

Empowering Under-Represented Middle School Youth in Engineering Knowledge and Productive Identity Work

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Abstract: Drawing from critical sociocultural perspectives, we report on how urban middle school youth from non-dominant backgrounds engage in productive identity work in engineering in an after-school program, as well as the relationship between identity work and their participation and learning in engineering design. Longitudinal, ethnographic data of 14 youth were analyzed with our conceptual framework using constant comparative analysis. Findings indicate different pathways taken by youth. Data also revealed the iterative and on-going movement between a) investigating and b) communicating with and taking action in the community supports powerful learning in conjunction with productive identity work in engineering. The process of figuring out what and how to communicate to others about one's investigation in scientifically rigorous and culturally resonant ways, and in accounting for multiple outside perspectives, is pivotal to both *learning* and *identity development*.

Objectives

Studies reveal that student success in school science is not well correlated with the pursuit of engineering trajectories. Even when students are successful in learning science, many still see the subject as uninteresting and disconnected from their lives and pursuits. Identity gaps continue for students from non-dominant backgrounds. Long-term studies in engineering indicate that identity development is critical to how and why individuals pursue engineering trajectories (Eccles 2007). If one does not see oneself as scientific, or as a member of the engineering communities, this can negatively impact opportunities to learn (NRC, 2012).

Our research has shown that interest in science and engineering through the middle grades is sustained by opportunities to *be an expert in practice in community* and to be recognized by others as having relevant expertise (Tan, Calabrese Barton, Kang, & O'Neill, 2013). These opportunities to be such an *expert* supports the authoring of productive identities. We have learned that when youth positioned themselves as community science experts – or someone with knowledge of science and community needs and how to leverage that knowledge towards taking action – their learning gains were stronger and they more positively identified with science (Calabrese Barton & Tan, 2010). However, we do not have evidence for how to scaffold this kind of identity work as a part of the process of conducting community-based investigations.

Research Questions

Our research focuses on how and why youth construct identities in engineering in ways that bridge community expertise with engineering expertise: 1) In what ways do urban middle school youth from non-dominant backgrounds engage in identity work in engineering through participation in an after-school engineering program? 2) What ideas, resources, and identities youth move across spaces (investigation, action in the community), and how this movement matters in identity work and engagement in engineering? And 3) what is the relationship between identity work and their participation and learning in engineering design?

Theoretical Framework

Our study is grounded in social practice theories, which suggest that identities reflect one's on-going social existence in the world. As individuals move through the world, they are exposed to, positioned by, and react to a range of people as well as institutional and cultural structures and forces. As individuals join new communities of practice, they call upon salient practices and ways of being that are learned from other places, creating new hybrid practices that can position one as either central or marginal to their new community. Such acts of identity work are complex, for how one is recognized within new communities is an artifact of the power dynamics that operate there (Nasir, 2011) and which reflect the cultural norms of "local practice" and "historically institutionalized struggles" (Holland & Lave, 2009).

We use the phrase *identity work* to capture the idea that authoring oneself in engineering or in any domain involves an on-going effort, and positions the author with agency. It is through the actions people take and the relationships they form that they position themselves as particular kinds of people over time and space. Because identity work happens within and against local norms and expectations and as a part of longer standing sociocultural and historical narratives, its outcomes are always uncertain and gain new meaning as they get traced in time. The practices of the engineering learning community or the peer culture as informed by dominant

norms and routines position youth in particular ways and they react to those positionings. This identity work brings together “two forms of history” – the personal and the institutional – and as Holland and Lave argue, what emerges is a sort of “local contentious practice” grounded in “cultural-historical conjuncture” (p 13).

In our paper we discuss “productive identity work”, which references movement towards seeing oneself as an important producer and critic of engineering. We argue that productive identity work in engineering reflects 1) one’s developing *knowledge and practice* within a community of practice, and an ability to gain membership through knowledge and practice; 2) an ability to navigate the dialectic between *structure and agency* (Do students see themselves as someone who is capable, and can leverage an array of resources to gain understanding and take action?) and 3) *recognition/positioning* by others (Is one accepted by others as the person they desire to be and with the salient expertise?). This last point is salient for youth who experience a disjuncture between their home worlds and the world of engineering.

Research Methods

To build generalized claims about the youths’ identity work we employed longitudinal multi-sited ethnography case study, paying particular attention to the power dynamics involved. Multi-sited ethnography involves the study of learners across contexts, and inquires into the ways that “people, ideas, tools, artifacts and questions, move and become reconstituted across the boundaries of school, home, and community spaces *and* across multiple contexts and environments” (Vossoughi & Gutierrez, in press, p. 5). This approach requires the collection of multiple forms of data using different strategies such that the corpus of data results in complementary strengths and non-overlapping weaknesses, which is useful in expanding understanding and informing theory and practice. The longitudinal component maximizes opportunities to refine theory related to how decisions developed overtime by assuring a steady stream of data at different time points in the process.

Context

The study takes place primarily at the Boys and Girls Club of Great Lakes City, MI, a mid-sized midwestern city. The Club has served the community for 50 years, and welcomes over 2,400 youth annually between the ages of 7-17 from low income backgrounds. The club provides a safe place for youth to engage in many activities allowing opportunities to play, learn and have fun. One of the programs offered to members of the club is an informal science learning program, “Green Club.”

Green Club meets for 3 hours each week during the school year and 2 full weeks during the summer. The program has been designed on the premise that meaningful learning happens when youth engage in authentic investigations with scaffolded opportunities to communicate the findings of those investigations to others. It does so by providing a year-round after-school program that emphasizes youth development into science and engineering *experts* and *citizens* by using technology to take on relevant green energy issues and communicate findings to their community. An explicit goal of Green Club is to support youth in becoming community science and engineering experts – or youth who are uniquely positioned to draw upon their expansive knowledge of community and science/engineering to engage in meaningful, local practice.

For example, during the 2011-2012 school years, one of the two main years in which this study took place, Green Club youth investigated the design question of whether the Green Club could “get off the power grid.” Students engaged in activities investigating the electrical production system and its alternatives, with a particular focus on energy transformations in these various pathways and the feasibility of implementing one or more of these approaches into the current Club. Youth also studied the impact of these different transformation pathways on the local environment and economy. The youth designed a system where they generated the electricity for the lighting and mobile computer lab by riding bicycles attached to a generator and battery, and conservation techniques to accommodate the difficulty of producing all of their own electricity. They developed a plan to involve as many youth from outside Green Club in riding the bicycle during the club’s open hours, although instituting this broad participation proved a barrier. Youth recommendations for modifying their system included adding parallel bicycles to allow greater production during shorter time windows, and designing a solar system or wind system.

Participants

The target audience for Green Club are Great Lakes City area youth from underrepresented backgrounds. Child poverty in Great Lakes City has increased over 40% since 2000. 27% of Great Lakes City children live below the poverty line, with the rate jumping to over 40% for youth from African American backgrounds. Green Club strives to recruit a variety of youth with a range of skills and interests. Youth who have not performed well in school or in school science, or who are not interested in science or engineering, are encouraged to participate in Green Club. Within the program, youth are encouraged to leverage the various forms of expertise and interests they bring to studying energy and their environment by incorporating and valuing art, technology, and community concerns. The data presented in this paper is focused on the 14 youth participants from the 2011-2012 school year. However, most youth participate in Green Club for 2 to 3 years,

allowing us to draw upon multiple years of data. For 8 of the 14 youth, we draw upon 2 or more years of data. All of the youth were between ages ten and 13. Seven of the eight case study youth are African American and seven of the eight are also female (one African American boy, and one white female). The youth were in 5th, 6th or 7th grade dispersed in several local schools during the school year.

Data Generation

The findings of this paper are based on data collected from multiple sources during the 2010-2011 and 2011-2012 school years and included: 1) *Collaborative Conversations*. A researcher met with 6-8 youth weekly to debrief and develop a stronger sense of what they cared about with respect to green energy in their community. These conversations were held for fifteen weeks each year lasting between 60-90 minutes. 2) *Interviews*. Interviews were conducted with all participating youth. Interviews focused on the artifacts generated during the Green Club units and youth and researcher identified key moments, their role in creating these artifacts/moments, and the role these artifacts played in making change in their community. 3) *Transcripts of Green Club sessions*. Each week, Green Club was video and audio recorded and sessions were transcribed. Green Club held 20 regular sessions each year between October and April that lasted approximately 90 minutes each. We turned to these videos to situate and to make sense of students developing understandings and decisions. 4) *Student work*. We collected the artifacts youth generated as they investigated various green energy issues primarily from the “Getting off the Grid” unit (i.e., movies and raps about green energy and climate change, posters on alternative energy, PowerPoints and web pages, blog posts, and key data representations used in support of these, such as tables, graphs, and maps).

Data Analysis

We developed portraits of each case study youth that included background information, stories about current and future self(s), family, and science, participation over time in Green Club, and participation in Green Club work outside of Green Club. We focused on several focal events where the youth actively appropriated resources and positioned themselves in ways that supported engagement in engineering. The identified focal events were the ones that stood out retrospectively because of how they were referenced in future activities over time or how they appeared to reflect a shift in a youth’s perception of self and/or how others perceived them. We wrote descriptions of focal events, and analyzed the events using our figured worlds framework, including noting the (a) rules and norms, (b) tools and resources, (c) practices, (d) division of labor, and (e) object of work. Descriptions were shared at weekly meetings and debated until consensus was reached on the interpretation of descriptions and the emergent claims. We then analyzed the roles the youth played in each of the events, the ways in which the youth drew upon resources, and the produced identity artifacts. We paid attention to both resources and identity artifacts mediated the youth’s engagement in the activities, and the meanings produced about youth’s self(s) in engineering. These “role, resources, and identity artifact maps” were then shared at group meetings over the course of three months for further group analysis, discussion and debate.

Findings

We present two main findings. First, the youth in our study all engaged in forms of practice that positioned them as community engineering experts – as youth who are expert in engineering design and in the needs of their community, and uniquely positioned to leverage both towards taking action. However, how and why youth did so looked different across the youth, and had implications for how they positioned themselves as experts. Below we describe three pathways that frame their identity work in engineering along these lines:

Horizontal Movement as Critical Expertise

The six youth, whose identity work we would categorize in this way, privilege their horizontal expertise in engaging in engineering design (e.g., expertise gained in home and community, such as their funds of knowledge), and they leverage it towards advancing their opportunities to gain access and status within the engineering design process. Consider Quentin who writes a letter to his teacher explaining that he is not the C or D science student that he is viewed of in science class. He is really an A or B student who does “things out of school and out of Get City that involve science. I went to door to door and ask adults if they use CFL lights. The majority of the adults did NOT use CFL lights, I will try to decrease the amount of people who use incandescent lights. I did it on Wain Wright Ave and I did it because people’s bills are up because they use just Incandescent lights.” From this perspective, the work youth do to become expert in engineering, involves re-inventing that practice in ways that frame their cultural knowledge and expertise as critical to doing engineering.

Humanizing Engineering

For the five youth whose identity work falls into this category, we mean more than emphasizing the human elements of the practice. Rather we draw from critically oriented sociocultural studies which frame humanizing as relationships of dignity and care for both researchers and participants.” (Paris, 2011, p. 137).

While not applied to engineering practices or identity work (such ideals have been applied primarily to research and how participants are constructed & positioned through the process) we believe that this captures how youth frame their engagement with engineering – what they know and care about, what they do, how they view themselves, and want to be recognized by others. As Vossoughi & Gutierrez write, (2014), “actively cultivating new forms of perception can open up new ways of imagining and organizing environments for transformative and consequential forms of learning—a fundamental premise of our work on social design experiments” (p. 13). We present a discussion of the case of Hannah later to portray this pathway.

Distributed and Snowballing Expertise

This pathway, which helps to explain the identity work of three of the youth in our study, involve youth who iteratively play with ideas and designs as an important component of their engineering knowledge. This playfulness of ideas is accompanied by the on-going need to involve others and their relevant expertise. A critical piece of this is drawing upon their influence to recruit new insights, ideas, and participants from across communities to make their design work successful and accepted across their many communities of participation.

Our second finding focuses on the relationship between productive identity work and the design of the learning environment. Our data revealed the iterative and on-going movement between a) investigating and b) communicating with and taking action in the community supports learning in conjunction with productive identity work in engineering. The process of figuring out what and how to communicate to others about one’s investigation in scientifically rigorous and culturally resonant ways, and in accounting for multiple outside perspectives, is pivotal to both *learning* and *identity development*. The process involves on-going engagement with the design process, the embedded engineering content knowledge, and the needs/concerns of the community or end user. This iterative process approximates the work of engineers as they make on-going design decisions in light of ever-refining understandings of the problem space and design constraints.

We now use the case of Hannah below to illustrate the humanizing pathways and its implications for her identity work. Hannah has been an active participant of Green Club for the past 4 years. She first joined Green club because her friends were participating. Hannah is not deemed a strong student in school, and is on an individualized education program (IEP). Her grades are poor, in the range of Cs and Ds. Hannah articulates a future career as a hair dresser. When she first joined Green club, she did not come with an interest in science or engineering. Her motivation for being part of Green club was to socialize and spend time with friends. Through her Green Club participation, Hannah started to see herself as a “make a difference expert”. Her desires to make a difference in her community caused her to find ways to tackle the hard job of learning science and math.

When asked about her high point or a really significant moment with science and engineering, Hannah chose to talk about bringing what she had learned about energy efficiency and the design of different types of light bulbs to younger students at her school. With a small group of other middle grades girls, Hannah took what they had learned about energy efficient technologies and behaviors from Green Club and adapted the content to teach some younger students at her school. They prepared a Powerpoint and then led the class through an experiment looking at the difference between CFL and incandescent light bulbs. Hannah was to co-teach this class with her friend, a girl who is also a Green club member and who is an academically much stronger student. However, when her co-presenter was suddenly beset with acute stage fright, Hannah stepped up admirably. A typically dead silent girl in science class, Hannah presented the mini-lesson and hands on experiment with aplomb. Hannah points to this episode as a significant moment for her because she showed everyone she can do this kind of work, and she was helping her peers make a difference in their community.

During one Green Club session, Hannah and her friends, in their effort to explain the difference between Green Club science and school science, came up with what they termed “Fcience”: “Fcience \ˈfi-ən(t)s\ - “Fcience is what describes Green Club. It’s science that’s fun. Green Club knows how to make science fun without getting bored. Instead of a bored face, you will have a happy face” (Summer & Hannah). The girls also stated at Green Club, they did “science that matters.” When we asked Hannah to tell some of the other youth at one of the first Green Club sessions of the year, she stated that science that matters is: “Doing things that are good for the community because of what we know. We know a lot of science and we also know a lot about our community. Who else can put these ideas together?”

In a following conversation group where the similarities and differences of Green Club science and school science were again debated, the researcher asked the group (which included Hannah), to elaborate on “Fcience” and how “the science in Green club matters.”

- Jayah: “I think it matters because science in school we just sit there and read a book and that is not doing anything. All we do is sit there and read a book about doing something. And when we do something, it is like an experiment maybe that doesn’t really matter.
- Quentin: “And the teacher does it.”
- Jayah: “Yeah, and the teacher just shows you. Then he said, well you guys are going to get to do this, no – never mind, I can just show you. So all we did was make water drip into a

- bucket through a straw. When we are in Green Club we actually do something. We don't just sit there and read a textbook and watch our teacher drip water through a straw.
- Hannah: Is watching a straw and water drip through it even science? That is not even science.
- Researcher: Anyone else want to disagree or agree with the statement that the science in Green Club matters? So does it matter?
- Kat: It matters to the future.
- Quentin: And if you want to do engineering like Brittany.
- Researcher: Ok, so it is important to the future of the Earth and your own future. Usually when we say something matters we say it matters to someone. So who does this science matter to?
- Hannah: Me.
- Jayah: Our community. They don't know it yet, but our community. Watch, when we save the Earth from all of the disastrous stuff that is going to happen to us, they are going to be like, oh I should have, yeah.

Hannah had consistent opportunities to explore and engage in engineering practices, while also engaging in educative actions, directly applying her new knowledge. That Hannah still wants to be a hair dresser when she grows up is important. We do not see her future career choice as problematic or incompatible with her growing interest and facility with science and engineering knowledge and practices. Hannah views her engineering self as a part of being a good citizen. It is important to her that as a good citizen she has the expertise in some areas of science and engineering that is relevant to everyday life, and that she can use her expertise to make a difference now. In the future, she also wants to use green energy techniques at her hair studio that she will one day own. Hannah thinks that making a difference happens in the little things, but that you have to work hard to figure it out. Even though Hannah does not profess to “love engineering” nor aspire to a STEM career, she has engaged in productive identity work in engineering through her performances as a “make a difference expert” identity. And, this identity has supported her in tackling difficult learning moments.

Significance

In the US, youth from low-income and non-dominant backgrounds express interest in or opt to move into engineering at extremely low rates. For example, African Americans make up only 5% of the engineering workforce, with a majority holding technician rather than managerial or leadership positions. This statistic has changed little despite reform efforts. Our research sheds light on mechanisms that support productive identity work in engineering, how that might be scaffolded, and how such scaffolds can transport across context. We also offer insight into approaches for breaking the cultural barrier to engineering for underrepresented youth.

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