THE IDENTITY-FRAME MODEL: A FRAMEWORK TO DESCRIBE SITUATED IDENTITY NEGOTIATION FOR ADOLESCENT YOUTH PARTICIPATING IN AN INFORMAL ENGINEERING EDUCATION PROGRAM

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Abstract

Background. STEM identity has emerged as an important research topic and a predictor of how youth engage with STEM inside and outside of school. Although there is a growing body of literature in this area, less work has been done specific to engineering, especially in out-of-school learning contexts.

Methods. To address this need, we conducted a qualitative investigation of five adolescent youth participating in a four-month afterschool engineering program. The study focused on how participants negotiated engineering-related identities through ongoing interactions with activities, peers, and adults, and the patterns of identity negotiation that emerged across program sessions.

Findings. Through the investigation, we developed an *Identity-Frame Model*, positing that identity negotiation is an ongoing process of performance and definition work by an individual and recognition and positioning work by other adults and peers that creates emergent, context-specific *identities* and *activity frames* that are made particularly salient during critical identity moments. We also categorized model elements that appeared to be specific to engineering, such as situated identities and activity frames related to failure, collaboration, competition.

Contribution. The study advances the understanding of identity negotiation related to engineering and provides a new framework for investigating situated identity in informal STEM learning contexts.

The Identity Frame Model: A Framework to Describe Situated Identity Negotiation for

Adolescent Youth Participating in an Informal Engineering Education Program

In recent years, there has been an increased interest in describing and understanding identity

development in both formal and informal education settings. STEM-related identity

development, in particular, has emerged as an important topic of research and a predictor of how

youth engage with STEM inside and outside of school (Brotman & Moore, 2008; NRC, 2009)—

even becoming an explicit goal for a variety of programs, classes, and educational experiences

(Calabrese Barton & Tan, 2019; NRC, 2009, 2015). Researchers have argued that the

development of a STEM identity is a critical component of STEM interest, engagement,

learning, and career choice (Archer et al., 2010; NRC, 2009; Packard & Nguyen, 2003).

Additionally, some have also seen the development and support of STEM identities as an

important factor in addressing equity issues and underrepresentation in STEM. For example,

patterns of gendered STEM identity have been observed in children as young as 11, suggesting

that understanding how boys and girls construct and negotiate their identities at an early age may

be key to stimulating interest in and pursuit of STEM-related fields (Archer et al., 2010; Tai et

al., 2006).

Although researchers have explored the concept of identity across a variety of STEM

topics and contexts, less work has been done specific to engineering, even though engineering

has now become a prominent focus of the education curriculum over the last several decades

(Capobianco et al., 2015; Cunningham, 2018). This is especially true in informal STEM learning

environments, which have been argued to be important sites of identity development (J. Bell et

al., 2018; NRC, 2009). To contribute to the small but growing body of research on *engineering*

identity (Capobianco et al., 2015; Douglas et al., 2014; Yoon et al., 2014) and explore new approaches to studying situated identity in informal STEM learning contexts, we conducted an in-depth, qualitative investigation of diverse adolescent youth in an afterschool Boys & Girls Club (BGC) engineering program. The study described in this article was part of Designing Our World (DOW)—a five-year, National Science Foundation-funded project (Johnson et al., 2014) led by the Oregon Museum of Science and Industry (OMSI)—and focused particularly on developing a framework for understanding and describing how participants constructed and negotiated engineering-related identities during the program activities.

Youth STEM and Engineering Identity

There has been an explosion of research on youth STEM identity over the last several decades, highlighting the complex relationship youth often have with these topics (Brotman & Moore, 2008). Studies have emphasized how youth STEM identity is bound up both in how youth perceive themselves and how they perceive STEM topics and careers (Archer et al., 2013; Krogh & Andersen, 2013; Shanahan & Nieswandt, 2009). If youth are to develop strong STEM identities, they must see STEM as compatible with their interests and goals (Basu & Calabrese Barton, 2007; Bøe, 2012; Buck et al., 2009). In practice, this can be particularly challenging for youth confronting gender stereotypes related to STEM or struggling with tensions between their STEM- and school-related identities and their cultural backgrounds (Archer et al., 2012; Fies & Langman, 2011; Sayman, 2013). As research shows, these tensions can ultimately shape how youth construct their ongoing relationship with STEM (Archer et al., 2012; Brown, 2006; Sayman, 2013).

Within this literature, fewer studies have specifically focused on *engineering identity*. The majority of these have investigated undergraduate and graduate students or practicing engineers (Capobianco, 2006; Cech, 2015; Hatmaker, 2013; Tonso, 2006). Only a handful have examined engineering identity with youth, with most of these focused on the impact of teacher professional development and classroom interventions for elementary students (Capobianco et al., 2015; Douglas et al., 2014; Yoon et al., 2014). As Capobianco and colleagues (2012) noted, although "identity and engineering has become an emerging field in educational research… Little is known about how pre-adolescents begin to construct their earliest conceptions of engineering and potential career aspirations" (p. 698).

Despite this lack of research, studies from the related field of making suggest both the potential promise and challenges of building engineering-related identities through informal education experiences. Making programs create opportunities for youth to share their knowledge and expertise, build STEM-related identities, and connect to broader communities of practice (Bonnette & Crowley, 2020; Calabrese Barton & Tan, 2018; Davey et al., 2018; Holbert, 2016). However, these experiences can also undermine youth STEM-related identities or reinforce traditional stereotypes about STEM activities and fields (Calabrese Barton & Tan, 2018; Kafai et al., 2014). Given the close connections between making and engineering (Martin, 2015), these mixed findings suggest the importance of better understanding the dynamics of how identities are shaped and supported during informal engineering education programs.

Sociocultural Turn in Identity Research

The majority of studies of STEM identity, and especially on engineering, continue to adopt a relatively static perspective and, consequently, focus more on the distal factors

influencing identity development, such as attitudes and cultural stereotypes, (NRC, 2009; Watt & Eccles, 2008). However, there is a growing body of literature focused on better understanding the micro-level, interactional processes influencing STEM-related identities and adopting more situated, context-specific perspectives on *identity negotiation*. This work has highlighted the ways that youth continually position themselves and others during STEM learning experiences relative to authority and knowledge (Fields & Enyedy, 2013; Kane, 2015; Radinsky & Tabak, 2016), group membership and status (Olitsky, 2007; Ryu, 2015), and ideas about gender and masculinity (Archer et al., 2016; Bhana, 2005; Carlone et al., 2015), with peers and teacher acting as supports or "gate closers" for youth participation and identity development (Ryu, 2015; Takeuchi, 2016; Tan & Calabrese Barton, 2008).

Across these studies, scholars have grappled with two central dilemmas. First, studying situated identity involves capturing both the ways youth position themselves and author their own identities, as well as the ways that larger educational and social structures shape and constrain this work (P. Bell et al., 2017; Carlone, 2017; Nasir & Vakil, 2017)—or what some have called the "structure-agency dialect" (Gutiérrez & Calabrese Barton, 2015; Varelas, 2012).[1] For example, identity researchers have emphasized the close connections between the micro processes of identity work, broader cultural patterns, assumptions, and implicit and explicit goals underlying learning environments, and the social structures and normative expectations related to race, class, and gender that afford or constrain identity (P. Bell et al., 2017; Carlone et al., 2015). Second, researchers have struggled to capture situated identity at multiple time scales, including the dynamics of specific interactional moments, when situated identity is at play, and the ways these moments accumulate over time to create longer-term identity development patterns. Normative classroom expectations about what counts as allowable and legitimate disciplinary

practices, for instance, develop over time but are substantiated, reinforced, and contested within specific learning interactions (Carlone, 2017; Polman & Miller, 2010; Ryu, 2015).

Fully understanding these processes of identity negotiation requires investigating both agency and structure at different timescales—including how agency and structure play out in specific moments among groups of learners (Takeuchi, 2016) and how these moment-by-moment interactions add up over time to shape particular identity trajectories (Calabrese Barton et al., 2012). Because it is difficult for any one study to attend to all of these elements and timescales simultaneously, researchers often try to coordinate one or two aspects, such as describing the development of classroom norms and learner identities related to science over several years (e.g., Allen & Eisenhart, 2017) at the expense of a close analysis of the micro-interactions that shape these trajectories. Other studies avoid the challenges of capturing moment-by-moment interactions by focusing instead on narrated identities, exploring how youth describe their identities through interviews and how these descriptions and self-perceptions change over time (e.g., Nilsen, 2016). These decisions are important not only theoretically but also for informing practice, since some design decisions can be acted on at broader level, such as overall classroom lesson formats (e.g., lecture versus hands-on investigation), while others operate at a more micro-level (e.g., specific educator moves to support learners).

Current Study

In the current study, we attempted to advance the field both theoretically and methodologically by developing an approach and framework that accounts for the complexity of moment-by-moment interactions in STEM learning contexts, acknowledges both agentic and structural aspects of these interactions relative to identity negotiation, and traces these patterns

over time for particular youth. The study applied a situated identity perspective to the topic of

engineering, where identity has primarily been investigated through student and teacher surveys.

Furthermore, we conducted our research as part of an informal STEM education program, which,

aside from a few notable exceptions (Polman & Miller, 2010; Tan, Calabrese Barton, Kang, &

O'Neill, 2013), represents an understudied context in the literature and a promising strategy for

supporting STEM identities (NRC, 2015). Given these limitations, and the recognized need to

better understand and support engineering identity for youth, the current study was intended to

advance the field's understanding of engineering identity as a fluid, situated construct and extend

the literature to out-of-school learning environments.

Theoretical Framework

To inform a more dynamic perspective on engineering identity for adolescent youth

participating in an informal engineering education program and capture both agency and

structure dynamics relevant to identity development, we drew from two theoretical perspectives:

(a) *situated identity* and (b) *activity frames*.

Situated identity. Many scholars, especially within the learning sciences, recognize that

identity is actively negotiated through social interaction within specific contexts (Esmonde,

2009; Falk, 2009; Gee, 2000; Norris, 2011; Penuel & Wertsch, 1995). This perspective, often

referred to as situated identity (Penuel & Wertsch, 1995), uses social interaction as the primary

unit of analysis and focuses on the highly dynamic and situated nature of the self-impressions

that we communicate.

Researchers have emphasized several key assumptions of this perspective. First, identity

is a rhetorical process of acting and performing "concerned with persuading others (and oneself)

about who one is and what one values" (Penuel & Wertsch, 1995, p. 91). In other words, identity is seen as "doing" rather than "being" (De Fina, 2011, p. 267). Second, identity is a negotiation between social interactants concerning the "kinds of people" (Gee, 2000) individuals wish to be seen as and the kinds of people they are recognized as by others (Carlone & Johnson, 2007; Gee, 2000). Individuals position themselves and are positioned by others as identities are "ascribed, rejected, and assumed by people in a constant negotiation with one another" (De Fina, 2011, p. 273). Therefore, identities are not static or pre-existing, but instead are actively negotiated in each interaction and may or may not achieve a level of coherence within the moment or over time (Norris, 2011; Norris & Jones, 2005). Third, this process of identity negotiation is constrained and afforded by the social, cultural, historical, and physical context of the interaction (Bakhtin, 2014; De Fina, 2011; Gee, 2000), including the "cultural tools" that individuals have available to carry out actions and realize their intentions (Penuel & Wertsch, 1995).

In their model of science identity, Carlone and Johnson (2007) built on the literature above to provide a concrete structure for operationalizing this dynamic notion of situated identities negotiation within the context of STEM education. The researchers outlined three aspects of science identity: (a) *performance*, or the "social performances of relevant scientific practices—e.g., ways of talking and using tools;" (b) *recognition*, or "recognizing oneself and getting recognized by others as a 'science person';" and (c) *competence*, or "knowledge and understanding of science content" (p. 1191). For the current study, this model provided an initial framework and vocabulary for thinking about how situated identity negotiation might play out in the context of informal engineering programs for adolescent youth. We chose to foreground the performance and recognition aspects of the model, recognizing that program participants were

likely just becoming familiar with engineering and some may not exhibit competence aspects of identity, as defined by Carlone and Johnson.

In their model, Carlone and Johnson primarily used interview data to look at individuals' reflections on themselves and how they were recognized by others. For our research, however, we were interested in directly observing these dynamics during the programs, including how participants made *bids* for identity recognition during the programs; how other participants and adults recognized or responded to these bids; and how participants and adults positioned each other relative to being involved, taking active roles, and proficiently and competently using age-appropriate engineering practices. We believe these social interactions are the driving force behind long-term identity development. These routines of identity negotiation become "patterned and habitual" (Carlone & Johnson, 2007), thus shaping how youth come to perceive themselves and be perceived by others beyond a specific interaction.

Engineering activity frames. Another component of social interactions that is actively negotiated among participants is the meaning and goals of the interaction within the specific time and context that it occurs—often referred to as the *situation definition* or *frame* (Goffman, 1986; Hand et al., 2012; Rowe, 2005). For example, although the DOW programs were designed with specific engineering messages and practices in mind (e.g., engineering as collaborative and iterative), early in the study we realized that the ways the engineering activities, and the embedded engineering practices, were perceived and experienced by the youth participants was also an aspect of active negotiation, in addition to engineering-related situated identities. During a single program session, we often observed evidence of distinct and shifting perceptions about engineering and engineering practices across youth and adults (sometimes shared and sometimes in conflict), such as expectations about the importance of collaboration or the role of iteration in

engineering and design. We therefore explored evidence of socially constructed expectations and definitions related to engineering and the engineering activities that emerged during the programs, as a way of embodying how educational and social structures influence identity negotiation (Hand et al., 2012; Hegedus et al., 2014).

To conceptualize this dynamic, we turned to literature from sociolinguistics and mediated discourse (Norris, 2011; Norris & Jones, 2005; Rowe, 2005; Scollon, 1998) and, specifically, the notion of *situation definitions*. Researchers studying human social interactions have long asserted that a critical aspect of communication is the negotiation of situation definitions, or the implicit expectations and assumptions about the meanings, goals, and ways of behaving that underlie a particular experience (Norris & Jones, 2005; Rowe, 2005; Scollon, 1998; Wertsch, 1998). Drawing from prior work, Rowe (2005) defined a situation definition as "a socialculturally particular type of activity or context that specifies what we are doing in a given moment or what we take to be the background against which our utterances and actions are to be interpreted" (p. 123). These situation definitions are the "dynamic and only partially shared" (p. 124) notions held by each of us in a given situation about the underlying purpose and meaning of that situation, helping us navigate the world by "rendering what would otherwise be a meaningless aspect of the scene into something that is meaningful" (Goffman, 1986, p. 21). For example, a group of individuals talking could be understood either as an informal conversation among friends or a formal business meeting with colleagues, depending on the underlying framing, context, and relationships. In other words, whereas the idea of situated identity captures "who I am" in a particular context, the situation definition describes the understanding of "what I and others are doing" in that context.

In our work, we have chosen to use the term *activity frame* (Goffman, 1986; Hand et al., 2012; Tannen, 1993) to describe the concept of situation definitions relevant to our understanding of engineering identity negotiation. This term highlights the way that frames are situated within specific activities—particular interactions between individuals in particular moments with specific sets of goals or purposes. Although drawn from prior experiences and cultural norms, these frames are specific to a situation, actively negotiated among interaction participants, and thus are an emergent property of the particular interaction and context. Furthermore, just as a particular scene can be framed in different ways, multiple activity frames can be at play and in negotiation simultaneously within one interaction, including both frames that are firmly established and exist in parallel and conflicting frames being expressed and contested by different individuals or during different moments (Goffman, 1986; Rowe, 2005).

Activity frames offer a window into the social structures and practices that individuals are referencing, intentionally or not, and that are informing a particular interaction (Wertsch, 1998)—including social structures that play a role in undermining or supporting STEM identities for youth. As noted, individuals use cultural tools (e.g., language, gestures, symbols, physical objects, etc.) to imply and negotiate specific ideas about the goals and meanings of a situation (i.e., the activity frames). And these cultural tools, in turn, draw their meaning and significance from common cultural understandings situated within broader social structures and practices (Ash, 2002; Penuel & Wertsch, 1995; Rowe, 2005; Wertsch, 1998). For example, raising a hand during a group meeting is a cultural tool that draws its meaning from cultural practices within formal schooling.

Based on the cultural tools used to invoke them and the social structures from which these tools draw their meaning, activity frames create constraints and affordances around what is

possible in a given situation and the roles and identities that individuals are able to negotiate and perform (Norris & Jones, 2005; Rowe, 2005). By establishing the context for making meaning, activity frames privilege certain meanings, roles, and identities over others, and thus are associated with dynamics of power and authority (Rowe, 2005), including expectations about "right" or "wrong" ways of behaving (Gee, 2000; Hutchison & Hammer, 2010; Jimenez-Aleixandre et al., 2000). Continuing the example above, raising one's hand can invoke not only an activity frame related to school but also associated ideas about a teacher being the source of knowledge and authority. Therefore, activity frames provide an analytic bridge between the dynamics of specific moments and the broader structures and cultural forces shaping that moment for these youth.

The concept of activity frames has been used previously to describe the ways students understand STEM education experiences in the classroom and the ways these frames shape classroom discourse, knowledge transfer, and argumentation patters (Elby & Hammer, 2010; Hutchison & Hammer, 2010; Jimenez-Aleixandre et al., 2000; Shim & Kim, 2018). For example, Hammer and colleagues (Elby & Hammer, 2010; Hammer & Berland, 2014; Hutchison & Hammer, 2010) described how student expectations about whether the goal of science argumentation was getting the right answer or persuading others shaped the depth and nature of scientific discourse. In our work, we extend this line of research to explore how framing interacts with identify negotiation in out-of-school STEM learning contexts. During the afterschool engineering activities, we expected activity frames to emerge that referenced different cultural meanings and implied different interpretations of the engineering activities and their associated engineering practices—with implications for how youth were positioned and positioned themselves relative to power, authority, and other aspects of identity.

Research Questions

Building on these theoretical perspectives (situated identity and activity frames), the overarching goal of this descriptive study was to develop a framework for understanding situated identity negotiation related to engineering for youth participants that attended to structure and agency aspects of identity and captured both the nuances of identity negotiation within specific interactions and patterns of identity negotiation over time. To this end, the study was organized around three research questions:

1) What are indicators of situated identity negotiation, including performance and recognition, for youth participating in an informal engineering education program?

2) How are the dynamics of situated identity negation and context-specific activity frames related, as representations of the structure-agency dialect?

3) How do specific moments of identity negotiation relate to broader patterns throughout and across program sessions for individual youth participants?

Methods

To address the research questions above, we conducted a qualitative study, including in-depth analysis of video data collected during the DOW engineering programs. Given the lack of research on situated identity negotiation for youth in engineering programs, qualitative research provided a powerful tool for understanding the complexities of identity negotiation through discourse and identifying important processes and factors previously overlooked by research and theory (Morgan, 2014; Patton, 2015).

Throughout the research, we aspired to engage authentically with our partners and follow best practices in culturally responsive research (Allen et al., 2007; Frechtling, 2010). Specific strategies included engaging a multicultural research team with similar lived experiences to study

participants, continuously examining cultural assumptions underlying our work, collaborating

with partners to use culturally appropriate and responsive approaches, and disseminating findings

broadly in ways that were relevant to local communities. Two members of the research team

(second and third authors) are bilingual and bicultural and all data collection and analysis

followed OMSI's guidelines for handling data in two languages, including preserving the source

language throughout the collection and analysis process. All instruments, procedures, and

informed consent protocols were approved by an institutional review board before data collection

began.

Study Context

The research was conducted as part of the NSF-funded *Designing Our World (DOW)*

project. Led by the Oregon Museum of Science and Industry (OMSI) in partnership with Oregon

State University, Boys and Girls Clubs of Portland, Girls Inc, and Adelante Mujeres, the DOW

project focused on STEM equity and addressing the need for more girls from traditionally

underserved communities to pursue engineering and fill vital workforce gaps, with a particular

focus on Hispanic/Latino youth and families from low socioeconomic backgrounds. Women

from Hispanic/Latino and low socioeconomic backgrounds face a variety of barriers to pursuing

engineering degrees and careers (Hill et al., 2010; McGraw, Lubienski, & Strutchens, 2006; ED,

2014), such lack of support, mentorship, and culturally and linguistically relevant learning

resources (NASEM, 2018; Tate & Linn, 2005). In 2013, women accounted for only 15% of the

engineering workforce and only 6.9% of women in science and engineering fields identified as

Hispanic (NSB, 2016). DOW strategically integrated science center exhibits, existing

partnerships with local girl-serving organizations, educator and parent professional development,

and afterschool programming to impact engineering-related interests and identities for girls from these communities.

The first year of DOW programming was conducted with Boys and Girls Club participants attending an afterschool site in a suburb outside of Portland, Oregon. The site serves up to 350 youth daily from diverse backgrounds with a variety of afterschool programming and resources. Many attendees qualify for free or reduced lunch and most of the program materials are available in both Spanish and English. During the program, the DOW project team worked closely with BGC staff to plan and implement the DOW project, recruit and gather informed consent from youth participants and families, and coordinate activities.

The DOW programming took place from December 2014 through March 2015 and consisted of seven sessions held at the BGC site and two field trips to the Oregon Museum of Science and Industry (OMSI). Activities were designed and facilitated by OMSI educators and included group discussions, presentations from guest engineers (serving as role models), and small-group engineering challenges. BGC staff actively contributed to the development and facilitation of the program. For most of sessions, one of the two program designers and project co-PIs launched the activities and then co-facilitated with other OMSI and BGC staff members.

Overall, the DOW program was designed to engage participants with key aspects of the engineering design process (Crismond & Adams, 2012; Cunningham, 2018), such as understanding the problem and design constraints, generating and representing ideas, and iteratively testing and revising designs. DOW was also intended to encourage engineering mindsets, such as viewing failure as a positive aspect of the design process (Litts et al., 2016; Martin, 2015), and foster interest in engineering by making engineering more broadly appealing (NAE, 2008), especially for girls from traditionally underserved communities. The engineering

role models and the engineering challenges emphasized the altruistic, collaborative, and social aspects of engineering. For example, one activity challenged participants to work in groups to design and test a model of a safe wheelchair ramp using a peg board, rubber balls, and various materials—thus highlighting how engineers collaborate to make the world a better place for others. Other activity topics included designing surgery tools and building a zipline to carry an injured person. Throughout the program, educators talked explicitly about persistence through failure, including brainstorming strategies to use when participants were stuck or having trouble.

The number of participants in the sessions fluctuated, with group sessions averaging 15 participants, most of whom were girls. The age of youth ranged from 7 to 12, with an average of 9 years old. Although two boys originally signed up to participate, only one of these attended beyond the first session. Similar to the overall makeup of the BGC site, many program participants spoke both Spanish and English, although the majority of group discussions during the program were in English.

Focal Youth Participants

After the program was complete, we conducted an initial review of the data in order to select a subset of participants for analysis. Focal youth were chosen from participants who had attended the majority of the sessions and completed the majority of the secondary data collection activities, as described below. The final selection was also made to represent the range of how youth participated in the programs, based on the research team's experiences and initial review of the video, from more passive to more active participation and from more individual to more collaborative orientations during group work.

The final group of participants included in the analyses reported in this article included five youth between the ages of 9 and 12: Raven, Britany, Ariel, Jaime and Priscilla.[2] Britany and Ariel were the oldest in the group. Ariel, Jaime, and Priscilla were siblings and all three spoke Spanish and English. Jaime was the only boy to consistently participate. All five youth had been active in the BGC program for at least a year before the start of the DOW project.

Data Collection

Data collection took place over four months and included videotaping of youth participating in program sessions, researcher observations and reflections, interviews with BGC and OMSI staff, interviews with parents, and reflective activities conducted with youth. Because the focus of the study was on understanding the dynamics of situated identity negotiation during and across the program sessions, the primary data collection method was videotaping.

During each session, the research team used a video camera and a wireless mic to record activities and capture youth and adult conversations. A member of the research team also conducted observations and took running notes. Observations were guided by the research questions and were used to inform researcher reflections written immediately after data collection was complete, such as descriptions of the activities, examples and evidence of situated identities and activity frames, and reflections on physical and social context factors potentially influencing identity negotiation. In total, we collected 10 hours of video data with youth program participants.

Secondary data collection to support the analysis and interpretations of the video involved reflective activities and discussions with focal youth embedded into the final program session, interviews with parents, and conversations with OMSI and BGC staff members. The

embedded reflective activities included a word choice game during which focal youth were

asked to select three words that they would use to describe themselves and then talk about why

they chose those words; a parallel activity asking youth to pick three words they thought their

teacher would use to describe them; a drawing activity in which participants described what they

liked to do with their families; and small-group discussions about the program itself, including

aspects that participants liked the most, aspects that were challenging or that could be improved,

and things they learned. Interviews with BGC staff and parents focused on general background

about each focal youth, reflections on the youth's program experience and relationships with

other participants, and parents' goals and aspirations for their children.[3]

Data Analysis

The full details of the coding and analysis approach are available in the online

supplementary materials [link to supplementary materials]. Broadly, our approach drew from

techniques in grounded theory (Charmaz, 2006; Glaser & Strauss, 1967) and multimodal

discourse analysis (Norris, 2011; Norris & Jones, 2005), as well as general recommendations for

increasing the trustworthiness and transferability of qualitative research findings (Creswell,

2013; Marshall & Rossman, 2011). Although the process of qualitative analysis is not linear,

building on Charmaz (2006), we generally followed five phases of analysis: (1) researcher

reflections, (2) initial coding, (3) focused coding, (4) youth profile development, and (5)

interpretation. All video coding and analysis was conducted using NVivo software, preserving

the original language of study participants.

Through an iterative process of video review and discussion during the researcher

reflection and initial coding phases, we developed a set of codes to describe and organize the

critical aspects of identity negotiation observed in the data. The final focused coding framework (see online supplementary materials) included both *micro* codes applied to specific actions and behaviors for each focal youth (Table 1) and *macro* codes applied to whole video segments for each focal youth (overall engagement, overall roles during small group activities, overall roles during large group activities, and social orientation). These two sets of codes were designed to be applied separately for each focal youth so that we could understand and describe identity negotiation from the perspective of each participant. We also developed a set of secondary codes that were applied to each instance of a primary micro code. These identified the specific nature of the identity bids and positioning actions and how youth, peers, and adults responded. This process allowed us to identify meaningful identity moments and activity frame indicators within the interactions, describe the social dynamics of identity negotiation surrounding those moments, and explore the process through which peers and adults reacted to, recognized, and positioned youth during ongoing identity negotiation. Finally, the focused coding framework included a set of contextual codes (activity setting, activity type, group composition, and adult facilitation) that were applied to whole video segments and were not specific to individual focal youth.

During coding, we were sensitive to reoccurring types of interactions or moments in which the negotiation of situated identities and activity frames became particularly visible and salient, such as when the understanding of the situation and the roles and identities of participants within that situation are "at stake" (Penuel & Wertsch, 1995) or "being called into question" (Hammer et al., 2005). As Penuel and Wertsch (1995) noted, "identity research must examine contexts in which identity is contested or under transforming shifts" in order to understand "the way that individuals and groups can struggle against dominant discourses of their identity to co-construct a different way of speaking about themselves and develop new

forms of action" (p. 90). Similarly, Hammer and colleagues argued that activity frames are "most visible when they are called into question… occasions for frame negotiation—moments when the participants challenge each other's understanding of 'what's going on here.'" Therefore, during initial and focused coding, we were attentive to potential moments of heightened identity and activity frame negotiation, when one or both of these facets of the interaction were being contested and identity negotiation was more visible for participants. As described below, we adopted the term "critical moment" as both an analytic and conceptual tool to help identify these types of situations and explore how they intersected with identities, framing, and the engineering content.

Table 1. *Primary micro codes used for focused coding of the video data.*

Code	Definition
Identity bid	Action or comment by the focal youth that appears to be an attempt by youth to: (a) claim knowledge, confidence, competence, or success related to activity or topic; (b) seek acknowledgment of knowledge, competence, or success related to activity or topic; or (c) contribute (either prompted or not) ideas, suggestions, or critiques related to the activity or topic.
Positioning action	Action or comment by a peer or adult that, purposefully or not, appears to position the focal youth relative to the engineering activities or topics, including positioning around knowledge, competence, or success.
Failure moment	Instance during which the focal youth fails at an activity or is noticeably struggling to succeed. These moments are either "self-recognized" (i.e., focal youth verbally acknowledges failure or struggle) or "other-recognized" (i.e., peer or adult verbally identifies focal youth's failure or struggle).
Other important identity moments	Catch-all code for important identity moments that do not fit easily into other primary micro codes (but are still related to the engineering activities or topics). This code can also be used broadly for any actions or behaviors that seem critical but do not directly relate to any of the existing codes.

Because evidence of emergent activity frames or frame negotiation was often difficult to attribute to a specific action or comment, an additional step was added to the focused coding

phase. During focused coding, researchers used a broad "situation definition" code to identity moments, actions, or talk that suggested specific expectations or understandings related to the engineering activities. After coding was complete for a specific session, the researcher then reviewed the tagged moments and wrote a narrative description of their impression of the activity frame negotiation dynamics throughout the session, including the different expectations and understandings that appeared to be communicated by youth, what overall activity frames appeared to be more prominent and persistent (if any) throughout the interaction, and how these frames related to the goals and expectations communicated by educators and through the activity design. This description was then included as part of the interpretive process described below.

After qualitative coding, we also conducted a second layer of analysis on the video and secondary data. In order to capture reoccurring patterns of identity negotiation emergent across sessions and contribute to the field's ongoing efforts to coordinate the study of identity over multiple timescales, we developed narrative-style profiles for each youth (Calabrese Barton et al., 2012). These described the experiences and behaviors of the youth during the program and highlighted patterns and characteristics of that participant's identity negotiation that emerged from the coding results and review of the secondary data from the appropriate youth. A second team member then reviewed the summary and together the two researchers discussed and revised the description until consensus was reached. These youth profiles were also the opportunity to continue to explore the emergent activity frames evident in the interactions by looking at the data for each youth and reflecting on the types of activity frames these youth appeared to suggest through their talk and action, as well as how these frames related to those being suggested by other participants.

The analysis process described above generated detailed coding summaries, session descriptions, and a narrative-style profile for each focal youth. These were reviewed and discussed by the research team and used to identify themes and patterns emerging from the data, including the identification and description of the types of situated identities and activity frames that were prominent during these interactions, the exploration of when and how these identities and frames emerged, and the ways that the two concepts were potentially connected during the interactions. This inductive process resulted in the conceptual model described below. Throughout analysis and interpretation, we used a variety of strategies to check our interpretations and support the credibility and trustworthiness of study findings (Creswell, 2013; Marshall & Rossman, 2011), including triangulating data across multiple perspectives; working closely with project team members and partners and remaining deeply involved in the program in order to gain a rich understanding of the context and the experiences of participants; and using grounded theory coding and constant comparative approaches (Charmaz, 2006; Glaser & Strauss, 1967).

Results

Through our first-hand experiences with the program and in-depth analysis of the video and secondary data, we developed a rich understanding of the ways that the participants negotiated their engineering-related identities during the DOW project. In this section, we begin by outlining the descriptive framework that emerged during our analyses. We then describe the experiences of two focal youth in depth, both to illustrate the evidence supporting the framework and to demonstrate how this framework sheds light on the experiences and identity negotiation of

program participants. Although we highlight these two examples, the study findings represent the themes and patterns that emerged across all five focal youth.

Descriptive Model of Identity Negotiation

The conceptual framework that emerged from the analysis, or what we have called the *Identity-Frame Model*, is designed to (a) describe engineering-related identity negotiation in the context of informal engineering learning experiences for adolescent youth from traditionally underserved and under-resourced communities, (b) coordinate aspects of both structure and agency in our analysis, and (c) track patterns of identity negotiation across multiple time points. The model posits that situated identity negotiation is an ongoing process of *performance and definition work* by an individual and *recognition and positioning* work by other adults and peers that creates emergent, context-specific *identities* and *activity frames* that are made particularly salient during *critical identity moments* (Figure 1).
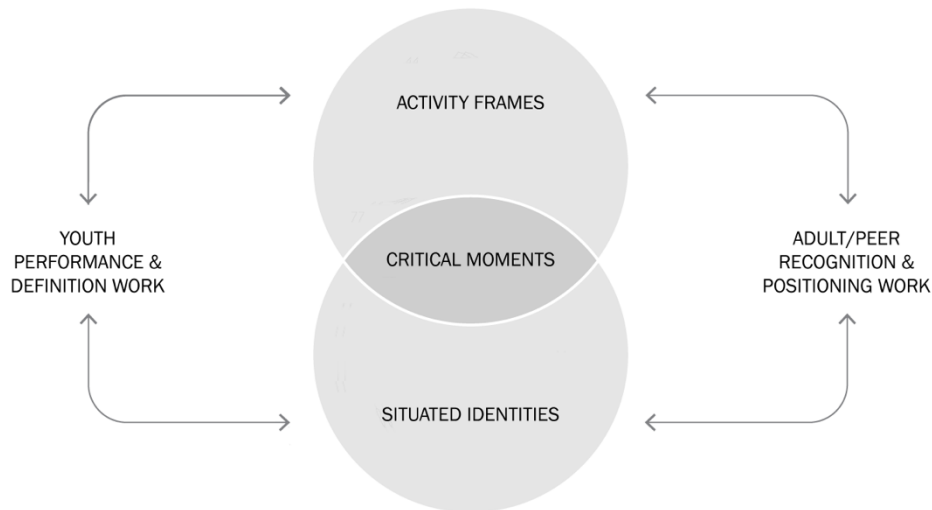

Figure 1. Identity-Frame Model of youth situated identity negotiation (Pattison et al., 2018).

To illustrate this model, Table 2 shows a typical example with Priscilla, Raven, and one other participant working to create a ramp on a peg board that would allow a person in a wheelchair (modeled with a small ball) to travel safely from the top of a mountain (i.e., the top of the board) to the bottom. The adult approaching and asking a question triggered a critical identity moment (i.e., a moment of increased intensity and frequency of actions and talk related to situated identities and activity frames), and the talk among youth immediately increased, with Priscilla apparently eager to demonstrate her knowledge and skill (performance work) by showing the facilitator what she had been working on (lines 1-3) and testing and critiquing the group's design (lines 5-6). Subsequently, she continued to make identity bids as knowledgeable of the activity and possible design strategies (line 8-13). In this case, her bids were primarily supported by her peers (recognition and positioning), who did not prevent her from redirecting their previous design (line 9) and followed her lead in starting with a different approach (lines 11 and 14). Throughout the interaction, talk and behavior suggested an emergent understanding (activity frame) of the design challenge as collaborative, which both Priscilla and other participants supported by contributing to the group design and using "we" to describe their work.

Table 2. *Priscilla, Raven, and two other participants engaging with the wheelchair challenge.*

Line no.	Conversation	Behavior
1	Priscilla: I made a ramp on my own!	Talking to facilitator as the adult approaches the table.
2	Facilitator: Nice!	
3	Priscilla: I made a ramp.	Showing the ramp made out of three tubes stacked on top of each other.
4	Facilitator: Have you guys tested this? If you drop a ball, does it go at an angle?	Signaling the ramp design that was on the board (different from what Priscilla was doing).

5	Priscilla: No, I don't know. I haven't tried. Let me try it.	Moving to the end of the board with the design.
6	Priscilla: It falls off when I put it there.	Referring to what happens to the ramp made of popsicles sticks when they test the design with a ball.
7	Raven: What?	Acting surprised and trying unsuccessfully to fix the popsicle sticks with the other group members.
8	Priscilla: Wait, why do we even need these here?	Starting to remove the pegs from the board that were holding up the popsicle sticks.
9	Participant 1: I don't know. I just put them there.	Helping Priscilla remove all of the pegs from the board.
10	Priscilla: We don't even need these things here! We are just going to make it go like this.	Showing a steeper angle on the board with the pegs.
11	Raven: I actually like this. We can put this like that.	Putting pegs and a popsicle stick in a different part of the board different to what Priscilla was showing.
12	Participant 2: Wait guys.	
13	Priscilla: Just take everything off for now.	Suggesting they start with a new design.
14	Participant 2: I thought this was going to be easy! Let's make a low start.	Suggesting they start to build the ramp from the bottom of the board to the top instead of the top to the bottom.

As illustrated in this example and shown in Figure 1, we believe the activity frames and identities that emerge from these processes in turn afford and constrain further identity negotiation by individuals and other adults and peers. In the example in Table 2 above, although Priscilla made a strong bid to be seen as knowledgeable and skilled, including critiquing the work of the group, the negotiated activity frame of the engineering challenge as collaborative appeared to support other youth in contributing ideas, participating, and making bids for their own situated identities. In other cases, however, emergent activity frames, such as those that

focused on correct answers or competition among participants, seemed to afford the identity performance and recognition of some youth but undermine the work of others. In other words, the model highlights how particular situated identities and identity negotiation patterns may be more productive at supporting the identity bids of participants given certain emergent activity frames.

Another example of this can be seen in Table 3. Priscilla, Raven, and Britany were working at different stations for the surgery activity, building and testing tools to complete challenges that modeled different types of surgery (e.g., removing a marble from inside a long tube). From the beginning, an expectation appeared to be shared across participants that the activity was a competition, starting when Priscilla asked to borrow some materials ("Can I use that one?") and Britany strongly asserted her ownership over her own materials ("No!"). This expectation set the context for a series of conflicts, including participants becoming frustrated with failure (lines 1–2), undermining the solutions of others (line 4), fighting over materials (lines 8–11), and accusing others of cheating (lines 20–27). Even though the facilitator tried to encourage collaboration (lines 9, 21, 28), the interaction continued to focus on competition and undermine the identities and successes of other participants.

Table 3. *Brittany, Priscilla, and Raven at the surgery activity station*

Line no.	Conversation	Behavior
1	Raven: Ughh!	Working on a different engineering challenge from Britany and Priscilla. Trying to remove some Play-Doh through a hole in a cup with a stick the Play-Doh falls almost as she manages to get it out.

2	Facilitator: Try to think of ways.	Referring to other ways Raven can try to get the Play-Doh out of the cup.
3	Britany: I want to try that one again.	Pointing to a different station. Britany grabs a straw and tries to use it to suck a marble out of a tube.
4	Priscilla: Eww!	Looking at how Britany is using the straw.
5	Britany: How is that eww?	
6	Priscilla: You can use this one… It's eww!	Grabbing a different straw and looking inside of it.
7	Priscilla: That is mine!	Referring to the rubber band that Britany has just taken from the table.
8	Britany: Is a rubber band.	Twirling the rubber band in her finger, bringing it closer to Priscilla and pulling back as Priscilla reaches out to grab the rubber band.
9	Facilitator: Britany you need to share the supplies with the other people in your team.	
10	Britany: I picked it up and she said it's her and it's a rubber band.	
11	Priscilla: I was just trying to tie something	
12	Facilitator: Which one are you trying to figure out?	Asking Priscilla which design challenge, she was working on.
13	Priscilla: That one!	Pointing to a different challenge than the one she is standing at with Britany.
	(About a minute passes as Priscilla continues to work on her challenge and Raven successfully completes a different challenge station.)	
14	Raven: I almost, I did almost all of them.	Referring to the design challenges.
15	Facilitator: Almost all? Which one are you missing?	
16	Raven: Eehh.	Pointing to a design challenge.
17	Facilitator: That one over there? Is that the only one you are missing?	
18	Raven: Yes	

19	Facilitator: It's a tricky one. Why don't you try looking at some of the things they are doing and see what can you do differently?	Referring to design ideas from Britany and Priscilla.
20	Raven: They are cheating.	Pointing towards Britany and Priscilla.
21	Facilitator: No!	
22	Priscilla: It fell.	Referring to the Play-Doh she was trying to pull out a cup with a stick.
23	Facilitator: As far as I know is a tricky one.	Referring to the design challenge Britany and Priscilla were working at.
24	Britany: Who is cheating?	
25	Raven: You guys were cheating!	
26	Britany: No, we are not.	
27	Raven: That's what I thought.	
28	Facilitator: Looking at other people's ideas is not cheating.	

Dynamics like those shown in Tables 2 and 3 are constantly at play. However, our analysis suggests that certain critical moments, such as an adult entering a peer group interaction (Table 2) or a youth conflict over materials (Table 3), spark focused identity negotiation and make identities and activity frames particularly salient. These critical moments, therefore, are important both conceptually, as catalysts of identity negotiation, as well as methodologically, as markers of emergent frames or identities that may otherwise be implicit (Carlone, 2012).

As might be expected, youth participants had varying degrees of success gaining support for their identity performance and framing work. In some cases, such as the example with Priscilla in Table 2, the identities and activity frames that a particular youth appeared to be negotiating were supported by peers and adults, both directly, through positive recognition of the youth's identity negotiation, and indirectly, through the ways they positioned the youth and supported through their talk and actions relative to particular activity frames. In other cases, such

as in Table 3, peers reacted negatively to a youth's identity work, positioned that youth in

opposition to the identities she appeared to be negotiating, or contributed to the negotiation of

activity frames that seemed to undermine the youth's identities and roles.

Engineering-Related Identity Negotiation

These patterns of identity negotiation described above had specific characteristics in the

context of the DOW informal, engineering-related activities (Figure 2). Based on the

complexities of the interactions and the emergent meanings and interpretations, we describe

many of the situated identities and activity frames listed below as continuums. This

conceptualization recognizes that the emergent meanings were never black and white and that

the talk and actions of youth and adults often appeared to position them and others between,

rather than at, the extremes of different identities and frames. This conceptualization also

highlights how these categories by necessity oversimplify the complex nature of the social

interactions, during which identities and frames were rarely static and hardly ever conformed to

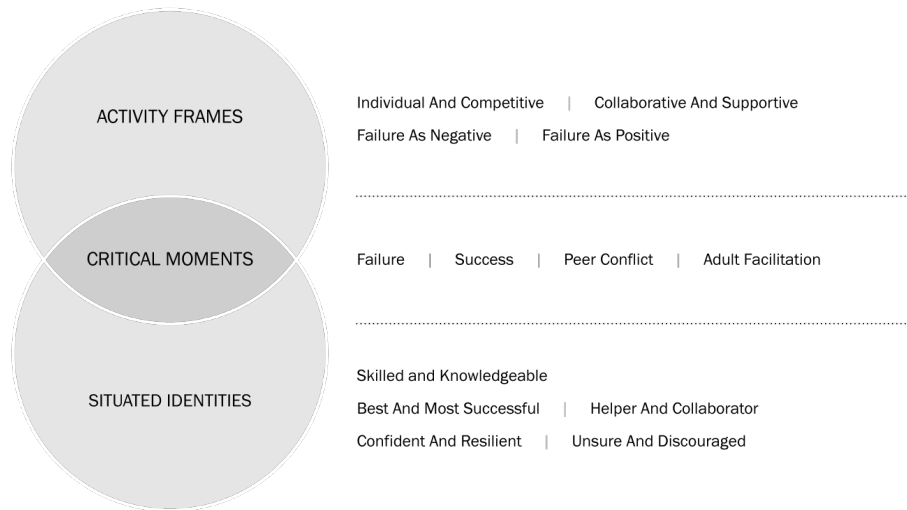the exact descriptions outlined below.

ACTIVITY FRAMES

Individual And Competitive | Collaborative And Supportive

Failure As Negative | Failure As Positive

CRITICAL MOMENTS

Failure | Success | Peer Conflict | Adult Facilitation

SITUATED IDENTITIES

Skilled and Knowledgeable

Best And Most Successful | Helper And Collaborator

Confident And Resilient | Unsure And Discouraged

Figure 2. Elements of the Identity-Frame Model specific to the afterschool engineering program (Pattison et al., 2018).

Critical identity moments. As noted, critical moments represented key points during the program when we consistently observed increased intensity and frequency of actions and talk related to situated identities and activity frames. Four types of critical moments emerged as important in the qualitative analysis: (a) success with the engineering challenges, (b) failure with the engineering challenges, (c) peer conflict, and (d) adult facilitation.

Success and failure moments are clearly tied to how youth position themselves, and are positioned by others, related to their success and competence with the activities. In this model, success and failure moments were defined from the perspective of the participants and were identified by ways that the youth, their peers, and adults signaled success or failure (e.g., "You did it!" or "Mine didn't work!"). When youth participants successfully completed challenges, they found opportunities to share their accomplishments, claim responsibility for the success, and highlight their progress relative to others (e.g., Table 2, lines 1-3). On the other hand, when youth struggled, we often observed them reacting strongly, such as redirecting the cause of the

failure (e.g., "Do I have the same stuff as everyone else?") or expressing frustration or helplessness (e.g., "This is too hard, I give up").

The *presence of adults* and *conflict with peers* also appeared to be important opportunities for identity negotiation and positioning. After program leaders launched the activities, groups often spent much of the time working together without adult facilitation. Program leaders moved about the room, checking in briefly and occasionally spending more time with particular groups or youth. When adults did become involved, we observed many youth participants more actively performing their identities for the adults, such as racing to answer adult questions, sharing either group or individual successes (e.g., Table 2, lines 2–3), or critiquing the work of others (e.g., Table 3, line 20). Similarly, conflict between participants naturally became moments of identity negotiation. While working together, youth were required to collaborate with each other, share resources, and determine how they would achieve the design challenges, either individually or collectively. Conflict occasionally arose, especially around the use and control of materials (e.g., Table 3), and these conflicts highlighted power dynamics, implicit hierarchies, and identities related to competence and control.

Situated identities. Several common situated identities emerged during data analysis related to how youth positioned themselves and others relative to the engineering design challenges and how they negotiated their roles. Throughout the program, we observed almost every youth participant working to position themselves, intentionally or not, as *skilled and knowledgeable* relative to the engineering activities and content. In Table 2 above, both Priscilla and participant 2 made strong identity bids by claiming to have a solution to the design challenge. Similarly, in Table 3, Raven highlighted her success at solving most of the challenges (line 12) and contrasted this with other groups that she accused of cheating (line 18).

Throughout, youth often celebrated their success, shared their knowledge of the activity goals or possible solutions, and competed to answer adult questions.

We also described two important identity continuums relative to which youth and adults appeared to position themselves and others, either intentionally or not. The first continuum was characterized by youth positioning themselves, or being positioned by others, as the *best and most successful* participants at one extreme and as *helpers and collaborators* at the other extreme. Evidence of "best and most successful" situated identity negotiation included claiming individual success or knowledge, rather than group success; claiming success for work by other youth; quickly responding to adult questions and working to get the "correct" answer; and negatively critiquing others (e.g., Table 3). In contrast, "helper and collaborator" situated identity negotiation was characterized by claiming success for the group, rather than for oneself; praising others and recognizing or positioning others positively; and working collaboratively with peers (e.g., Table 2). Overall, the "best and most successful participant" identity negotiation pattern emphasized individual success, while the "helper and collaborator" identity emphasized group success.

The second continuum involved how youth were positioned relative to failure during the activities. On the one extreme, some youth appeared to negotiate identities as *confident and resilient* in the face of failure and challenge. Evidence of this identity included persistence through failure; trying out multiple ideas and learning from past iterations, and attributing failure to the design or materials, rather than one's own abilities (e.g., Table 2). On the other end of the continuum, evidence of an *unsure or discouraged* (e.g., Table 3, line 1) identity negotiation pattern included giving up after encountering failure or challenge, moving on to a new design activity after one attempt, frequently seeking help from peers and adults even before attempting a

design challenge, and attributing failure to oneself and one's abilities, rather than to the materials or the design. Often this identity continuum appeared to be associated with negative emotions, although some youth were observed using humor or topic shifts to put a positive spin on the situation.

Activity frames. Within the context of DOW program, negotiated understandings of the activities appeared to revolve around expectations about activity goals and peer collaboration. In this study, we described two activity frame continuums related to engineering and engineering practices that repeatedly emerged during the interactions. These activity frames, not surprisingly, appeared to be closely linked with the situated identity patterns during the interactions, since how youth were positioned held significance relative to the meaning and purpose underlying the engineering activities.

First, we observed indications that youth, and adults, negotiated expectations about the design and engineering activities along a spectrum of *individual and competitive*, at one end, and *collaborative and supportive*, on the other. At the one extreme, many comments and actions suggested a collaborative, supportive activity frame for the engineering activities, as in Table 2. Indicators of this frame included youth working together and supporting each other; claims of group success and praising others (e.g., "we did it!"); sharing materials and roles; and helping, supporting, and offering positive suggestions. At the other end of the spectrum, evidence of an individual, competitive activity frame included conflict among the participants related to roles and materials; comments highlighting individual success (e.g., "I did it first!" or "I win!"); taking credit for other participants work; a focus on quickly getting the "correct" design or answer, rather than trying out different ideas; and negatively critiquing the work of others (e.g., Table 3).

A second activity frame continuum involved the interpretation of *failure as either negative or positive*. Evidence of failure being negotiated as a positive, constructive part of the activities and the engineering design process included positive emotional responses to failure; persisting through failure and trying multiple iterations with the same challenge; recognizing failure but attributed it to the materials and the design process, rather than to one's own skills or abilities; using humor to deal with failure and challenge; and celebrating multiple iterations or solutions. In Table 2, the group recognized their initial design had failed (line 6), but then quickly began work on a new design, building on lessons from their initial attempt (line 14). On the other hand, evidence of failure as a negative outcome included negative emotional reactions to failure and challenge; comments focusing on past success, rather than trying out new ideas; getting stuck or giving up after a failed design; attributing failure to oneself, rather than the process or the materials; being secretive or covering up failure; and focusing on who had completed the challenges, rather than celebrating multiple solutions and the design process. In Table 3, Raven had trouble getting past her struggles with one of the activity stations (line 1), and although she completed many of the challenges, she often focused on the failure of other groups (lines 20–28) rather than her own design process.

Like youth, adults also communicated information that contributed to the ongoing negotiation of activity frames during the interactions. Sometimes these messages were explicit, such as when program leaders launched the session emphasizing the collaborative nature of engineering or when adult facilitators encouraged the sharing of ideas and supplies (Table 3, lines 9 and 19). Many times, however, the messages were subtler and could even contradict the previous messages. For example, an adult facilitator might encourage youth to collaborate at

outset but then ask individuals in a group who had solved the challenge first, thus implying a competitive framing (see examples below).

Connections among critical moments, identities, and activity frames. Unique configurations of these different elements varied across youth and program segments and appeared to be associated with unique engineering-related identity negotiation patterns. As we describe in the examples below, success moments could be used as opportunities for a youth to position herself as the best and most successful participant or as a helper and collaborator who had contributed to group success. These identity bids, in turn, contributed to the negotiation of activity frames around engineering and design as an individual, competitive activity or as a collaborative, supportive endeavor. Similarly, the emergence of particular activity frames appeared to be connected with the significance of critical identity moments and how youth were able to negotiate their situated identities. If the talk and behavior of participants suggested that the engineering activity was individual and competitive, failure might be interpreted as a critical moment of identity crisis that needed to be overcome for participants to position themselves as the best or most successful. In these situations, youth who used failure or success moments as opportunities to support others and negotiate identities as good collaborators might find their roles undermined. In contrast, if activity frames emerged that interpreted the engineering challenges as collaborative and failure as positive, failure and success moments could become opportunities for multiple youth to support their identity negotiation and contribute to the design process, as was the case with Priscilla and her peers (Table 2).

Examples of Two Focal Youth

The results above provide an overview of the *Identity-Frame Model* developed through the study and the engineering-specific aspects of that model that emerged from the data. To illustrate this model more concretely, and provide more evidence from the data, we next describe the experiences of two focal youth in detail. These two examples also illustrate the way we were able to use the model to look at the connections between situated identities and activity frames over time for individual participants. In the first example, Britany exemplifies a youth who appeared to strongly position herself, and be positioned by adults, as skilled, knowledgeable, and successful in the context of the engineering activities and confident and resilient in the face of failure. Her actions often suggested an individual and competitive activity frame. And although she always persisted through failure, her frustration when she was not successful, and her comments to her peers, emphasized an understanding of failure as a negative aspect of the engineering process. In the second example, Ariel also appeared to position herself as skilled, knowledgeable, and resilient in the face of failure. In contrast to Britany, however, Ariel's actions were more aligned with an emergent activity frame of the engineering activities as collaborative and supportive and, in several instances, she took more of a helper and collaborator role, especially compared to Britany.

Britany identity negotiation. As a 12-year-old, Britany was one of the oldest in the program. Throughout, she showed an effervescent and boisterous personality and seemed excited to participate. She was very active at the BGC, including other STEM-related programs and as part of her school's band, appeared to be highly independent, and seemed to like to be in charge while working on the design challenges.

During DOW, Britany participated in three out six sessions at the BGC and both of the OMSI visits. She was a consistently active participant and showed a high level of engagement that remained stable throughout the program. During the small-group engineering activities, Britany worked independently and was hands-on with the materials. This occasionally caused critical moments of interpersonal conflict with peers, especially when Britany appeared to want to retain control of materials or offered unwanted critiques of other participants' designs. Despite this dynamic, Britany was able to work successfully in one activity with Jaime, the only boy in the group. This interaction appeared to be as close as Britany got to collaboration with others. However, it is important to note that during this activity she was mostly in control of the decisions and materials but was open to hearing Jaime's ideas and suggestions. Britany was one of the only girls who actively engaged in both the small group activities and also the large group discussions.

Britany consistently made strong bids to be recognized as knowledgeable and skilled in the engineering activities (58 bids total).[4] Beyond individual skill and knowledge, her actions also seemed to position her as the best and most successful in the group, regardless of how she performed on the design challenges relative to others. The majority of these identity bids involved moments when Britany expressed or claimed knowledge, success, and competence (e.g., "I win," "I know how to do this one," "I'm on a roll here," and "I've got an idea"). This excitement appeared to stem particularly from being "successful" at solving the challenges, as evident when she used phrases like "we are gliding through" and when she celebrated her accomplishments by cheering ("woo-hoo!") multiple times.

Other common identity bids from Britany included times when she contributed suggestions, ideas, or critiques to other members of the small groups. For example, in one

instance she explained the flaw in a specific challenge, telling her group that a magnet wouldn't be useful to get a penny because magnets only attract certain types of metal. At other times, she tried to order other group members around or provided critiques that did not seem helpful to other youth, often resulting in interpersonal conflict.

In relation to failure, Britany usually seemed confident and resilient during critical failure moments, although like many youth, she often showed frustration in these instances. Overall, Britany had few expressed failure moments across activities ($n = 7$). She occasionally showed frustration during these moments (3 out of 7), but in the vast majority of cases she had a constructive reaction (5 out of 7), persisting through the challenge and trying out a different idea rather than giving up or switching focus.[5] The majority of these failure moments (5 out of 7) were self-recognized but not self-attributed.

Closely aligned with her identity negotiation, Britany's behaviors often supported emergent activity frames of the engineering activities as individual and competitive and failure as a negative aspect of the engineering process.[6] This was highlighted by several critical moments when Britany compared herself to her peers and expressed a feeling of competition among group members. In one case, Britany's excitement over solving a challenge seemed to diminish as another group member solved a different challenge at the same time. In another occasion, Britany worked with Ariel during the engineering activity and praised her for solving a challenge. However, during a critical moment of adult facilitation, Britany then took credit for the group's success when one of the program facilitators asked who had created each design. As noted, although Britany regularly persisted through failure, she also communicated a strong, implicit message that failure was something to be avoided.

Table 4. Example of Britany identity negotiation patterns at the surgery activity.

Line no.	Conversation	Behavior
1	Facilitator: Look at this mess on top of the body! What is going on here?	Approaching table and remarking on the messy appearance of the table.
2	Britany: We needed to get the tools that were in the bottom.	Referring to the group sorting through the materials bin and making a mess at the work station.
3	Facilitator: If this was an operating table, I don't know… So, what have you guys figured out so far?	Other participants laughing. Brittany tries to respond right away. Ariel and Jaime keep working.
4	Britany: Umm, we used chopsticks for the ice cube. We sucked the penny out with a straw and poked the Play-Doh.	Quickly moving through the stations and showing the different tools and items they used.
5	Jaime: And we are going to go fishing.	Showing a tool that he built.
6	Facilitator: Let's see!	Ariel, Brittany, and the facilitator move to watch Jaime try to work with a tool he and Brittany worked on prior to the facilitator arriving.
7	Britany: Can't touch the tissue! Tissue! Yeah, that thing is not working!	Telling Jaime as he accidentally touches the border representing the tissue.
8	Facilitator: That's okay.	
9	Britany: Paper clip!	Grabbing a paper clip and trying to remove obstacle with it. Ariel and Jaime step back.
10	Facilitator: Nice!	
11	Facilitator: I think you guys are going to get far with this but you are going to have to design one tool that can do this thing. Right now it's taking two of you to do the same thing. Can you work together to make something?	
12	Jaime: This is falling apart.	Referring to one of the challenge setup as he steps back from station.
13	Facilitator: So, who came up with each idea?	

14	Britany: I came up with the pokey thing.	Responding immediately as Ariel tries to talk at the same time.
15	Ariel: Mmm, I…	Interrupted by Brittany.
16	Britany: I came up with the straw thingy and I came up with the chopstick thingy.	
17	Facilitator: Sounds like you are the lead surgeon here.	
18	Britany: She started doing it with the popsicle thing.	Pointing to Ariel and mentioning a design Ariel used previously.
19	Facilitator: Cool! You want to show me?	Asking Ariel to show her what she had tried. Ariel proceeds to show her.

An example of these dynamics is shown in Table 4, with Britany negotiating her identity with Ariel, Jaime, and an adult facilitator while the youth engaged with the surgery activity. The three had been working either in pairs or independently when the facilitator initiated a critical moment by approaching the table and asking what the group had figured out so far (lines 1-3). Both Brittany and Jaime used this question as an opportunity to make identity bids by highlighting their progress and simultaneously implying a collaborative activity frame, describing the successes of the group using the term "we" (lines 4-5). However, as Jaime was demonstrating one of his designs, Britany positioned him negatively by pointing out the failure of his design (line 7). In doing so, she suggested a more competitive activity frame, focusing on the success and failure of individual group members and working to achieve her own success in competition with her peers (lines 7-9). Although the facilitator made a few comments to shift the focus towards collaboration and positively position others (e.g., lines 8 and 19), the adult primarily followed Britany's new competitive frame by complementing her design when she took over from Jaime (lines 9-10), emphasizing individual ownership of the design ideas (line 13) and positioning Britany's knowledge and skills in contrast to her peers (line 17). Although

Britany ended the segment by positively positioning Ariel and her design (line 18), she also took the opportunity to highlight her own success (lines 14-16), which was supported by the facilitator (line 17). Notably, as in other collaborative group interactions with Britany, the other participants stepped back or decreased their engagement with the activity in response to her identity negotiation strategies (e.g., lines 9 and 12).

As in this example, Britany appeared to be relatively successful in her identity negotiation and her alignment of situated identities and activity frames, including how she was recognized and positioned by adults. The individual and competitive activity frames that her actions implied often appeared to dominate or be implicitly supported by others and seemed to afford the negotiation of her role as a successful and confident participant. We identified seven adult positioning moments for Britany across all the sessions and all of these were coded as supportive. Adults also positioned Britany as knowledgeable and competent during several critical success moment when Britany solved the design challenges. For example, adults highlighted that Britany had great ideas or suggested other group members ask Britany for suggestions. In Table 4, the educator called her "the lead surgeon" and continuously credited her with coming up with the best ideas, despite the fact that her peers had contributed as much if not more to the solutions. Adult reactions to Britany's identity bids were primarily neutral or no reaction (79%, or 46 out of 58), although there were a fair number of positive reactions (17%). Similarly, peers usually had neutral or no reaction to her identity bids (90%), with occasional positive reactions (7%).

These patterns of identity negotiation were supported by Britany's own reflections. During the reflective activities, she described herself as different, creative, and smart and made it a point to explain that she "wasn't like anybody else." She told us that her teachers would

describe her as smart, loud, and hard-working. Britany also mentioned that she enjoys writing, friends, and family and finds math to be a hard subject. A BGC staff member described Britany as caring and kind but said she could also be defiant and sometimes had difficulty working with others because she wants things done "her way." Perhaps not surprisingly, Britany said she enjoyed the activities but found the group work challenging.

Ariel identity negotiation. In contrast to Britany, Ariel was less talkative during the activities, although she could be more vocal in groups that she seemed to feel comfortable with. She was the oldest child in her family and appeared to be very close to her siblings, two of whom also participated in the program. Ariel seemed very caring and always made sure her siblings were doing well and felt included in the activities. At the time of the study, she was 11 and, similar to Britany, one of the oldest participants. Ariel and her siblings spoke both Spanish and English during the program.

Ariel attended and participated in four out of the six sessions and one of the two OMSI visits. She was highly engaged throughout but often did not participate as vocally in the group discussions compared to others. Many times, when educators and engineers posed questions to the group, she would quickly raise and then lower her hand as if she had changed her mind or felt embarrassed. She did not seem interested in competing for attention with other kids. If she answered questions or made comments, she would do it in a softer voice that sometimes made it hard for others to hear her. Even so, she almost always seemed to be thinking deeply about the discussion, and if somebody said something that appeared to resonate with her, she would nod in agreement.

In smaller groups, Ariel was a relatively quiet but still hands-on participant who seemed motivated to complete the engineering challenges. With her two siblings, she was more verbal

and took more of a leadership role, often obtaining affirmation from her siblings. In these cases, she continuously tried to help them with their designs, make them feel included, and provide support, especially for her younger sister, Priscilla.

Table 5. *Example of Ariel identity negotiation at the zip line activity.*

Line no.	Conversation	Behavior
1	Facilitator #1: This is going to be your pretend person.	Handing the group a small ball to represent the person that needs to be carried safely down the zip line.
2	Priscilla: Ahhhh!	Looking surprised as the facilitator explains the challenge.
3	Facilitator #1: Can you put your person in there and make sure that the person doesn't fall out?	Priscilla grabs the zip line and carefully hands it to Ariel with the ball inside.
4	Jaime: That's a challenge, a real hard challenge.	
5	Facilitator #2: How did you make it? How did you guys make it go so fast?	Asking about the design they had tested before the additional challenge of adding the person.
6	Jaime: Well you see that…	Looking at Ariel to speak.
7	Ariel: We put these two straws and poked it with a paper clip to use a little heavy metal, heavy equipment and then…	
8	Facilitator #2: What does the weight do?	
9	Priscilla: It pushes itself hard.	
10	Ariel: It pushes the...	
11	Jaime: Makes it overweight.	
12	Facilitator #2: It weighs it as it goes down, is that what it is? That's cool.	
13	Facilitator #1: Great! Let's try it.	Encouraging the group to try the design with the pretend person inside.
14	Facilitator #2: Are you guys working on something else? Your own method?	Referring to other materials and designs on the table. Ariel's design falls from the zip line and the group groans.

15	Facilitator #1: Try it again!	
16	Priscilla: It needs to bend more.	Providing a suggestion on how the zip line should attach to the line.
17	Jaime: The person dies!	
18	Priscilla: Put two of them (paperclips) together. There are more pennies!	
19	Jaime: We can try more pennies or [inaudible].	
20	Ariel: Why don't we use all of the little metal things and then…	Trying to add more weight to the zip line.
21	Facilitator #2: Does it slide yet? Have you tried it?	Asking Priscilla about a design she has been working on separate from the one they are working with in the group.
22	Priscilla: No	
23	Facilitator #2: Putting more weight, huh?	Asking Ariel about her strategy.
24	Jaime: We could try putting more; here are some new ones…	While Jaime talks, Priscilla tries her design and it doesn't go all the way to the end. It is stuck in the middle.
25	Ariel: I have a good idea for that one but let's try this one first.	Ariel tries the design they have been working on and it reaches the end. The group cheers.

Table 5 shows an example of Ariel negotiating her identity relative to the engineering activity during an interaction at the zip line challenge. At this point in the video, Ariel, Jaime, and Priscilla were working together on a zip line basket. Ariel had taken the lead on a design, while Jaime and Priscilla worked separately. As Ariel tested her creation, two facilitators approached and gave her a new challenge.

From the beginning of the interaction, Ariel was positioned positively by the others, even as they worked relatively independently. Approaching the group, the adult facilitators began asking questions (critical moment) to help them think about the new challenge (lines 1-5). Jaime began to respond but then positioned his older sister as knowledgeable by looking to her for the

answer (lines 6-7). The whole group then made a series of identity bids, quickly responding together as the facilitator asked more about how the weight influenced the basket design and performance (lines 8-12). Another critical moment occurred as their design failed (line 14), but the facilitators and youth responded quickly with new ideas, suggesting an emergent activity frame of engineering as a positive part of the design process (lines 15-20). There also emerged an underlying frame of the experience as collaborative, with participants sharing ideas (e.g., lines 18-20), using "we" instead of "I" (e.g., lines 19-20, 24), and celebrating each other's success (line 25). As the group worked on various designs, Ariel made an identity bid with her idea for an improved basket, which was supported as Jaime and Priscilla celebrated her success (line 25). Afterwards, the group continued working on Priscilla's design, with Ariel providing new ideas and suggestions.

Although she played a strong role in this interaction, in general Ariel had fewer clear identity bids per session than other focal youth, including Britany, likely because in large group discussions she was quiet and during small group activities she often worked by herself and hardly spoke. Her intense concentration on her work and lack of interaction with others provided fewer explicit identity negotiation opportunities. However, as mentioned, there were several situations when she acted more like a leader and had more easily identifiable identity moments. In majority of Ariel's identity bids, she expressed or claimed knowledge and success (e.g., "We can use this" and "I have a good idea"). Her identity negotiation was also highlighted by her in-depth and thorough explanations of her designs and the ideas and suggestions she offered for completing the challenges.

Ariel was more reserved during adult facilitation critical moments and had very few visible identity bids related to peer and adult acknowledgement. In fact, in only one case did she

try to explain her accomplishments to an adult, prompted by an educator asking the group what they had done (Table 4). She tried to respond but was interrupted by Britany, who proceeded to highlight her own success (lines 15-16). After this exchange, Ariel continued working in silence. Similarly, she had fewer identity bids involving suggestions, ideas, or critiques to other participants.

Ariel's response to failure was also distinct. Her most common reaction was to remain focused and continue improving her design. For example, in the Surgery activity, while working in a group with Britany and Jaime, Ariel focused on one station, working quietly to build a tool that could remove an "obstruction" (penny) from a dog's stomach. She iteratively built and tested four different designs, explaining them to an adult facilitator but failing to remove the penny. When the session came to an end, Ariel continued to work for a few minutes while the adult facilitator told her she had some great ideas and encouraged her to continue refining her designs at home.

It was not uncommon for Ariel to have more expressed failure moments than successes, yet she did not seem fazed by failure, as highlighted in the example above and shown in Table 5. On the other hand, when she did find success, she seemed more confident, and in one case it seemed to encourage her to talk more to others and share her designs. Ariel was coded for nine visible failure moments and none of these were self-attributed. She also had a very low proportion of visible frustration reactions (2 out of 9), and she was never coded as switching her focus after a failure moment or having a non-constructive reaction to failure.

Aligned with her distinct patterns of identity negotiation, the activity frames suggested by Ariel's comments and actions differed markedly from those communicated by Britany. Because she was relatively quiet, focused on her designs, and often worked independently, Ariel appeared

to assert less influence on how the framing of the activities and situations were negotiated during the program sessions. However, in some instances her talk and actions supported an understanding of the engineering activities as collaborative, including helping and motivating others, praising their success, and working together to solve the challenges (see Table 5). She would often smile or softly congratulate her peers when they created a successful design. Unlike Britany, we never observed Ariel acting in ways that implied that the activities were competitive. In fact, she seemed embarrassed when adults attempted to praise her contributions.

Looking across the sessions, the results of Ariel's identity negotiation appeared to be more mixed compared to Britany's experience. For the most part, adults and peers had neutral or no reaction to Ariel's identity bids (32 of 53 for adult reactions, 39 of 53 for peer reactions). However, there were a fairly large number of instances of positive reactions (15 of 53 for adults, 18 of 53 for peers).[7] These included times when other youth praised Ariel for solving the design challenge (e.g., "Ariel, you are so smart!" and "Ariel how did you get so smart?"). Adults also occasionally positioned Ariel in a supportive manner. In one particular session, the educator highlighted how Ariel had come up with great ideas and surely would have been able to solve the challenge if there had been more time.

Although Ariel was often positioned positively, she had several key instances of unsupportive positioning by both adults and peers (two instances of each). This is in contrast to Britany, who had no instances of unsupportive positioning. In the example in Table 4 above, during the critical adult facilitation moment when an educator asked about the group's progress, Britany quickly talked over Ariel's attempt to describe her contributions. Subsequently, the educator praised Britany and, unintentionally, positioned Ariel as a more marginal member of

the team. Again, Ariel did not try to respond, but instead returned to working quietly on the design challenge by herself.

Like Britany, Ariel had an opportunity to reflect on her time during the DOW program and to provide information about herself. Similar to our observations, she talked about herself as a helper, quiet and shy, and said her teacher would describe her the same way. Ariel indicated that she likes supporting her family, especially helping around the house, cooking, and cleaning, and that she enjoys art and writing. Similarly, BGC staff members described Ariel as a helper, caring, giving, quiet, and smart. They mentioned that she has a couple of friends to whom she is extremely loyal, rarely ventures out to make new friends, and can become worn out when the club is too busy.

Other Focal Youth

The examples of Brittany and Ariel exemplify many of the patterns we observed for the other focal youth included in our analysis. For example, like Britany, Raven also frequently worked independently on the design challenges and rarely communicated an expectation that the activities were collaborative. However, Raven was less forceful in her positioning of herself as the "best and most successful" in the group. Perhaps because of what appeared to be her quirky and independent nature (e.g., drawing fantasy characters, working by herself, seeming to reject gender norms), she was more likely to receive negative reactions from peers to her identity bids and was more frequently positioned negatively by other youth. On the other hand, Jaime was much more similar to his sister Ariel and frequently aligned his actions with an emergent collaborative activity frame, praising other youth and willingly following the lead of his peers. Interestingly, Jaime was one of the only participants who seemed to be successful at

collaborating with Britany, allowing her to take the lead. However, as with Ariel, this also meant that on several occasions Britany was positioned as a leader and most knowledgeable in the group, even when Jaime had been integral to solving the design challenge.

Discussion

This work is part of an ongoing research agenda to understand how youth negotiate engineering- and STEM-related identities in specific contexts and how these processes contribute to identity development over time. In this study, we developed a descriptive framework for understanding identity negotiation during an informal engineering program. Our goals were to bring a situated identity lens to the engineering education field, which to date has primarily used more static identity perspectives, and contribute to the gap in the literature on STEM identity negotiation outside of school. We also tested new approaches to understanding the complexities of identity negotiation by accounting for the agency-structure dialect and coordinating micro-analyses of specific moments with the exploration of identity negotiation patterns over time.

Through the in-depth, qualitative analysis of five youth participating in the DOW programming, we developed a general *Identity-Frame Model* highlighting five facets of situated identity negotiation: youth performance and definition work, peer and adult recognition and positioning, emergent situated identities and activity frames, and critical identity moments. Within this framework, we defined categories of identity bids, activity frames, and critical moments that appeared to be important within the context of the engineering activities. In addition to youth positioning themselves as knowledgeable and competent, the model describes two identity negotiation continuums: (a) focusing on individual versus group success and (b) negotiating oneself as confident and resilient in the face of failure versus unsure and

discouraged. These were closely linked to two continuums of emergent activity frames that appeared to afford and constrain youth identity negotiation: (a) activities as individual and competitive versus collaborative and supportive and (b) failure as a negative versus positive aspect of the engineering challenges. Our analysis suggested that indicators of these identities and frames were particularly visible and salient during specific critical moments, such as activity failure and success, adult facilitation, and peer conflict.

This preliminary framework provides a foundation for further research on situated engineering identity negotiation, especially in out-of-school contexts. Currently the vast majority of research on engineering identity adopts a relatively static perspective and, consequently, focuses more on distal factors, such as attitudes and cultural stereotypes. Extending the work of Carlone and colleagues (2007), this study provides a conceptual map for investigating how engineering identity is negotiated and constructed in particular moments, through interactions with peers, adults, and engineering activities. It also sheds light on patterns of identity negotiation that have implications for program design and adult facilitation. For an example, the DOW project team used the model to develop a facilitator reflection tool that encourages educators to notice identity negotiation dynamics within their programs and explore strategies for guiding how activities are framed and the opportunities youth have to build engineering-related identities.[8]

The *Identity-Frame Model* described in this article is well aligned with existing theories. For example, descriptions of mediated discourse highlight how identity is formed and negotiated within specific contexts, how emergent and conventional expectations related to the goals and meanings within these contexts afford and constrain identity negotiation, and how particular situations can make the process of identity negotiation more salient (Norris & Jones, 2005;

Pattison & Dierking, 2013; Scollon, 1998). The contribution of this study, therefore, is not in the development of these ideas but rather making them concrete in the context of informal engineering learning experiences, describing and understanding how the abstract processes play out in the interactions of youth and adults, and identifying types of identities, activity frames, and critical moments that may be of particular relevance to engineering.

Although the concept of activity frames has rarely been used in the study of informal STEM learning, it provides an excellent tool for navigating the agency-structure dialect of identity research, since activity frames are created in specific interactions but draw their meaning and significance from larger cultural understandings (Penuel & Wertsch, 1995). Researchers studying engineering lessons in elementary classrooms have referred to these processes as "cultural productions," or "meanings produced by groups in everyday practice that reproduces and/or counters historically enduring cultural narratives" (Hegedus et al., 2014), such as notions of a "smart engineer" or "smart student." The current study highlights how these broader, more established cultural norms evolve and are substantiated through the dynamic process of activity frame negotiation during particular moments and in particular settings. Our findings suggest that the negotiation of situated identities and emergent activity frames are closely linked and that particular activity frames, such as the understanding of an engineering activity as competitive and individual, may afford the identity negotiation for some youth while constraining that of others, with potentially long-term implications for the identity negotiation routines that youth adopt and the ways youth come to see themselves relative to engineering.

It is important to note that although we sought to use the concept of activity frames to explore how broader social and cultural structures intersect with and influence situated identity negotiation within specific moments, we do not claim that this theoretical perspective can

capture all aspects of these complex structures. The way that social structures influence activity frames through cultural tools is messy and emergent, and the analysis of activity frames cannot directly identify which structures are being referenced. The advantage of this perspective is that it focuses the research on the point of interaction—when the power of social structures is embodied in the way they influence human interaction. The use of activity frames as a theoretical lens, therefore, represents a compromise between ignoring social structures and making them the sole focus at the expense of micro interactional dynamics.

        We also recognize that categorizing activity frames can be problematic, given that the recognition of these frames is dependent on connecting particular behaviors and talk with different cultural contexts and meaning, which may or may not be shared across participants or between participants and researchers. In our work and in this study, we have looked for reoccurring interaction patterns that suggest social and cultural meanings and seem to have important implications for identity negotiation. We have also tested our interpretations by engaging the perspectives of participants and staff, including program facilitators participating in reflective practice after program sessions. Additionally, we looked to examples of activity frames in prior literature (e.g., Hutchison & Hammer, 2010; Jimenez-Aleixandre et al., 2000; Shim & Kim, 2018). Nonetheless, future research should explore the extent that these frames represent recognizable understandings of different situations for different participants, and how this recognition influences the identity negotiation process.

        We also recognize the inherent challenge of distinguishing and studying the connections between situated identity negotiation and activity frames, since both are inextricably linked. What an individual communicates about himself or herself in a particular situation often carries implications for the implied understandings of that situation (e.g., positioning yourself as a

teacher implies a set of expectations about learning goals, the learning environment, the learners, etc.). Similarly, making bids for a particular activity frame often accompanies claims for the type of identities and roles the individual would like to assume within that frame (e.g., a classroom frame is evoked by someone claiming to be the knowledgeable teacher). In our analysis, we often found that the same youth action or utterance provided evidence for both situated identities and activity frames. As appropriate to a qualitative approach, the analysis of this evidence was inductive, interpretive, and nuanced. However, it remains to be seen whether this distinction between identities and activity frames is possible (or meaningful) in other studies or other contexts.

Despite these challenges, we believe the study makes a critical contribution to the literature by advancing our understanding of identity negotiation outside the context of school, in the growing sphere of informal STEM education. Scholars have long argued that informal STEM learning programs offer important opportunities for supporting youth STEM identities (NRC, 2009, 2015). However, findings from this study suggest that the identity negotiation dynamics of these settings cannot be taken for granted. Even in an informal STEM learning program, we suspect there are patterns of identity negotiation that may propel some youth to continue to build STEM identities and may discourage others, although more research is needed to understand connections between identity negotiation in the moment and long-term identity development processes. Some of these patterns may be similar to those in classroom settings, such as when student roles are positioned narrowly, science is portrayed as "hard" or "not for everyone," or educators do not support youth identity negotiation work (Aschbacher et al., 2009; Shanahan & Nieswandt, 2009).

Other aspects of the informal context may create unique challenges and affordances. In this program, participants spent much of their time in small groups with only occasional adult facilitation. In these situations, we observed that the intermittent moments of adult facilitation appeared to be associated with a greater frequency and intensity of identity and activity frame negotiation among participants. These critical moments, along with the emergent group dynamics, often unintentionally supported the identity negotiation of some youth at the expense of others, thus raising the question of how and when informal STEM educators should provide more structure or support for these types of experiences (see also Pattison et al., 2018).

The study also raises additional questions about the roles that informal STEM educators should play during these activities and how their own identities related to engineering influence the interactions. The educators that facilitated the DOW program had varied backgrounds and different levels of experience with informal education, engineering, and program design. As noted, the program sessions were primarily led and facilitated by one of the two DOW program developers and project co-PIs, both of whom had years of experience working at OMSI and facilitating informal STEM education programs. The facilitation team also included other OMSI educators who supported program implementation and BGC staff engaged in professional development as part of the project. These educators had less experience facilitating informal STEM education and may have just been learning about engineering themselves. Some of the interactions observed during the study feature these individuals, but it is difficult to say how the varied identities and experience levels of the facilitators influenced their engagement with the youth. Using the facilitation reflection tool mentioned above, all of the educators engaged in ongoing reflective practice about understanding and supporting the youth's identity negotiation.

Nevertheless, understanding more about the role that adults play in these contexts and how their own STEM identities impact the participant experience remains a promising area of research.

Implications for Future Research

The strength of qualitative research is to illuminate complex patterns and relationships in naturalistic settings, rather than make definitive claims about causality or directionality (Morgan, 2014). Our descriptive *Identity-Frame Model* provides a set of interrelated hypotheses about the aspects of these interactions that are important for engineering identity negotiation and possible connections among them. More research is needed to tease apart causal connections, although it is likely that many pieces of the model are highly transactional (Sameroff, 2009). Similarly, the model represents only a starting place in the ongoing research effort to understand the factors that influence identity negotiation and how these processes influence long-term engineering identity development.

To begin, we recognize that the processes outlined in the *Identity-Frame Model* occur within, and are influenced by, specific social, physical, personal, and historical contexts—which are themselves shaped by larger social structures. One focus of future research is to better understand these broader contextual factors and how they influence the dynamics described in the model, including through the negotiation of emergent activity frames. In current study, we have observed how patterns of identity negotiation can change based on program design. For example, some participants exhibited very different patterns of identity negotiation during group discussions with guest engineers compared to small-group work. Other factors that we observed include group size and composition, adult facilitation and participants' relationships with specific adults, and the design constraints and affordances of the activities and materials.

Sibling relationships also clearly played a role in the types of interactions that we observed, since three of the focal participants (Ariel, Jaime, and Priscilla) were from the same family. Because the goal of this study was to develop a framework for understanding identity negotiation in the context of an informal engineering education experience, rather than make general claims about the specific types of the interactions that we observed, we do not believe this undermines the utility of the findings or model. Undoubtedly, the prior relationships and interactions of these three siblings mattered. Nevertheless, we believe the fundamental importance and connection between situated identities and activity frames applies to other youth with different types of relationships, as we observed with Brittany and Raven. Future research can help test the extent to which the model transfers to different groups of youth (e.g., Pattison et al., 2018), especially during programs designed to include siblings and other family members.

Similarly, our study was situated within a unique program context where the majority of students are from low-income families and traditionally underserved racial and ethnic communities. Perhaps because of this, race and ethnicity did not emerge explicitly as themes in our data, even though scholars have highlighted the importance of these factors in shaping identity (e.g., Brown, 2006; Sayman, 2013). We also did not see gender emerge as a theme, likely because the program was designed for and primarily engaged girls. Nevertheless, we believe these factors play a critical role in identity negotiation and remain important focus areas for future research. As discussed by Tan and colleagues (Tan et al., 2013), individuals inhabit multiple worlds and are involved in diverse communities, usually bringing a repertoire of identities that are influenced by context and complex social structures. Awareness of inequities within STEM education motivated the DOW project and the research team to select this context for the study and to purposely implement culturally responsive and inclusive researcher

practices, helping to ensure the findings reflected the experiences and perspectives of diverse participants. The results provide insights that educators and developers can use for programs like DOW to support STEM identity negotiation for diverse youth.

This study also sets the stage to identify the situated identity negotiation dynamics that are similar and unique across different STEM learning contexts and content domains. Currently, we cannot be sure if the engineering-specific aspects of the model in this study are indeed unique to this topic domain or are relevant more generally to STEM. There may be different implications for youth identity negotiation based on fundamental distinctions between the STEM domains and the types of educational activities that are associated with each. For example, while science is primarily focused on building knowledge about the natural and social world, engineering involves using this knowledge to design solutions and address specific human needs (NAE & NRC, 2009). In an education context, both science and engineering topics may incorporate hands-on experiences, but engineering is more likely to involve the creation of a design or object to achieve a specific purpose, while the science activity is more likely to focus on the exploration and understanding of a phenomenon or topic (NGSS Lead States, 2013). We suspect, therefore, that critical moments, activity frames, and identity negotiation patterns related to failure will be particularly salient in an engineering education context. On the other hand, science learning experiences may motivate more identity negotiation related to knowledge and expertise (e.g., Fields & Enyedy, 2013; Kane, 2015; Shim & Kim, 2018). Across both domains, other aspects of identity negotiation dynamics may be similar, since adults and youth participants often draw from the broader lexicon of school-related identities and activity frames (Hutchison & Hammer, 2010; Jimenez-Aleixandre et al., 2000).

Martin (2015) identified "failure-positive" perspectives (e.g., celebrating failure as part of

the creative process and recognizing the importance of "getting stuck and unstuck"), also

referred to as "productive failure" (Litts et al., 2016), as critical to making, design, and

engineering (See also Weiner et al., 2018). Martin (2015) also highlighted collaboration and

sharing as critical to engineering and design and contrasted this with the "typically competitive

and replicative nature of classroom learning, where the (sometimes tacit) goal is to acquire a set

of pre-existing knowledge, and to do so more effectively than one's classmates" (p. 36). Some

researchers have argued that informal engineering and making activities can help disrupt the idea

of a single "right" answer by encouraging opportunities to develop multiple solutions and

consider the tradeoffs among different designs (Kafai et al., 2014). However, this study suggests

that certain emergent activity frames can prevent this type of exploration and, in turn, undermine

collaborative-oriented identity negotiation patterns that might support youth in coming to see

themselves as people who engage in engineering or see engineering as part of their future.

Creating space for failure and iteration may be particularly challenging for youth from

marginalized communities who "attend schools in which missteps of any kind are likely not to be

tolerated" (Bevan et al., 2017, p. 2). Thus, it is important for researchers to explore how the

dynamics of identity negotiation shape engagement that is more or less aligned with the

characteristics of engineering and design thinking that will help youth succeed in school, life,

and work (Crismond & Adams, 2012).

Another area of additional research will be to continue to explore the concept of critical

moments, both as an analytic tool as well as a theoretical concept. In our study, the idea of

critical moments emerged both from the literature and from our qualitative exploration of when

and how youth and adults negotiated situated identities and activity frames. For our analysis, we

defined these moments as reoccurring situations that appeared to be associated with a greater frequency and intensity of identity and activity frame negotiation among participants. By identifying critical moments related to the engineering activities, we were able to focus on segments within the sessions when identity and frame negotiation might be more visible and to identity other similar segments for additional in-depth analysis. However, we acknowledge that the identification of these moments is inherently limited by what we as researchers can see and hear. It may be that identity and frame negotiation is more ongoing but is often less visible because it is not directly connected to spoken utterances or explicit actions. Future research can investigate how the critical moments identified in this study transfer to other settings and how representative they are of the less explicit (e.g., non-verbal) identity and framing work that is happening within a particular interaction.

Finally, this research leaves open the question of how these dynamics shape the long-term identity development of these youth beyond several months. Although our approach allowed us to compare and contrast situated identity negotiation patterns within and across program sessions, the study followed participants over a relatively short period of time, and we can only speculate on the implications for the long-term identity trajectories of the youth or the impact on participants' perceptions about who they are and who they can be. A growing number of studies point to STEM identity as a key factor in shaping how youth engage with STEM throughout their lives and their evolving perception of their own interests, abilities, and aspirations. Researchers broadly agree that proximal processes, or the interactions of individuals with their social and physical environment, are the drivers of learning and development (Bronfenbrenner, 1979; NRC, 2000). However, we are just beginning to connect the moment-by-moment processes of situated identity negotiation to the broader timelines of identity

development. By understanding these dynamics, accounting for both agency and structure, and coordinating analysis of specifics moments with broader patterns over time, we can help educators create learning experiences that support positive STEM identity negotiation for youth and ultimately set the stage for life-long STEM learning and engagement.

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Notes

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[1] This discussion reflects the long-standing exploration in the social sciences about the intersection of these two forces, such as work in activity theory and mediated discourse that theorizes how cultural structures afford and constrain how individual accomplish goals and negotiate their identities during specific interactions (Norris & Jones, 2005; Penuel & Wertsch, 1995; Wertsch, 1998).

[2] All participant names used in this report are pseudonyms.

[3] Unfortunately, after repeated attempts in collaboration with BGC staff, only the parents of one focal youth completed the interview.

[4] The coding frequencies and counts presented in this section are not meant to imply generalizability or overstate the precision of the qualitative analyses, but rather to make transparent the coding results that informed our interpretations (Morgan, 1993).

[5] In some cases, multiple types of responses were evident for one failure moment. Therefore, code frequencies could total to greater than one.

[6] Aligned with our situated perspective on identity and activity frames, we acknowledge that these descriptions often oversimplify the dynamics of situated identity negotiation during the programs. As noted, situated identities and activity frames are constantly in flux, meaning that multiple frames and identities may interrelate and be at play at once, making it unlikely that a single identity or frame will be completely static or coherent in any given moment.

[7] Like failure moments, the frequency of codes for reactions to identity bides could add up to more or less than one because of multiple types of reactions per bid or, in a few cases, because the reactions were unclear or ambiguous.

[8] https://www.informalscience.org/stem-identity-reflective-tool-educators