**Study Costs**

The study costs will be covered by the researcher, including transportation costs to interviews in locations of your choosing to protect your privacy and costs for a diary and art supplies if needed.

**Consent to audio recording solely for purposes of this research**

This study involves audio recording. If you do not agree to be recorded, you CANNOT take part in the study.

\_\_\_\_\_ YES, I agree to be audio recorded.

\_\_\_\_\_ NO, I do not agree to be audio recorded.

**Questions**

For questions, concerns, or complaints about the study you may contact my faculty sponsor Dr. Cecilia Orphan at the Morgridge College of Education Department of Higher Education at the University of Denver. Her contact information is [Cecilia.Orphan@du.edu](mailto:Cecilia.Orphan@du.edu). 303-871-3619

If you are not satisfied with how this study is being conducted, or if you have any concerns, complaints, or general questions about the research or your rights as a participant, please contact the University of Denver (DU) Institutional Review Board to speak to someone independently of me at 303-871-2121 or email at IRBAdmin@du.edu.

**Signing the consent form**

I have read (or someone has read to me) this form, and I am aware that I am being asked to participate in a research study. I have had the opportunity to ask questions and have had them answered to my satisfaction. I voluntarily agree to participate in this study.

I am not giving up any legal rights by signing this form. I will be given a copy of this form.

**Printed name of participant** \_\_\_\_\_

**Signature of Participant** \_\_\_\_\_

**Date** \_\_\_\_\_

**Please take all the time you need to read through this document and decide whether you would like to participate in this research study.**

Please keep this form for your records.



## Appendix D: Orientation Protocol

Student name \_\_\_\_\_

Date \_\_\_\_\_

Location \_\_\_\_\_ Type (in person, online, phone)

Start time \_\_\_\_\_ End  
time \_\_\_\_\_

**The student participants will choose the location and type of orientation: face to face, phone, or online through Zoom or Skype. The orientation's purpose is to collaboratively create the specifics of the research with the student.**

**Identifying information contained in this document will be stored securely in a separate encrypted file from the data collected using the student's alias.**

### **1. Informed Consent Form Review and Signing**

I reviewed the Informed Consent document with you and need you to sign it before we can begin. Do you have any questions about it or the study? I will email you a copy of the signed document for your records.

### **2. Participant Alias**

As I mentioned before, you need to choose an alias that will be used in the written dissertation as well as all my notes and the interviews to protect your privacy. What alias name did you choose for the study?

Student participant's chosen alias/artist name \_\_\_\_\_

### **Orientation**

I am going to take handwritten notes and record our conversation. I will transcribe the recording of our conversation and provide you with a copy to review for accuracy. If at any time during this orientation you want to end the conversation, please feel free to do so. Do you have any questions before we get started? I am going to start recording now. Is that okay?

### **Background questions to build rapport.**

1. So, tell me a bit about yourself and why you are interested in participating in this study?
2. How did you come to choose engineering for your career?
3. How did you choose the Colorado School of Mines for your education?
4. What is your major and why did you choose it?
5. Where are you from—what is your hometown?

[information will be used to populate the Student Information Form besides building rapport]

## **1. Transparent Sharing to Uncover What the Student Wants to Explore and How**

We need to decide what we will explore specifically about your experiences. I am using the engineering education diversity literature as a guide for our interview agenda items but am open to it going in different directions based on your interests and experiences. Remember, our framework allows our process to emerge as we go.

So, this is where our various social identities come into the study—both mine and yours because I am a learner with you, not an expert from outside. And because we are different people, we bring our different experiences and backgrounds to the study. Does that make sense? The culturally responsive part of my framework requires that I transparently share my own social identities and what I bring to our collaboration, so you get to know me. The goal is to build trust between us.

To this end, I am 55 years old and identify as a White cis-gendered heterosexual woman. I also identify as working-class and as a first-generation student, which means I am the first one in my family to attend college. I do not have learning disabilities that I know of, but I do have some chronic pain issues due to work experiences in the past. I have an interdisciplinary background and a wide range of work experiences. I have a Bachelor of Fine Arts in painting and photography; a Master of Liberal Studies, which is an interdisciplinary degree; and I have a Master of Science from here at Mines in the international political economy of resources, with minors in mining engineering and engineering and technology management. I also have worked in a variety of sectors, like retail, food service, construction, manufacturing, interior design, occupational safety, and environmental compliance, to name a few. My interest in doing a PhD in higher education arose from my experiences at Mines and experiencing the lack of diversity in engineering. I was also a graduate student representative on the Campus Sustainability Council and the Mines Diversity Council.

***QUESTION: Do you have any questions so far about me? I am happy to answer anything. [keep awareness on rapport and the student's interest level; how much do they seem to want to know?].***

I also need to clearly share my academic agenda with you, again, for power sharing and transparency. Like many students, I am getting a degree for practical career reasons and doing the dissertation research and completing the degree is obviously a priority for me. However, I want to clearly state that my biggest priority is genuinely understanding your experiences because I believe making engineering education more inclusive and equitable will increase diversity. And part of changing it to be more equitable and inclusive requires learning about specific student experiences like yours.

***QUESTIONS: Does this make sense? Does any of this resonate with you? Do you have any questions? I am happy to share more if you want to know more.***

## **2. Identifying the Student Participant's Social Identities to be Explored**

So now we need to discuss you as a participant and what you hope to get from the study so we can customize it to you.

***QUESTION: Can you tell me more about your social identities that you want to explore in relation to engineering in our collaboration? [listen and work with the student to determine the intersectionality of their stated identities with the salient research literature].***

**Social identities that student identifies with and wants to explore:**

Thank you for sharing [respond and build rapport based on what student says and how comfortable they appear; check my own identities and self-reflect].

***QUESTIONS: What do you hope to gain from the study? What do you want to learn about your own experiences in engineering? [purpose is to build rapport and start marking the borders of the study with the student].***

Thank you for sharing [build rapport and converse about what student shared about their goals with the study; connect student responses with the literature (below)]. I noticed a few repeated patterns in the research on engineering culture and want to offer these as topics for us to explore, but only if they feel important to you.

- The culture of rigor and extreme difficulty like the weeding out processes and concerns about your competency as an engineer.
- The narrow focus on technical issues and lack of space or time for political, cultural, and other non-technical aspects of being an engineer that is referred to in the literature as socio-technical dualisms.
- Learning styles and preferences for how you learn best, but also what you struggle with.
- Your various identities in relationship to your engineering major and/or department.
- Your experiences of feeling invisible and/or hyper-visible, which might be related to the previous point on your experiences in your major and department.
- Your support networks both on and off campus, including family, professional organizations, and mentors.
- Any historical aspects to engineering education and the professions that interest you.

[through dialogue, determine the student's interests]

## **3. Create our Custom Interactions and Data Collection Methods**

Now we need to design our collaboration, like what topics you want to explore in the interviews and a tentative schedule. I have a few questions to help us with this task:

- You said before that you were interested in exploring... [work with student to determine the focus of our research based on their previous answers; sketch out the interview/conversation protocol and questions with the student if they desire].

- I suggest 3 unstructured interviews for us to explore your interests with some depth. We can decide the topic for all 3 interviews now, or let the topics for the 2<sup>nd</sup> and 3<sup>rd</sup> interviews emerge from our first meeting—which would you prefer? And of course, the process is flexible, and we can change it at any time.
- You said before that your workload is (light, moderate, heavy). Is there a specific day and time that you have open that we can schedule the times we will meet? Or would you prefer to do the schedule differently?
- Where/how would you like to meet? I am happy to meet anywhere you want and where it is convenient for you [power sharing with assumptions of in-person meetings, not digital].
- You said before that you were comfortable with doing X as a creative practice... what materials do you need? How often do you want to share what you create with me? You have complete ownership of what you create and do not have to share everything with me.
- How do you want to keep a self-reflective diary? What format do you want to use? What can I do to help? How often do you want to record your reflections? I suggest at least 30 minutes each week until we are done with the interviews. You do not have to share every entry with me either; diaries or journals have been shown in research to be helpful tools to reflect as you go through the process and my goal is to have all three of these forms of data generation work together to provide us insights into your experiences.
- What questions or concerns do you have that we have not discussed?

### **Wrap up**

So, what I have written down is the following: [review what was discussed and confirm we agree; make changes as necessary until agreement is reached].

Great, thank you for participating. I will write up my notes and the details of our conversation and email it to you along with a transcription of the recording for you to review for accuracy. I will also send a copy of your signed Informed Consent form for your records. I look forward to our conversations and learning about your experiences. Please do not hesitate to reach out to me at any time if you have concerns, questions, ideas, or insights you want to share. You can reach me through email or through my cell phone.

## **Appendix E: Consent to Participate in Focus Group Research**

**Study Title:** Exploring Underrepresented Engineering Student Experiences of Professional Socialization Using Culturally Responsive, Arts-Based, and New Materialist Methodologies

**IRBNet #: 1828830-1**

**Principal Investigator:** Katherine A. Robert, doctoral candidate

**Faculty Sponsor:** Dr. Cecilia Orphan, Assistant Professor Morgridge College of Education

**Study Site:** Colorado School of Mines campus

**You are being invited to participate in FOCUS GROUP as part of the research study you have been part of.** Your participation in this focus group is voluntary and you do not have to participate. This document contains important information about this focus group and what to expect if you decide to participate. Please consider the information carefully as you read it. Feel free to ask me any questions before making your decision on whether to participate. If you decide to be involved in this focus group, this form will be used to record your permission.

### **Purpose**

If you participate in this focus group, you will meet the other 2 participants who consent to participate in the focus group. The purpose of the focus group is 1) to meet the other participants in the study as a form of support and validation, and 2) to provide an opportunity for collaboration and to provide feedback on how the results of the study are presented and to offer recommendations for the institution you attend. The meeting will take place in a private room on campus and will last approximately 90 minutes. The meeting will be audio recorded and transcribed. A copy of the transcript will be provided to you for your approval.

### **Risks or Discomforts**

Potential risks, stress and/or discomforts of participation in the focus group include exposure of your participation in the study to the other participants, which may include emotional and psychological stress and anxiety. Your sharing of confidential information about yourself and your experiences in the focus group may also produce anxiety and stress. To mitigate these risks, I will provide prompts to guide the meeting for group discussion and you do not have to disclose any information you are not comfortable sharing. You will also be provided with a transcript of the meeting for review and will approve any of your information being used in the final document. Another risk of participating in the focus group is that another participant could intentionally or unintentionally expose your identity and participation in the study, which could cause

emotional distress. To mitigate this risk, each participant in the focus group who signs this consent form promises to keep the other participants' identities confidential.

### **Benefits**

The benefits which you may reasonably expect to result from your participation in this focus group include a sense of validation through discussing your experiences as an underrepresented engineering student with others who share this identity and who have had similar experiences. You may also feel a sense of support as a participant in the study with others who share in this experience, which could last into the future. The focus group also offers you the opportunity to guide how the results of the study are presented and interpreted and to make recommendations to the school. These recommendations may also benefit the school by contributing specific insights and stories about the school that can be utilized by them to improve their diversity, inclusivity, and equity efforts. Other possible benefits include aiding the broader engineering education community's understanding of how to make their programs more inclusive and equitable to different students to increase diversity. However, I cannot and do not guarantee or promise that you will receive any benefits from this study.

### **Confidentiality of Information**

#### **Limits to confidentiality**

All of the information you provide during the focus group will be confidential and limited to the group of participants. However, know that there is the risk that another participant could break the confidentiality of the study and either intentionally or unintentionally expose your participation and thereby end the confidentiality of your participation. I will continue to use your alias name you chose in any report, and your responses in the focus group will be assigned to your alias name. With your permission, I would like to audiotape the focus group so that I can make accurate transcriptions that I will share with you to review for accuracy. The audio recordings will be destroyed at the end of the study. Your name will not be in the transcript or my notes.

### **Use of your information for future research**

All identifiable information like your name will be removed from the data collected in this focus group and in the final written dissertation. However, know that the information in the published dissertation may be used for future research by other researchers without your additional informed consent. At the end of the study, you will have a choice on whether you want to continue our relationship or not for future collaborative research. I will not use your data from this study in any future research or publications without your consent.

**Incentives to participate**

Food and beverages will be provided during the focus group meeting.

**Focus group Costs**

The focus group costs will be covered by the researcher, including the food and beverages provided at the focus group.

**Consent to audio recording solely for purposes of this research**

This focus group involves audio recording. If you do not agree to be recorded, you CANNOT take part in the focus group.

\_\_\_\_\_ YES, I agree to be audio recorded.

\_\_\_\_\_ NO, I do not agree to be audio recorded.

**Questions**

For questions, concerns, or complaints about the study you may contact my faculty sponsor Dr. Cecilia Orphan at the Morgridge College of Education Department of Higher Education at the University of Denver. Her contact information is [Cecilia.Orphan@du.edu](mailto:Cecilia.Orphan@du.edu). 303-871-3619

If you are not satisfied with how this study is being conducted, or if you have any concerns, complaints, or general questions about the research or your rights as a participant, please contact the University of Denver (DU) Institutional Review Board to speak to someone independently of me at 303-871-2121 or email at IRBAdmin@du.edu.

**Signing the consent form**

I have read this form, and I am aware that I am being asked to participate in a focus group. I have had the opportunity to ask questions and have had them answered to my satisfaction. I voluntarily agree to participate in this study and to keep the identities of the other participants confidential. I am not giving up any legal rights by signing this form. I will be given a copy of this form.

**Printed name of participant** \_\_\_\_\_

**Signature of participant** \_\_\_\_\_

**Date** \_\_\_\_\_

**Please take all the time you need to read through this document and decide whether you would like to participate in this research study.** Please keep this form for your records.

## Appendix F: Unstructured Focus Group Protocol

Student participants' aliases \_\_\_\_\_

Date \_\_\_\_\_

Location \_\_\_\_\_

Start time \_\_\_\_\_ End time \_\_\_\_\_

We will meet in a designated private room on campus where the participants will meet each other for the first time. Time will be devoted at the beginning of the focus group for the participants to talk to each other and introduce themselves if they are not already acquainted. This portion of the meeting will not be audio recorded for privacy purposes.

### Interview Protocol

#### *Introduction*

Thank you for meeting with me and agreeing to participate in this focus group. This meeting will last approximately 90 minutes. If at any time during our focus group you do not want to answer specific questions, please feel free to decline to answer. A reminder that you all have agreed to keep each other's participation and identities confidential.

Do you have any questions before we get started? I am going to start recording now.

#### *Warm-up questions*

1. After reading the draft of the results of our collaboration, were you able to identify each other in the document?
2. How does it feel to meet each other?

#### *Focus group prompts*

The purpose of this focus group is for you to meet each other and work as a group to provide feedback on the results of the data collection that were shared with all of you prior to this meeting. Another purpose is to collaboratively create recommendations for Mines and STEM education and educators generally based on the results of our study.

1. Do you have any questions or concerns about the study or this focus group?
2. Discuss why you wanted to meet each other.
3. How does meeting the other participants affect your experience of the study?
4. Discuss the results of the data collection as presented in the written draft of the chapter of the dissertation, which you have read.
  - a. How do you feel about the study and results?
  - b. What changes or additions do you feel are needed for the results?
5. What recommendations do you want to make to the institution and STEM educators based on your participation in the study and the results?