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STEM Identities: A Communication Theory of Identity Approach

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Abstract

Education and psychology research has established STEM (science, technology, engineering, and mathematics) identities as an important factor in explaining student persistence in STEM fields. Few studies in social psychology of language or communication have investigated STEM identities, despite the fundamentally communicative nature of identity. Identity talk produced in semi-structured interviews with undergraduate engineering majors ($N = 16$) at three U.S. universities was analyzed qualitatively using the Communication Theory of Identity (CTI) as a sensitizing framework. The analysis showed that these students' STEM identities emphasized personal attributes such as work ethic and a desire to make a positive difference in the world as well as relationships with peers in engineering. A number of potential identity gaps which might present barriers to forming a STEM identity were also evident in the data. These results underscore the importance of a communicative (interactive and relational) perspective in understanding students' development and expression of STEM identities.

Keywords

identity, education, science, engineering, qualitative analysis

According to U.S. National Science Foundation (NSF) statistics, in 2016 women, Blacks/African Americans, and Hispanic/Latinx were underrepresented among new STEM (science, technology, engineering, and mathematics) bachelor's degree graduates. These disparities were especially pronounced in engineering, physical sciences, and computer science, where, for example, women earned only about 20% of degrees

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awarded (NSF, 2019). These disparities result from what is sometimes called the "leaky STEM pipeline," from which too many college students—especially women and minoritized students—elect out of STEM majors to maintain a sufficiently large and diverse pool of STEM professionals to meet anticipated demands (e.g., Doerschuk et al., 2016). According to the U.S. Bureau of Labor Statistics (BLS), through 2029 STEM occupations will grow at more than twice the rate of occupations outside of STEM with a 124% higher median wage (BLS, 2021). Despite the projected growth in STEM occupations, one potential reason this "leaky pipeline" persists is that many students do not identify with STEM fields. Specifically, students may experience barriers to developing STEM identities based on race, ethnicity, and gender (e.g., Chang et al., 2011; Hazari et al., 2013; Tyler et al., 2020), as well as socio-economic, first-generation, or post-traditional (aged 25 or older) status (Jackson & Seiler, 2013, 2017; Wilson & Kittleson, 2013). Conversely, students—particularly women and minoritized students—with stronger STEM identities are more likely to elect and remain in STEM majors and choose to work in STEM careers than those with weaker identity ties to STEM (Chemers et al., 2011; Chen et al., 2021; Perez et al., 2014; Robinson et al., 2018).

This paper reports the findings of a qualitative study of STEM identities of first- and second-year engineering majors who are academically well-qualified (based on grades and standardized test scores) and have documented financial need (as determined by their Application for Federal Student Aid [FAFSA]). The goal of study is to employ the Communication Theory of Identity (CTI: Hecht, 1993; Hecht et al., 2003) as a framework for understanding the social, interactive, and relational nature of these students' STEM identities. In the following section, I offer a definition and framework for STEM Identities. I then describe the CTI framework and review the literature on CTI. Finally, I discuss how each of the four identity layers proposed in CTI—personal, enacted, relational, and communal—relate specifically to STEM identity by drawing on existing STEM identity research.

What are STEM Identities?

Carlone and Johnson (2007) define STEM Identity as one's recognition by self and others as a STEM person and propose a STEM identity framework comprising three dimensions: (1) *competence*, or one's knowledge and understanding of STEM; (2) *performance*, or one's ability to engage in various STEM practices; and (3) *recognition*, or being seen by others and seeing one's self as a STEM person. This framework also recognizes that STEM identities are shaped by broader social identities including race, ethnicity, and gender (for example, due to experiencing explicit or implicit bias from STEM faculty). In summary, "a [STEM] identity is accessible when, as a result of an individual's competence and performance, she is recognized by meaningful others, people whose acceptance of her matters to her, as a [STEM] person" (Carlone & Johnson, 2007, p. 1192). In other words, students who are consistently able to successfully perform their STEM competence and have these performances recognized by others will likely develop a strong and enduring STEM identity. Since *STEM* comprises multiple disciplines, so, too, would STEM identities include multiple, potentially overlapping and sometimes competing disciplinary identities (Simpson & Bouhafa, 2020). Specific instantiations of STEM identity would often be more specific in terms of discipline (e.g., engineering, mathematics, or biology identity), but may also include multiple STEM identities. For example, an "engineering person" may also see themself as a math, physics, or general science person (Godwin et al., 2013, 2016).

Although Carlone and Johnson's (2007) framework is powerful and influential, Kim and Sinatra (2018) critique it as being too focused on individuals' perceptions of whether their competence and performance is recognized by others and not enough on the contexts in which such recognition occurs. They argue for an "interactionist approach" to STEM identities that focuses on the interactions between individual psychological experiences and the STEM environments in which they occur. Within this approach, a STEM "identity develops in relation to and through interactions with others, making identity inherently social in nature. Accordingly, the experiences in science educational settings . . . with peers, teachers, professors, mentors, and materials in those settings, inform individuals' understandings of self" (p. 2). Social Identity Theory (Tajfel & Turner, 1986) and Uncertainty-Identity Theory (Hogg, 2007) offer psychological frameworks for understanding the interaction between individual perceptions and social contexts, foregrounding how students reduce uncertainty about their STEM identities and negotiate STEM in- and out-group memberships (Kim et al., 2018). I argue for a communicative framework because students' STEM contexts, subjective experiences, and sense of identity are necessarily mediated through communication. Developing a STEM identity is a complex, multi-layered phenomenon that is "inherently a communication process and must be understood as a transaction in which messages and values are exchanged" (Hecht et al., 2003, p. 230).

The Communication Theory of Identity (CTI)

CTI foregrounds the interactional and relational basis of identity (Hecht, 1993; Hecht et al., 2003). Central to the theory is that identity comprises four interpenetrating frames, or layers: the *personal layer* (identity as individual characteristics, "stored as self-cognitions, feelings about the self, and/or a spiritual sense of self-being," Hecht, 1993, p. 79); the *enactment layer* (how individuals enact or perform identity through communication and social interaction); the *relational layer* (how identity is co-constructed within and through relationships with others); and the *communal layer* (how identity is defined and shaped in terms of broader social groups). Below, I discuss research showing the interpenetrating nature of identity layers, research on "gaps" between identity layers, and CTI research focusing specifically on college student identities.

While each of the four identity layers is significant, they are not separate from one another, but instead are interpenetrating (Hecht, 1993). For example, the centrality of a Jewish American communal identity to one's personal identity may influence how that group identity is expressed within the relational and enactment layers and whether and how individuals choose to self-disclose their group identity (Hecht & Faulkner, 2000; Hecht et al., 2002). Similarly, for Arab women in the United States, the use of communal identity labels intersected with relational identities and shifted depending on who they were interacting with (e.g., "Arab American" when speaking with a stranger; Witteborn, 2004).

CTI also includes the concept of "identity gaps" or "discrepancies between or among the four frames of identity" (Jung & Hecht, 2004, p. 268). For example, students may experience gaps between their personal or enacted STEM identities and their co-constructed relational identities if their friends and family devalue STEM or do not ascribe to them a STEM identity. Quantitative studies have demonstrated that identity gaps have direct and indirect effects on a variety of communication, relational, and psychological variables (Jung, 2011, 2013; Jung & Hecht, 2008). Qualitative studies have shown how identity gaps are expressed and experienced among immigrants and refugees (Bergquist et al., 2019; Urban & Orbe, 2010), LGBTQ people (Faulkner & Hecht, 2011; Nuru, 2014; Wagner et al., 2016), divorced fathers (Pettigrew, 2013), and in intraracial interactions (Drummond & Orbe, 2009). People may experience gaps not only between identity layers, but also within them (Colaner et al., 2014).

Identity gaps among college students are often, but not necessarily, associated with negative outcomes. For example, for international students in the United States, higher personal-enacted identity gap (between how they view themselves and their performance of self) was associated with higher levels of depression and lower levels of educational satisfaction (Jung et al., 2007; Wadsworth et al., 2008). Similarly, female international students reporting higher personal-enacted and personal-relational gaps (between how they view themselves and the identities ascribed to them by others) reported lower levels of communication satisfaction (Daniels & Rittenour, 2018). Among U.S. college students, higher personal-communal gap (between how they view themselves and how they view their university community) was associated with lower satisfaction, motivation, and liking of the university, and higher intentions to leave the university (Murray & Kennedy-Lightsey, 2013). But identity gaps are not always negative. For example, U.S. students participating in online intercultural communication experiences described a personal-communal identity gap, where they perceived their personal identity as "culturally and communicatively competent" in contrast to a communal identity of a "typical" or "everyday American" (Brooks & Pitts, 2016, p. 58). This particular identity gap was desirable for these students in this context. However, these students also described personal-enacted identity gaps where they did not feel they performed their identities accurately as well as enacted-relational gaps between their performance of identity and how that identity was perceived by others.

Orbe (2004) explored how first-generation college (FGC) student identity is experienced and negotiated within multiple layers. FGC identity was most salient for "students of color, students from a lower socioeconomic status, and non-traditional female students" (p. 140). In contrast, traditional-aged white male students at 4-year universities did not see FGC status as salient to their identity. FGC student identity is relational, defined in terms of whether immediate family members went to college, and in how they relate to their family and community as an FGC student. For some, this identity was celebrated by family and friends, but others expressed a need to conceal or downplay this identity at home. With respect to enacting identity, students reported not disclosing FGC identity to other students due to stigma. FGC identity would be disclosed to other FGC students and those who were sympathetic, or in instances where they confronted students about their privilege. FGC students did not experience a communal or group identity. In fact, participating in focus groups was the first time the majority of participants had been part of a large group of FGC students. In the following section, I discuss how the CTI framework can be applied specifically to the study of college students' STEM identities.

CTI and STEM Identities

Although only one previous study has used CTI to study STEM identities (Brooks, 2017), much of the STEM identity research touches on CTI's identity layers. Indeed, Carlone and Johnson's (2007) model roughly maps onto CTI's framework, with competence corresponding to the personal layer, performance to the enactment layer, recognition to the relational layer, and racial, ethnic, and gender identity to the communal layer. These correspondences are only approximate, however, as this model tends to emphasize individuals' beliefs regarding competence, performance, and recognition, and not the social and interactive nature of how these beliefs are negotiated and re-negotiated (Kim & Sinatra, 2018). This focus on self-cognitions (i.e., personal layer) is especially apparent in studies that use quantitative self-reports to measure these dimensions of STEM identity (e.g., Godwin et al., 2013, 2016).

Other studies point to the enactment and relational layers and the interpenetration of these layers in STEM identity. For example, talking about science with friends and family (Dou et al., 2019) and the influence of parents and teachers (Jackson & Suizzo, 2015; Stitt Richardson et al., 2019) during childhood are associated with stronger STEM identity. In college, students' interactions with STEM faculty with whom they have a relationship are also positively related to STEM identity (Hurtado et al., 2011; Nadelson et al., 2017) as are formal mentoring relationships with faculty (Piatt et al., 2019; Robnett et al., 2020) and serving as a peer mentor (Huvard et al., 2020). Informal and formal interactions with peers are also positively associated with STEM identity (Espinosa, 2011). Within peer tutoring interactions, encouragement talk, sensemaking checks, and metadisciplinary talk were identified as ways that tutors and tutees co-constructed relational identities that helped to socialize both students into STEM disciplinary communities (Agne & Muller, 2019). Finally, enacting STEM identity through formal STEM communication curricula has also been shown to be associated with stronger STEM identity (Cameron et al., 2020; Linvill et al., 2019).

Using CTI as a framework to study communal STEM identity, Brooks (2017) found that students who perceived being a scientist as "not social, not creative, and not fun" (p. 118) rejected a scientist social identity. Even though many of these students were studying and planning to work in science-related fields, they separated that work from being "a scientist." As Brooks states, "When students do not see themselves as scientists but work in science communities or alongside other scientists, there exists an identity gap in need of additional interrogation in the sciences" (p. 123). In addition to potential gaps between certain kinds of personal identities and the perceptions of "a scientist" social identity, many studies of STEM identity have investigated how various social identities may conflict or be integrated with a STEM identity. Students may not be ascribed a STEM identity by peers, faculty, or others, based on their (intersectional) racial, ethnic, or gender social identities (e.g., Avraamidou, 2020; Malone & Barabino, 2008). Women and minoritized students who perceived gaps between gender or racial stereotypes and STEM stereotypes may experience barriers in developing a STEM identity (Chang et al., 2011; Deemer et al., 2016; Starr, 2018). Other studies have shown how individuals navigate gaps between minoritized social identities and STEM identities to create identities that integrate STEM with their other social identities (Jones, 2019; Mattheis et al., 2020; Morton & Parsons, 2018).

Method

Context

The context for this study is the Urban STEM Collaboratory, an NSF-funded program at University of Colorado-Denver (CU-Denver), Indiana University-Purdue University Indianapolis (IUPUI), and the University of Memphis (UofM). The Collaboratory is designed to help well-qualified engineering students who might be at risk for dropping out of STEM due to financial aid need (for example, because of a need to work outside of school, they may switch to another major that requires less out-of-class work). In addition to scholarships to help close their financial aid gap, the program also offers academic, social, and career programming. One of the primary goals of the project is to help participating students build and maintain a strong STEM identity. The first cohort (2019–2020) comprised a total of 59 Urban STEM Scholarship recipients (Urban STEM Scholars) who met GPA and standardized test score requirements and had unmet financial aid need as determined by their FAFSA. These students participated in a variety of activities, including summer bridge programs and an academic social networking site across all three campuses, as well as mentoring, peer-led team teaching, community outreach, and other activities that varied by campus and individual student interest. Urban STEM scholars earned "badges" for participating in activities and must earn a minimum number of badges (i.e., micro-credentials awarded by the program) and maintain a minimum GPA to maintain their scholarship (see Goodman et al., 2020, for more details on the Urban STEM Collaboratory).

Participants and Procedures

The current study included a volunteer sample (6 women, 10 men) from the first cohort of Urban STEM Scholars, all first- and second-year engineering majors, from all three campuses (CU-Denver $n=3$; IUPUI $n=8$; UofM $n=5$).[1] All members of the first Urban STEM Scholar cohort were invited to participate in these interviews, and all those who agreed to participate were included. Each participant was assigned an ID number (P1–P16). A total of 10 one-on-one and 2 small group (three participant) semi-structured interviews were conducted. The protocol for both one-on-one and small group interviews included questions such as "How would you describe your identity? What makes you who you are?", "How would other people describe your identity? How do other people see you?", "When you are communicating or interacting with your peers in the Urban STEM Collaboratory, do you feel like you can truly be yourself? Are there aspects of yourself that you don't express or reveal to these peers?", "What are some opportunities or advantages for you that might make it easier to embrace a STEM (engineering or math) identity?" and "What are some barriers or disadvantages that might make it more difficult to embrace a STEM (engineering or math) identity?" Interviews lasted 20 to 60 minutes, and the mean number of words per transcript was 3,496.33 ($SD = 990.67$).

Analysis

I entered interview transcripts into the qualitative data coding application Dedoose (2018) and coded them using thematic analysis to identify and analyze patterns across the data set (Braun & Clarke, 2006, p. 79). I first identified segments of these transcripts in which the participants were doing STEM identity work in their talk, or more specifically, segments in which they socially positioned themselves and/or others as "STEM people" (cf. Bucholtz & Hall, 2005). I initially coded segments using a priori categories derived from CTI (personal, enacted, relational, communal, and identity gap). I then inductively coded themes within each of these initial categories. In the personal layer, inductive themes included "intelligence/aptitude," "enjoyment/interest," and "experience/history"; in the enacted layer, "communicating STEM identity" and "talking about engineering"; and in the relational layer, "ascribed identity," "peer/classmate interaction," and "family influence." In the communal layer, only one theme, group membership, was included. Themes for identity gaps labeled specific gaps (e.g., personal-relational gap, relational-enacted gap). I then reviewed and refined these themes. For example, "intelligence/aptitude" was refined to include "competence," "intelligence," and "hardwork/work ethic." After refining these themes, I used CTI's identity layers and identity gaps as a thematic map to guide the final report of the findings (see Figure 1). Each identity layer and gaps between layers represented a coherent theme capturing important aspects of these students' emerging STEM identities, with Personal and Relational layers being the most salient in these data. Below I describe each identity layer in turn, followed by identity gaps.

Findings

Personal Layer

The most salient individual attributes, qualities, and beliefs that these students discussed in describing themselves or others as "STEM people" constitute the personal layer. Competence beliefs were important to how these students described what it

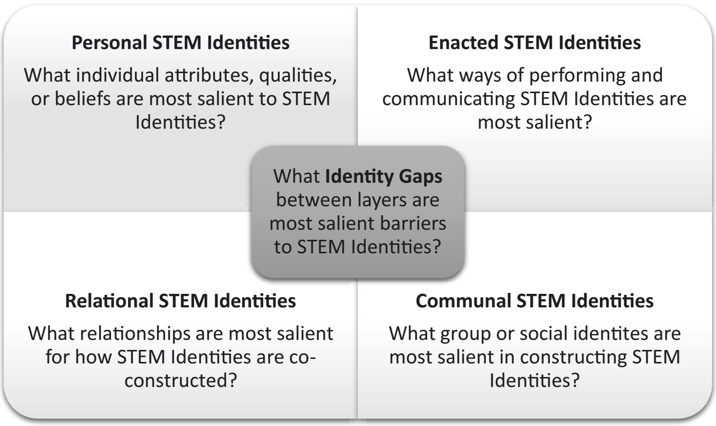

Figure 1. Thematic map of identity layers and gaps for STEM identities.

means to be a “STEM person.” In particular, these students described themselves and others in engineering as being intelligent in general and good at mathematics in particular. In addition to aptitude for mathematics, these students saw being able to solve problems and willing to work hard as key aspects of being an engineer. Students described being an engineer as having a particular world view or way of thinking. “Having the brain of an engineer,” as one participant (P14) put it, entailed having a particular focus on problem solving and analytical thinking. They described themselves and peers and being able to break things down into their constituent parts, visualize problems, and “[see] arrows and directions” (P1). Such descriptions highlight the relationship between the personal and communal layers of identity, as they describe “an engineer” as a category. However, these students tended to ascribe these attributes to specific individuals (self or peer) rather than to engineers as a collective, as shown in the extracts below.

Although some students attributed competence to being “gifted” or naturally good at something, hard work was seen for some students as more important than competence by itself, as shown in the following extracts:

(1) [Describing a classmate] She is very intelligent, but more than intelligent she is very hardworking. Like she’ll start studying for a math test 3 weeks in advance. She’ll go over topics before she even gets to class. And she just puts in so much effort and her results are so much higher than what people would have expected them to be. (P10)
(2) I was never naturally smart in high school. And I am made fun of a lot for it. And I really wanted to work hard toward something here. And that’s why I chose [biomedical engineering], because it was one of the hardest majors here. [. . .] You could not be very smart as somebody and work twice as hard as them and do better than them. (P9)

These students juxtaposed intelligence with hard work, and attributed success to hard work over intellect. Competence is more than a belief in one's ability or intelligence, but also willingness to work toward enacting competence. These beliefs may reflect or echo ideas such as "growth mindset" or "grit" that they may been exposed to their STEM educational experiences (e.g., Limeri et al., 2020; Pappas et al., 2013).

In addition to attributes like intelligence and work ethic, these students described being an engineer as something that fulfills one's passions and connects to one's personal interests and goals. Sometimes, this was intrinsic interest and enjoyment in STEM, with participants stating that they and others chose engineering as a major because they enjoy math, physics, technology, or (for mechanical engineering in particular) cars. For other participants, being an engineer does not only gratify one's STEM interests but also gratifies other personal goals and interests, especially to make a positive difference in the world. Carrigan (2017) described this motivation for being an engineer as "yearning to give back" and "leaving the world a better place" (p. 1178), as shown the following extract:

> (3) I like to think that I'm compassionate about people specifically. I love helping people in any way that I can, which is why I chose the field that I chose. So, I definitely think that's a huge part of my identity. (P14)

In summary, these students' identity talk suggests personal STEM identities that not only includes competence and aptitude in STEM, but also suggests that competence and aptitude are insufficient to identify with STEM. Their personal STEM identities connect STEM aptitude to other attributes such as work ethic, ways of seeing the world, and personal interests or passions, and in some ways, prioritize hard work and personal enjoyment over competence or aptitude. As one participant stated, "So, if I one day realize I'm not enjoying engineering anymore, that would be like, the end. I guess I shouldn't identify as an engineer if I'm not finding enjoyment out of it" (P2).

Enacted Layer

The most salient ways that students discussed performing or communicating their STEM identities constituted the enacted layer. Although most of the participants did not necessarily think they communicated their STEM identities to others explicitly, some students pointed to a variety of ways that they communicated their STEM identities through different kinds of messages. In particular, these engineering majors talk about engineering and math to classmates and to others, and this communicates their engineering identity:

> (4) I guess the way we talk and talk about mechanical things, things doing with engineering, it's like, oh, you're an engineer. Then they feel sorry for us. (P15)
>
> (5) I can carry an enjoyable conversation with people who are engineers and be talking about engineering and be my authentic self while I do that. (P2)

Several students made comments along these lines, that topics of conversation or how they might approach those conversations may mark them as engineering majors. While Excerpt 5 suggests that enacting STEM identity with out-group members (people who are not in STEM fields) may be less than positive, Excerpt 6 points to how, within a STEM in-group, this enactment is positive and "authentic." Students also described communicating their STEM identity to others non-verbally, by wearing t-shirts that identify them with their college or department or include other STEM markers like "a weird math pun" (P12) or "a bunch of binary numbers on them, just a bunch of zeros and ones. So, I guess, if you see that, then you think they must be a STEM major" (P14). And students described enacting their STEM identity by doing the work required by their STEM major. Many students mentioned the heavy workload and numerous projects as an aspect of being an engineering major.

Relational Layer

The relational layer is comprised of those relationships that were most salient in how these students discussed being a "STEM person." Although some students may stereotype STEM as being unsocial (Brooks, 2017), for these participants, social relationships with other STEM students were a key component to their sense of STEM identity. Through their relationships with peers, they could see that other students shared similar experiences and challenges, as exemplified in the following excerpt:

> (6) One thing that I know stops a whole lot of people is when something is difficult, like physics, they hit a wall and they start giving up. But getting help for that, going to office hours, and then like talking with your friends and seeing how they think of it and getting help from them as well. Interacting with people to help you and make it easier for yourself, then you can find more enjoyment out of it and see the cool stuff about it. So, like getting help and interacting with people, that definitely helps me with embracing my engineering side. [. . .] Yeah, once I know that there are people around me with the same strengths and the same struggles and maybe different strengths and different struggles, but we all are together in it, that really helps. (P2)

This student expressed not only that she is able to get help from peers on difficult STEM coursework, but that these relationships reinforce her personal enjoyment for studying STEM which reinforces her STEM identity. Peer relationships also help her to see not only similarities but also differences in STEM students.

Several participants indicated that their relationships with STEM peers went beyond being classmates to experiencing deeper friendships. These friendships were connected to finding meaning in and motivation for studying STEM. They also helped students hold each other accountable for their studies. Although not many participants indicated that they necessarily communicated a STEM identity to others on campus, some expressed that in their relationships with STEM peers, they could communicate their identities authentically:

(7) I can be like myself here with my friends. (P9)
(8) Being able to express myself as an engineer with others. Hopefully for them, it makes me feel like it means something. (P1)

These excerpts point to the interpenetration of layers of identity, with personal and enacted layers being expressed within the relational layer of friendships. That is, within these friendships, they are able enact ("be" or "express") their personal sense of self ("myself").

Although friendships with STEM peers were perhaps the most frequent and important relationship that the participants discussed, other relationships were also discussed. In particular they mentioned the role of family, especially parents, in introducing students to STEM and encouraging their studies. They also discussed how identities may be ascribed to them by peers outside of STEM:

(9) Because the first thing, if you say you're in engineering so they might think you're smart. (P16)
(10) Just like my friends, like I just talk about it. But also, sometimes [. . .] like there's events that happen and everything. And then they're like, "Oh, he's an engineering major. Like he won't be able to have time to like go out and stuff like that." Sometimes that happens. (P13)

These excerpts show how in friendships with peers outside of STEM, STEM students may be ascribed both positive (smart) and negative (unable to go out) attributes. Family members also ascribed attributes to STEM students.

(11) They think that I can take something that's broken and turn into something that's better than it ever has been before. And that's how my family sees me as well. Not even something as physical, even something as like emotional, like a relationship or something like a relationship that's battered. My family need me to fix it and then make it better than it's ever has been. And then I can do that with physical objects as well. (P4)

Here, family and friends ascribe to this student an attribute (ability to fix things) that they then generalize well beyond the bounds of STEM, perhaps leading to a potential identity gap as will be discussed in more detail below.

Communal Layer

STEM identity in the communal layer comprised how students related STEM to their social identities or discussed STEM in terms of being a social identity. Reflecting the interpenetrating nature of identity layers, many of the personal traits and attributes discussed above in the Personal Layer may cohere into a sense of what means to be an engineer or a "STEM person" collectively (Hecht et al., 2003), but most of these were discussed in terms of individuals rather than a group. Social identity categories, such as those based on gender, race, or ethnicity were not a significant theme in these students' talk about STEM identity, perhaps owing to a relative lack of diversity among the interview participants. However, these identity categories were discussed in relation to potential identity gaps, as will be discussed in the next section. To the extent they discussed STEM as a social or communal identity, it was an extension of relational layer, as friendships among STEM peers helped to create a sense of STEM community. They did not seem to strongly identify as "Urban STEM Scholars," but had also participated in the program for only about one semester at the time of the interviews. Students did mention the role of other STEM organizations in their STEM identity.

Identity Gaps

Even as STEM identities were realized through personal, enacted, relational, and communal layers, these participants pointed to different potential gaps between these layers as challenges or barriers to STEM identity. One such gap was a *personal-enacted gap*, which was expressed in terms of a gap between a student's STEM competence and the level at which they would need to perform in university STEM courses.

(12) Sometimes if [students] can't understand calculus or whatnot, they don't want to be an engineer. But I believe with enough hard work or working around that and learning, you could really beat that. But I think that's something a lot of people struggle with. (P12)

(13) There have been people that I know that find the major to be too hard for them. That's really hard to admit to themselves that they're focused on something for basically their entire life that they wanted to do when they finally get to college. And they just can't do it because it's too hard for them. And some people don't have that mental capacity that some doctors do or some, like, there are people that are geniuses out there that have obviously been born smart. And sometimes people don't want to put in the work to become something such as an engineer. (P4)

As these excerpts show, these students do not necessarily see this gap as insuperable; however, to bridge this gap would require someone to have the trait of being hard working (an important part of how they talked about personal STEM identity). Excerpt 13 suggests the source of this gap is at least to some extent, innate competence, while others pointed to inadequate high school preparation. As shown in these extracts, this gap was also often identified in talking about other students' struggles rather than their own, suggesting either that they had not personally experienced this gap or were more comfortable discussing these challenges for others rather than for themselves.

Participants also pointed to a potential *personal-relational gap*, between how students see their own personal STEM identity and how or whether friends or family perceive it (i.e., ascribed-relational identity). This gap was expressed in different ways. One was a gap in which they perceived other students (not themselves) majoring in

STEM primarily because of their parents or families, leading to their personal interests being misaligned with a STEM identity.

(14) Well, maybe some are [. . .] not passionate about engineering, but they just go in engineering because of their parents. Or, because of their friends. If you're in the major you want, it will go easier for you. (P16)

(15) And some people don't like math and science at all but feel like they have to go into engineering because their parents are engineers. (P2)

Besides identifying some students as being in a STEM major that they are not interested in due to relationships with parents or others, STEM students may experience a gap between their personal STEM identities and the STEM identities that are ascribed to them by friends and family. Some described family and friends attributing excessively positive attributes based on their STEM identity that they do not feel aligns with their own sense of self:

(16) I think that he thinks that I'm just this super-intelligent person that can do absolutely great at anything. And I'll say, "Oh, I have to stay up studying," and he'll say, "You don't have to study. You're fine." Well, he knows I have to study, but then he'll be like, "You know you're going to do fine. You got this," and he genuinely, I think he genuinely just believes that I'm super great at school, which I am good at school, but I'm not as great as I think he thinks that I am, if that makes sense. (P14)

In the above extract, the student's romantic partner attributes to her a level of intelligence that in some way obviates her hard work and is not entirely accurate in her view, creating a gap between her personal identity as a hard worker and her ascribed identity as someone who does not really need to study. Although her partner's messages were likely meant to be positive and supportive, there is still a gap between the traits they ascribe to her and the traits she ascribes to herself. Another student described how her family ascribes to her the identity of biomedical engineer even though she herself thinks of herself as "level two at most" (P7).

Other participants described personal-relational gaps due to being ascribed negative traits by peers outside of STEM and other gaps between their personal STEM identities and how they are perceived by those peers.

(17) 'Cause I know a lot of people would struggle with the fact that they don't want to be perceived as some uptight, smart, snob or whatever. (P12)

(18) Like growing up in high school, people knew I was hard working in sports, but they never really saw me. They didn't like seeing what I did when I went home working that night, and then having to study for chemistry, math, all that. I don't, like, no one in high school really knew me how they know me here. I guess that is how you would say it. So, I think people here see me as hardworking. (P9)

(19) My friends knew who I was growing up, but that was me back then. So as of now, I might not even be showing my friends who I really am, because who I was in the past isn't who I am now. So, with the learning community, they're seeing the real me, but not to the full extent. They don't know who I was in the past. So, in that sense, neither group knows who I really am. (P1)

Excerpt 17 shows that peers outside of STEM disciplines may ascribe negative attributes to STEM students, and Excerpts 18 and 19 show how these out-group peers may not be able to fully perceive or understand their STEM identities. But, as Excerpt 19 further elaborates, because STEM is not the whole of one's identity, there is also a potential gap between other aspects of his personal identity and his relational identity with STEM peers.

Participants also pointed to *enacted-relational identity* gaps between how or whether they communicate or perform a STEM identity and the identities others ascribe to them.

(20) Something will happen to me like, "Oh that's such and such principal." Or, "I can model that with such and such force." And my friends or family will be like, "What?" (P12)

(21) But like talking to other people who are not engineering majors, like my friends that aren't engineering majors, I for sure would talk about like, different topics different stuff for sure. (P3)

In Excerpt 20, this student finds that performing a STEM identity by talking about engineering may be met with a negative response from friends and family. This could lead to responses such as in Excerpt 21, where the student avoids engineering talk with peers outside of STEM. Another enacted-relational gap may occur when a student performs a non-STEM aspect of their identity, which may lead to peers being less able to ascribe to them a STEM identity.

(22) Because I love scrapbooking and sewing patches onto my jackets and drawing with different colors and stuff. I was talking about this in a study house that I go to and one of the people there turns to me and goes "you're an art major right?" and I say no I'm an engineering major. And his follow up question was "were you an art kid who wanted to make money?" Which everyone thought was really funny. (P2)

In the above excerpt, the student's artistic activities lead a peer outside of STEM to assume that she was an art major, due to the apparent perception that being artistic is incompatible with being an engineer. Learning that she was in fact an engineering major, he then ascribed an extrinsic rather than intrinsic motivation to her major.

Finally, communal identity gaps were expressed, primarily with respect to gender. For one student, this was expressed as a potential gap or barrier, but one that she anticipates experiencing rather than one that she has experienced directly.

(23) I don't know for sure but one that usually comes up for people is the barrier of being a woman is going to make life more difficult. I know that there's a history of it being harder for women and it being exclusive. And I'm kind of expecting that when I get to my later classes, but as of now, I don't see it. It feels inclusive. (P2)

This student anticipates her gender identity perhaps becoming inconsistent with a STEM identity in a general way. Another student tied the potential gap between being a woman and being an engineer to other communal identities (i.e., culture) and how cultural gender ideologies are communicated relationally:

(24) I definitely think culture. It depends on family structure. [. . .] Yesterday, actually, I was in my biology lab, and my partner was telling me about her grandmother and how her grandmother always tells her, "You shouldn't be in engineering. You should be a secretary or something like that," and I was telling her some people are just stuck in time. A lot of older people are just simply stuck in that time, and I wouldn't say it's their fault, you know? (P14)

Although these excerpts point to the reality of her peers experiencing sexism and that bias creating a gap between their gender and STEM identity, this student sees these gender ideologies as rooted in particular cultures and family structures. However, later on this interview, the student questioned whether equal opportunities for members of different groups truly exist in STEM fields.

Discussion and Conclusion

As shown in this analysis, these students' STEM Identities implicated each of Hecht's (1993) four layers of identity, illustrating the utility of CTI as a framework for understanding STEM identities. Their talk demonstrated the particular importance of the personal and relational layers to their understanding of STEM identity and that their STEM identities are experienced through social interactions and relationships. Their ideas of STEM identity as self-concept encompassed values such as hard work and a desire to giving back to their communities, which were seen as perhaps even more important than STEM competence. And their relationships with STEM peers were central to how they viewed and experienced their STEM identities. These relationships helped reinforce their STEM identities by offering opportunities to enact these identities in their interactions and also to hold one another accountable in their schoolwork. This finding also suggests that being recognized as a STEM person by one's peers may be as or more salient than recognition by professors or STEM professionals (cf. Kim & Sinatra, 2018). The importance of peer relationships should not be surprising given that STEM students, especially early in their college careers, likely have far more peer relationships and interactions in which to be recognized and recognize others as STEM people, as opposed to relationships and interactions with faculty mentors or STEM professionals. This relational theme is also, perhaps, counterintuitive. STEM people may be stereotyped as unsociable (e.g., Brooks, 2017), but in these interviews, being a STEM person seemed in some ways fundamentally social and relational.

Themes related to the enacted and communal layers were less salient in these interviews. These participants did not necessarily feel that they communicated a STEM identity outside of their courses or with non-STEM peers, although they did sometimes communicate in ways that would mark them as STEM people. Showing alignment between layers of identity, the personal trait of being hardworking necessarily implicates the enactment layer, since being hardworking entails not only a personal attribute but also the enactment of that attribute. Likewise, regarding STEM as a communal or group identity, these students' STEM peer relationships extended such that they felt they were part of a larger STEM community. However, this communal aspect did not seem to be as central to their STEM identity. The enactment and communal layers may become more salient to these students as they advance in their STEM studies. For example, the enactment layer may be more salient for STEM students later in their studies, when they may be more involved in projects and internships where performing as a STEM person is more central to their experience than in early, more basic coursework. Likewise, thinking about STEM as a communal identity, especially as a professional identity, would also likely be more salient for more advanced students with greater STEM work experience and concern with becoming a STEM professional after graduation.

These analyses also highlighted some potential identity gaps, especially between the relational and other identity layers. These students pointed to gaps between their STEM identities and the identities ascribed to them by family and friends. The gaps these students experienced were not because they were not recognized for their competence, but rather how others ascribed identity characteristics to them that were not consistent with how they thought of themselves or the identity they wished to perform. In some cases, these ascribed identities were positive, attributing a level of knowledge or abilities that the student did not (yet) possess. In other cases, friends or other peers may not ascribe a STEM identity or ascribe negative attributes based on their STEM identity. There was relatively little talk of communal identity gaps of the sort that might arise based on perceived gaps between STEM identities and race, ethnic, or class identities. Women did identify potential gaps based on gender, but these were discussed as hypothetical or anticipated gaps or gaps experienced by others rather than experienced by themselves.

These findings reflect and are therefore limited to their disciplinary, institutional, and individual contexts. They describe the STEM identities of a group of first- and second-year engineering majors who: (a) have personal financial aid need at institutions where such need is the norm, and (b) are being offered opportunities to build STEM identities through the Urban STEM Collaboratory that are not available to their peers. Engineering majors at different kinds of institutions (e.g., flagship state institutions or private institutions) or who do not have financial aid need may describe their STEM identities in different ways. Likewise, engineering majors at the same institutions but without the financial support and other programs these students are participating in may also describe their STEM identities differently (e.g., they may have fewer opportunities to interact with STEM peers). These findings may offer some insight into how programs like the Urban STEM Collaboratory support STEM identity development. For example, previous research with a similar population has shown that networking interventions were more effective than other educational interventions in promoting retention in STEM fields, perhaps because building peer relationships supported their STEM identities (Windsor et al., 2015). However, they cannot be generalized to the broader populations of engineering majors, even at the same institutions, or to students studying different STEM disciplines.

The CTI, however, does offer a sensitizing framework for studying STEM identities within and across these various contexts, as well as disciplinary identities outside of STEM fields. Importantly, STEM identities cross various disciplines, such that someone who sees themselves as “an engineering person” may also see themselves as “a math person,” “a physics person,” or “a science person.” Indeed, in these interviews, students often referred to “math,” “physics,” “science,” and “STEM,” as well as engineering. STEM Identities are also relevant to thinking about disciplinary identities that may not traditionally be considered STEM fields (e.g., math identity is relevant for accounting and finance majors, or biology, chemistry, and/or science identities are relevant to majors in health professional fields such as nursing).

This study extends an emerging line of research (Agne & Muller, 2019; Brooks, 2017) on STEM identity as a process that plays out through communication and interaction in informal and formal educational and social contexts. By using CTI to frame STEM Identity as a communicative and interactional process, rather than a set of individual cognitions or beliefs, this study shows that for these participants relationships and interactions with STEM peers are central to their emerging STEM identities and these relationships were more salient than those with faculty and other mentors. They suggest that programs designed to support the development of STEM identity—such as the one these students were participating in—may benefit from focusing not only on formal interventions (e.g., mentoring, experiential learning) but also on creating opportunities for students to form peer relationships and communities. Especially at access-oriented institutions, students who have the ability and desire to succeed in STEM fields may drop out because they lack the opportunities to enact a STEM identity through language and social interaction. They may have few opportunities to interact with others who see them as STEM people, and who they see as STEM people; they may have to work in jobs that are inconsistent with what they and others think a future scientist or engineer would do; they may be the first in their family to aspire to study and work in a STEM field. A CTI framework makes clear the multi-layered nature of STEM identities, and in particular, how students talk STEM identities into being through interaction and relationships.

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Note

1. Further demographics are not reported in order to prevent potential identification of participants and protect their confidentiality.

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