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Keywords

engineering, makerspaces, STEM, computational thinking, rural education, informal education, identity

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Abstract

In this article, we describe efforts to reduce barriers of entry to pre-college engineering in a rural community by training local teens to become maker-mentors and staff a mobile makerspace in their community. Following Nasir and Cooks (2009), we bring a communities of practice frame to our inquiry, focusing on inbound and peripheral learning and identity trajectories as a mechanism for representing the maker-mentor experience (Wenger, 1998). Through a longitudinal case study, we traced the individual trajectories of five maker-mentors over two years. We found a collection of interrelated factors present in those students who maintained inbound trajectories and those who remained on the periphery. Our research suggests that the maker-mentors who facilitated events in the community, taught younger community members about making, and co-facilitated with other maker-mentors were more likely to have inbound trajectories. We offer lessons learned from including a mentorship component in a pre-college maker program, an unusual design feature that afforded more opportunities to create inbound trajectories. A key affordance of the maker-mentor program was that it allowed teens to explore areas of making that were in line with their interests while still being a part of a larger community of practice. Understanding learning and identity trajectories will allow us to continually improve pre-college engineering programming and education opportunities that build on students' funds of knowledge.

Making Makers: Tracing STEM Identity in Rural Communities

In the field-framing essay, “The Promise of the Maker Movement for Education” (2015), Lee Martin sets the stage for connecting making with pre-college engineering and design practices. Connections include shared disciplinary content such as “defining problems” and “designing solutions” as core to engineering work and to making (Martin, 2015) and the development of “computational thinking,” which is central to computer science (Berland, 2016). Making can also promote an increase in creative confidence (Barron & Martin, 2016), self-efficacy and perseverance in problem solving (Peppler & Hall, 2016), resourcefulness (Sheridan & Konopasky, 2016), adaptive expertise (Martin & Dixon, 2013) and creativity (Saorín et al., 2016; Prahalad & Ramaswamy, 2003). Put simply, making is a productive pathway to engineering for pre-college students.

However, the Maker Movement is plagued by the same historical, institutionally racist and sexist practices that have prevented STEM college pipelines from becoming more diverse (e.g. Blikstein & Worsley, 2016; Buechley, 2016; Vossoughi, Hooper, & Escudé, 2016). One way of addressing this persistent challenge is to shift our focus from asking how making can reimagine engineering as more inclusive, to reconceptualizing who counts as a maker, pushing us to focus on what individuals bring to the community as a core part of how making (and therefore engineering) happens.

In this special issue, we join our colleagues in recognizing that engineering as a discipline is not a fixed entity, that is neither pure nor beyond examination (Medin & Bang, 2004). Rather, engineering education should be built upon students’ existing assets. To this end, we take an identity-focused approach that centers the experiences of learners who have historically been marginalized from mainstream schooling practices and reframes “what counts” as good making in terms of what communities and participants contribute to the setting (Peppler, Halverson, & Kafai, 2016). We see an identity-focused approach to designing and understanding making experiences as aligned with the asset-based approach to pre-college engineering education.

We are particularly interested in rural communities as sites for understanding the assets that high school students bring to making practices and maker communities, and whether and how those assets can be successfully leveraged for students to develop trajectories of participation in STEM and Computing (STEM+C). Through Exploring Making Through Emergent Technology (EMMET), we sought to eliminate barriers of entry to engineering-related communities of practice in a rural community in the Midwest by training local teens to become maker-mentors and staff a mobile makerspace. This project was designed both to establish credibility and sustainability for the makerspace in small, rural communities, and to understand whether and how young people who serve as maker-mentors develop robust STEM identities and expertise while participating in a community of practice.

In examining the ways in which we might improve issues of equity and access to STEM+C and engineering practices for high school students from rural communities we asked the following research questions:

- How do maker-mentors take up identity resources while participating in a rural STEM+C program?
- What types of programming and maker activities encourage rural high school students toward becoming full participants in pre-college engineering?

Following Nasir and Cooks (2009), we bring a communities of practice frame to our inquiry, focusing on inbound and peripheral learning and identity trajectories as a mechanism for understanding the maker-mentor experience in the EMMET program (Wenger, 1998). We traced the individual trajectories of five maker-mentors over two years. While EMMET sought for all maker-mentors to become full participants following an inbound trajectory, we found that instead maker-mentors moved along individual trajectories to achieve two levels of membership in the community of practice. Those maker-mentors who maintained an inbound trajectory joined and became full participants; whereas those maker-mentors with peripheral trajectories did not fully integrate into the community of practice (Nasir & Cooks, 2009). These trajectories provide a lens to understand what types of programming and maker activities encourage high school students toward becoming full participants in an engineering-centric community of practice.

Our work describes the maker-mentor trajectory for each of our five case study participants. While there was no distinct path toward inbound and peripheral trajectories, we found a collection of interrelated factors present in those students who maintained inbound trajectories and those who remained on the periphery. Maker-mentors who regularly participated in mentorship training activities, collaborated with their peers on making projects, and co-facilitated events throughout the community were more likely to follow an inbound trajectory whereas those who regularly participated in mentorship trainings, but only participated in one or two of the twelve community events never moved beyond the periphery. Our research suggests that the maker-mentors who facilitated events in the community, taught younger community members about making, and co-facilitated with other maker-mentors were more likely to have inbound trajectories.

We offer lessons learned from including a mentorship component in a pre-college maker program, an unusual design feature that afforded more opportunities to create inbound trajectories. One specific affordance of the program was the capacity for maker-mentors to explore areas of making that were in line with their interests while still being a part of a larger community of practice. Understanding learning and identity trajectories allows us to continually improve pre-college STEM+C programming and education opportunities that build on students' funds of knowledge.

Making as a pathway to STEM and Computing

Making activities have been clearly established as connected to the STEM practices and disciplines that comprise pre-college engineering learning (Martin, 2015; Martin & Dixon, 2016), physical science practices like circuitry (Peppler & Glosson, 2013; Qi, Demir, & Paradiso, 2017), and computer science practices like programming and computational thinking (e.g. Berland, 2016; Shapiro et al., 2016). We are especially interested in computational thinking, as a subset of STEM skills and habits of mind, since EMMET was funded as part of that National Science Foundation STEM+C program, which involved integrating computer science with STEM education and career preparation. Computational thinking involves engaging with computer science concepts to solve problems, design systems, and understand human behavior (Grover & Pea, 2013) and is foundational to preparing learners for careers in creative production, manufacturing, and engineering (Martin, 2015). Specifically, engaging in computational thinking through making has also been shown to build students' self-interest, confidence, and self-efficacy with STEM and computer technology content, skills, and habits of mind (Agency by Design, 2015). As this collection of research demonstrates, including making activities in formal learning contexts provides a direct link to better preparing k-12 students for STEM learning and careers.

Making Has an Equity Problem

While the promise of the Maker Movement is to open up the opportunity for a more diverse population of students to participate in STEM activities, women and people of color continue to be marginalized in making, perpetuating a one dimensional notion of what it means to be a maker (e.g. Kafai, Fields, & Searle, 2014; Martin, et al., 2018; Vossoughi, et al., 2016; Ryoo & Barton, 2018). While the face of making has shifted as scholars introduce new forms of making including e-textiles (Kafai et al., 2014), toy and game design (Holbert, 2016; McBeath, Duran, & Harlow, 2017) and traditional, cultural forms of making such as weaving (Vossoughi et al., 2016), making is often placed in a hierarchy wherein traditional STEM and computing activities are seen as more valuable than others exacerbating equity issues historically associated with STEM+C (Buechley, 2016).

So how can we realize the promise of the Maker Movement to make STEM+C knowledge, skills, and pipelines more accessible when making seems to reify the very divisions that have kept women, communities of color, and low performing students out (Lacy, 2016)?

Makerspaces can be more inclusive when they "are responsive to students' diverse and culturally relevant skills, knowledge, and interests" (Martin *et al*., 2018, p. 37) and recognize and support a multitude of makers and practices (Vossoughi, Escudé, Kong & Hooper, 2013; Buchholz, Shively, Peppler, & Wohlwend, 2014; Kafai, Fields, & Searle, 2014; Peppler, 2016; Barajas-López & Bang, 2018). It is through the lens of *makers as identities of participation*—and not *making as a set of activities*—and *makerspaces as communities of practice* that we try to understand the experiences of young people in EMMET.

Making with Rural Communities: An Argument for Equity and Access

Our project focuses on the development of a makerspace community in the rural Midwest. We recognize rural settings "not only to characteristics related to an area's demographics and geography but also to a culturally defined marker of identity constructed relationally and socially beyond geographic location” (Coggins, 2017, 666-667). This definition recognizes rural settings as a complex, relational construct with different "ruralities" related to local geography and culture (Coggins, 2017).

Little research has explored the role of STEM and engineering education in rural communities, despite the fact that 11.4 million children in the United States grow up in rural communities and one-third of American public schools are rural (Strange, Johnson, Showalter, & Klein, 2012; Williams, 2010). Recent studies have shown that rural students are increasingly likely to attend college (Byun, Meece, & Irvin, 2010; Meece et al., 2013), yet are also less likely to graduate from those programs (Peterson, Bornemann, Lydon & West, 2015).

Many rural communities are rethinking how they can both support their local economy and simultaneously provide more opportunities for young people. In rural regions in particular, many manufacturing companies are desperate for engineers and skilled employees who are STEM literate. Recruiting qualified personnel is challenging, and rural communities are experiencing pressure to “grow their own” STEM workforces. In the rural, Midwestern community where our research took place, a survey conducted with six local major employers who hire software developer-related occupations revealed that requiring candidates to have degrees in a computer-related field leads to difficulty finding qualified candidates. At the same time, area high schools struggle to get students to think of themselves as potential members of the technical, computational, or manufacturing workforce (Alcoa Foundation, n.d.; Croff, 2017; Jaschik, 2015). This is in large part because these communities of young people have been marginalized from access to STEM and computational skills beyond the job training available for work on the factory floor. Without some type of intervention, rural students may be less likely to pursue careers in engineering (Elam, Donham, & Solomon, 2012) which can lead to some of the more higher- tech and higher ranking positions in manufacturing companies. This project attempts to disrupt the trajectory from rural high school to factory floor by introducing STEM+C skills through making and mentorship training. It is also a means to bridge the formal/informal education divide in STEM that has marginalized young people from science class and devalued everyday science experiences (Stocklmayer, Rennie, & Gilbert, 2010).

Studying identity trajectories as an Asset-Based Approach

Makerspaces can be understood as communities of practice that are shaped by the trajectories of participation among members over time (Halverson & Sheridan, 2014). Institutionalized makerspaces—such as those found in museums and schools—often constrain possible trajectories of participation based on the available roles, goals, and tools available. What it means to be a "good maker" or a "knowledgeable member" is often pre-defined by the way the makerspace is designed. Community-based makerspaces, however, develop as a result of the funds of knowledge that members of all ages bring to their participation (Sheridan et al., 2014; Sheridan & Konopasky, 2016). Who counts as a maker, what knowledges and skills are leveraged, and how people interact with one another are all part of the collective funds of knowledge that make up the community of practice. These community-based makerspaces are successful in leveraging the rich histories of creating and sharing as ways of life found in many historically marginalized communities (e.g. Ryoo & Barton, 2018; Vossoughi et al., 2016).

Likewise, a funds of knowledge approach is important for rural education (Coggin, 2017). Foundational work framing students' assets as "funds of knowledge" has been transformational in recognizing the contributions of historically marginalized young people across learning environments. Moll et al. (1992) define funds of knowledge as, "the historically accumulated and culturally developed bodies of knowledge and skills essential for household or individual functioning and well-being" (p. 133). The funds of knowledge concept has been used to characterize thriving maker communities and to understand the culture and practice of rural learning communities (Coggin, 2017).

Rural students are rarely taught to view their out of school experiences as a repertoire from which they can draw on in formalized education settings (Morales, 2019). A funds of knowledge approach allows for us to center what young rural students know, rather than what they lack (Avery, 2013). STEM education that allows students to connect content to their everyday lives can enhance student success in science (Avery & Kassam, 2011).

In Nasir & Cooks' (2009) "Becoming a Hurdler: How Learning Settings Afford Identities" they propose that learning settings provide resources for participants to develop practice-linked identities. Identity formation is not necessarily the same for each individual and depends upon how an individual is offered and how they take up *material*, *relational*, and *ideational* resources:

- Material resources refer to the tangible, physical aspects and tools associated with a practice. In makerspaces, 3D printers, arduinos, and hacksaws are salient material resources with which makers have varying dispositions and familiarity.
- Relational resources describe connections between members of the same practice or community, which strengthen the connections with the practice itself. Within a maker space, a maker who specializes in circuitry working alongside a maker specializing in woodworking affords a more robust relationship to making as they can share their expertise and making abilities.

- Ideational resources are the ideas that make up the core features of a practice, as well as the shared culture and identity central to the practice. The goals, strategies, and ways of doing make up the ideational resources that link to the practice-specific identity. In this program, ideational resources involved maker-mentors' attitudes and beliefs about STEM+C for themselves, for their community, and for society as a whole.

These resources provide a framework by which participants' development may be usefully traced, as change etched over time, to delineate learning and identity outcomes. Specifically, material, relational, and ideational resources can be used to characterize rural spaces and the young people who live and learn there (Coggin, 2017). Foundational to our study is an understanding that each participant entered [project name] with a pre-existing set of resources. While tending to the resources available to and taken up by the participants in [project name], recognizing their already established resources respects and centers a funds of knowledge approach. This paves the way for participants to make meaningful connections between their community and their prior interests and skills to the STEM-based identity nurtured by [project name].

Methods

This article details the efforts of a research-practice partnership between a research university and a technical college to design and implement a mobile makerspace in a rural community in the Midwest. A key feature of this partnership—training local teens to staff the mobile makerspace—was designed both to establish credibility and sustainability for the makerspace in a rural community.

Research Context

In the rural area where this study took place, nearly one-third of the county's economy is manufacturing based. Additional workforce is divided among service, industry, and agriculture. The primary school district in this community reflects area demographics. According to the school district's website, 65% of students reported as white; 20% Asian; 6% Hispanic; 6% of two or more races; 2% Black; and 1% American Indian/ Alaskan Native. 46% of students are eligible for free or reduced lunch. In informal observations with area science teachers we often heard about the lack of resources available (e.g. a school having a $500 budget for science for the school year) and how this discouraged students' participation with science.

Participants

Over the course of two years, 37 maker-mentors participated in the EMMET. Some were recruited at the start of the program and remained through the two years while others came in later or did not continue to the end of the program. 70% identified as male. While this is disappointing relative to the program designers' interest in disrupting the male culture of making, STEM, computer science, and engineering, the self-identified female participants in the cohort (30%) is slightly higher than the 24% representation in STEM fields reported by the Economic and Statistics administration in 2017 and higher than female representation in Computer Science and Engineering undergraduate programs at the largest university in the state where only 13% of graduating computer science majors and 21% of engineering graduates are women (Schneider, 2018).

The maker-mentors were predominantly 10th and 11th grade students, all of whom attended local public high schools across two adjacent counties. Demographics regarding race and ethnicity are relatively in keeping with those for the broader area. 20% of the maker-mentor cohort self-reported as a person of color, which is consistent with the US Census report that 21%

of residents in this area identify as a person of color. This percentage is slightly above the 12% enrollment for students of color at the partnering technical college.

Maker-mentors attended monthly training sessions at the technical college and facilitated making events for younger students throughout the community. Maker-mentors were paid for their time as maker-mentors following the success of science museums that employ high school-aged “explainers” in their making spaces. EMMET aimed to professionalize maker-mentors and to value their contributions as knowledge workers. Bi-weekly mentor training workshops were used to teach both STEM+C skills and to help maker-mentors improve upon their facilitation skills.

Research design

This research took place through a longitudinal, intrinsic case study (Stake, 2000). Intrinsic case studies focus on the case itself as the primary focus. For this study, we were interested in understanding the unique case of training high school students as maker-mentors as an introduction to STEM+C. We traced the individual trajectories of five maker-mentors over their two years participating in EMMET. Case study participants were chosen for demographic diversity and access to their preliminary interest survey which served as a baseline of knowledge and interests across each case. Table 1 displays a brief description and data available for each of the five maker-mentors.

<Insert Table 1 about here>

Data Collection

Throughout the course of two years, we collected a range of data starting with preliminary interest surveys from 20 maker-mentors. The survey was designed to examine baseline computational thinking (Berland, 2016; Grover, 2017), identity formation (Cameron, 2004; Ellemers, Kortekaas, & Ouwerkerk, 1999; Jackson, 2002) interest & motivation (Hidi & Renninger, 2006), as well as self-concept (Velayutham et al., 2011).

We took ethnographic field notes and collected attendance records at monthly training sessions. We also video recorded maker-mentors when they worked collaboratively with their peers and anytime maker-mentors shared what they made with their peers or discussed making as a group.

We conducted semi-structured interviews with the maker-mentors throughout their time in the program. Interview topics involved describing making events, sharing reflections about the program, describing what they've learned and their understanding of making and computational thinking.

We attended mentor facilitated events, composed ethnographic field notes, and video or audio recorded events when possible. We were able to observe several maker-mentors simultaneously and observe how they co-facilitated events.

Data Analysis

Research Question 1. To determine how maker-mentors take up identity resources while participating in a rural STEM+C program we created deductive codes based on Nasir and Cook's (2009) material, relational, and ideational resources. In this study, we consider material resources to include the tools and artifacts available to maker-mentors before and during their time in the program. Tools ranged from coding programs, 3D printers, circuit boards to sewing machines, but they also included everyday items like water bottles and pipe cleaners. Relational resources include anyone that maker-mentors engaged with during training and facilitation events. Ideational resources center individual and group identity. In particular, ideational resources include maker-mentors' attitudes and beliefs about STEM+C for themselves, their community, and society. In addition, we compared maker-mentors' event attendance records. We recognized that each event offered opportunities to build identity resources making attendance important for maker-mentor identity formation.

We initially used three broad codes—material, relational, and ideational—to examine the trajectory of each maker-mentor from their preliminary interest survey to their final interview. We compared the material resources maker-mentors brought into the program to those gained during their time in the program and the ways they talked about their relationships with others in the program. During second level coding, we used "values coding" which combines a participant's values, attitudes, and beliefs as a representation of their worldview or perspective to track identity resources (Saldaña, 2016). We traced how their understanding of STEM+C or beliefs about its value for society shifted throughout the program. Using a time-ordered meta-matrix (Miles, Huberman, & Saldaña, 2014) we then compared material, relational, and ideational resources across the five maker-mentors from the beginning to the end of the program. This allowed us to determine how identity resources connected to inbound and peripheral trajectories.

Research Question 2. To answer our second research question, what types of programming and maker activities encourage rural high school students toward becoming full participants in pre-college engineering, we used "concept coding" to locate identity resources in particular moments in time (Saldaña, 2016). We reviewed field notes and video recording from monthly training sessions, community events and interviews locating identity resources in specific maker activities. Miles et al. (2014) also describe an analytic strategy that they term "stacking comparable cases" as a way to use a set of emic and etic variables to look across a set of cases (p. 103). We created a case-level display of the five maker-mentors' resources tied to the specific maker activities to analyze how different events encouraged students to engage in pre-college engineering practices.

Findings

In this section, we provide a brief biographical sketch of five maker-mentors sharing the words they use to describe themselves and their motivations for joining EMMET during their preliminary interest surveys. To answer the first research question, we describe the three factors that positively impacted maker-mentor participation: interest-based tasks within community-based projects, co-facilitation and sharing knowledge with younger kids, and aligning tasks with career goals. To answer the second research question, we describe the constellation of factors that surrounded mentors with inbound trajectories and those who remained on the periphery.

The Maker-Mentors

Sarah[1]

Sarah is a creative and confident junior in high school who describes herself as curious, artistic, creative, and positive. Sarah works a part-time job at a craft store and plays in the pep band. She joined EMMET because she is interested in being part of a community and because she enjoys designing, producing, and seeing projects from start to finish. As a method of assessing incoming maker-mentor' interest and expertise, we asked everyone to draw a picture of something they would like to make. Instead of drawing a picture, Sarah wrote the following: "I'm not 100% sure on the resources available but I'm excited to learn what they are and what I can make from them."

Anna

[1] All names used in the text are pseudonyms.

Anna is a sophomore who describes herself as artistic, inclusive, organized, open-minded, and as a designer. Anna is a member of the volleyball team, church youth group, and Girl Scouts. She joined EMMET because she thought "it would be a cool opportunity to learn and help others learn at the same time." When asked to draw a picture of something she'd like to make, Anna drew a picture of a solar operated car.

Martin

Martin is a freshman who describes himself as curious, dedicated, a problem solver, logical, and ambitious. He is a member of the robotics club and the golf team at school. Martin described EMMET as a "priceless opportunity", and is particularly interested in STEM activities and passing them onto the community. Martin entered EMMET already knowing how to program through his experience creating robots for a Vex robot competition. Martin wished to make a "simple Quadracopter" programmed with Arduino.

Luis

Luis is a sophomore who described himself as curious, dedicated, open-minded, and logical. Luis is a soccer player and member of the National Honor Society. He explained that he joined EMMET to learn about STEM+C to benefit him in his future. He shared that he liked "learning new things, science stuff." Luis wrote that he would like to make a hoverboard.

Nick

Nick is a sophomore who described himself as curious, open-minded, a teacher, ambitious, and positive. Nick is also a member of the computer club, works at the planetarium, and calls himself "a huge gamer". Nick was interested in EMMET because he loves working with other people and teaching them new things. Nick shared that he would like to make a generator that provides wireless power to electronic devices.

Maker-mentors entered EMMET with varying levels of familiarity with maker tools and artifacts. Nick and Martin entered the program with extensive prior experience with coding and building robots. Sarah entered the program with a little coding experience and Anna did not have coding experience but gained a little during the program. Sarah and Anna identified acquiring the most new material resources as a result of their participation. Nick and Martin continued to build upon the skills they knew prior to the program, transferring prior coding experience to use new programs, such as SolidWorks. Luis, who stated that he had never made anything prior to the program acquired new resources such as programming LEDs. Table 2 provides a full list of material resources mentors entered with and gained during the program.

<Insert Table 2 about here>

Three Factors That Positively Impact Maker-Mentor Trajectories

Our first research question focuses on how identity resources impacted maker-mentor trajectories into pre-college engineering work. We describe three ways maker-mentors were offered opportunities to build identity resources and describe how they took up resources throughout their time in the EMMET program.

Interest-Based Tasks within Community-Based Projects

In the second year of their participation, the maker-mentors all took part in one collaborative project. The use and mastery of tools and creation of artifacts through this project demonstrates how mentors called upon existing assets to co-participate in engineering and computational thinking through making.

Each year, the community hosts a holiday parade that features local businesses and organizations. EMMET had the opportunity to create a float and walk in the holiday parade to highlight and advertise the program. The staff asked the maker-mentors to brainstorm and determine a theme they would like to use for their float. Almost unanimously the maker-mentors decided on Star Wars.

One group chose to create lightsabers. Unsure of where to start, they looked up directions online, made a shopping list and asked one of the adult staff members to take them on a shopping trip to pick up materials from the local hardware store. After purchasing items they'd not previously worked with such as acrylic plastic tubes and a vacuum hose, they used the available tools in their makerspace—a soldering iron, screw drivers, hammers, and hack saw—to create a new artifact (field notes, October 14, 2018).

Martin and Nick joined two others in creating a model of R2D2. They had previously worked together building a robot for a Vex competition as members of their school's robotic club. Nick served as the programmer for the Vex competition and was able to use his previous experience programming to design the R2D2. First they created a 3D design in SolidWorks and then cut wood pieces using a laser cutter that could later be assembled.

Nick, having previous experience teaching himself how to program, succeeded at learning new software (SolidWorks) to design the model R2D2, and in turn taught others. Martin, who said that one of his favorite things he'd made prior to EMMET was a robot for a Vex competition because he enjoyed that it involved planning, designing, building, and programming (preliminary interest survey, February 26, 2018), was able to leverage his passion to create the multi-layered R2D2 project.

Sarah, Anna, and one additional female maker-mentor chose to create Jedi Robes for their whole team. Because the adult facilitators did not have experience with sewing they brought in a local seamstress.

Once the maker-mentors purchased material they sat down at the sewing machines and started trying to figure out how to use the machines. First, they had to learn how to use a bobbin. Sarah quickly figured this out using instructions included with the machine. She noticed that Anna was having difficulty threading the bobbin and moved over to Anna's machine to help asking "so, you know what a bobbin is, yes?" When Anna replied no, Sarah described and demonstrated the process she had just learned herself.

Sarah then started looking at the material when an adult staff member told her she needed to have a pattern. Sarah replied "but I don't know how to sew!" The area seamstress explained that they could find patterns online and Anna grabbed a computer to find a pattern they could use for Jedi robes (field notes, October 14, 2018). They found a pattern, printed it out, and the seamstress showed Anna how to use a rotary cutter to cut out the patterns. Finally, the seamstress helped the maker-mentors learn how to use the Brother sewing machines.

Co-Facilitation and Sharing Knowledge with Younger Makers

When maker-mentors facilitated community maker events for younger learners and community members, they were typically grouped into teams of four or five. These teams persisted throughout the program, nurturing collaboration. Co-facilitation looked different across teams. Some rotated leadership based on expertise, with maker-mentors swapping roles several times during an event while others maintained a singular leader, affording maker-mentors who preferred working one-on-one over group facilitation an essential responsibility.

Martin worked with the same three maker-mentors at six unique events. The group took turns serving in a variety of roles including lead facilitator, material preparer, and facilitator attentive to individual participants' needs. Martin explained that the ability to facilitate with the same group was essential to the success of events because, "the team dynamics we have are really, really good" (interview, July 12, 2019). If Martin was describing steps to participants the other maker-mentors would hand out materials. When other maker-mentors were describing steps, Martin would hand out materials. This structure was beneficial for maker-mentors like Sarah who needed additional time to feel comfortable facilitating events. Sarah explained that, "I realize that like at first I sit back but like now I know everybody in my group so now I'm like, I'm comfortable to explain and stuff" (interview, July 12, 2019).

Every event that maker-mentors facilitated was different so they had to constantly react to one another's actions. Maker-mentors working in concert often needed to rely on improvisation, those not leading the participants focusing on his or her instructions to ensure the next step was ready. Martin described how this functioned during facilitation:

> We usually choose one person just to introduce the activity. It depends on the event—if it's a larger event we break it into groups—but for smaller events we just have one person walk them through it. Who really wants to or who has the most experience with the event [leads it]. When they're explaining it, you realize something hasn't been prepared yet. And with your own experience and knowledge you try to figure out what needs to be done (interview, July 12, 2019)

Many of the maker-mentors also mentioned becoming better teachers as they recognized that teaching was not about telling someone what to do but about guiding (interview with Sarah, October 14, 2018). Maker-mentors like Anna spent more time working one-on-one with students at events. All of the maker-mentors believed that it was important to help their community by sharing their knowledge of STEM. Nick explains, "getting kids involved younger makes them more susceptible to having better ideas and more open mindedness later in life. So doing this where we get to go around and just teach the public kids and adults about STEM ideas is interesting and I think it will be helpful to our community" (interview, August 18, 2018).

Aligning Tasks with Career Goals

All of the maker-mentors saw their experience with EMMET as a pathway toward a future career, although they had different ideas about what those future careers would be. Table 4 displays each mentor's future career plans toward the end of their participation in the program.

<Insert Table 4 about here>

The maker-mentors who entered with confidence about their STEM related training—Martin and Nick—had clear ideas about their career paths. Martin, for example, knew STEM was important because his father was an engineer and he planned to follow in his father's footsteps. Nick also came into the program confident about his future career, but he aspired to be a professor.

Sarah and Anna entered the program to find out more about available career paths. Sarah's parents and teachers encouraged her to apply to the program to find out if she enjoyed engineering, encouraging her creative and artistic skills in a new way. At the end of the program, Sarah was able to define that what she liked most about STEM+C was solving problems (interview, July 12, 2019). She imagined going into a career like architecture where she could solve problems and design solutions. Although Anna was uncertain about her future career, she shared that "EMMET just helped me figure out things I didn't like and things I did like to help me think about what I want for the future" (interview, July 12, 2019). Luis knew that he planned to use STEM+C in his future career, but did not know what that career would be or what skills or tools exactly he enjoyed the most.

Maker Mentor Trajectories

Our second research question explores the types of programming and maker activities that encourage rural high school students toward becoming full participants in pre-college engineering. Through examining maker-mentors' experiences, we found collections of related factors that led to inbound and peripheral trajectories. We begin with an extended analysis of those mentors who maintained inbound trajectories—Martin, Sarah, and Anna—and those who remained on the periphery—Nick and Luis.

Inbound Trajectories

Maker-mentors that followed inbound trajectories entered the program with varying levels of material resources. Martin, who came in with extensive material resources, maintained an inbound trajectory similar to those who came in with little prior material resources such as Sarah. Part of this may be that all types of making were equally valued in the program and mentors' existing assets were leveraged to gain new material resources. Sarah's passion for art and design may have led her toward designing costumes for the Star Wars float where she learned how to sew. Through the process, she learned how to thread a bobbin and could help other mentors like Anna gain the same skill further building relational resources. Likewise, although Martin entered the program with extensive material resources, he often helped others, developing his identity as a mentor, an ideational resource.

Martin, Sarah, and Anna had regular occasions to build relationships and relational resources with other maker-mentors through regular attendance at training sessions and facilitation events. These regular occurring opportunities to learn with their peers and co-facilitate making events for younger makers helped them find a sense of belonging within the community. All of the maker-mentors reported that relationships were one of their favorite parts of being part of the group. While Martin was particularly social and friends with all of the maker-mentors and Anna preferred working alone sometimes, both reported positive connections within the group as a positive outcome of their experience. Anna and Sarah found they were able to build a closer relationship upon an initial acquaintance from attending the same high school. Moreover, EMMET helped mentors like Anna move out of her comfort zone to meet new people:

> I don't like to go outside my boundaries even though like I need to, so going into [name or project], there's only one other person from my school and I didn't really know her and so I had to meet kids from other schools who knew each other...so that way just getting used to being uncomfortable. I like the phrase being comfortable with being uncomfortable. (Interview, July 13, 2019)

While all three maker-mentors with inbound trajectories understood STEM+C to be important to society, they saw very different career paths. The types of aspirational career paths (engineering, architecture) were not divided on gender lines. In this way, EMMET was successful in connecting students to STEM and pre-engineering pathways. While such pathways are historically known to disproportionately benefit males, the success exhibited by Anna and Sarah may be linked to the asset-based approach EMMET employed.

Peripheral Trajectories

Luis and Nick's trajectories are more uncertain. In terms of material resources, Nick entered the program with experience similar to Martin's. Luis, who came into the program with material resources akin to Sarah's and Anna's, attended all of the training sessions the first year, accessing just as many opportunities to gain new material resources. However, both Nick and Luis attended fewer facilitation events than the other maker-mentors. Luis only attended one facilitation event in his two years in the program. His low attendance may have been a result of his time commitment to the soccer team or lack of transportation. However, the other maker-mentors without transportation often carpooled or received rides from adult staff. This limited the opportunity to build material, relational, and ideational resources unique to community events.

Nick, who attended almost all of the training sessions, attended only one event the first year and two the second year. Even though Nick entered the program to gain experience in teaching, he attended few of the opportunities available to practice these skills. This may have been tied to Nick's preference for programming and technology over what he called "the engineering side of things." Nick revealed that due to a condition which impairs the function of his right hand, he gravitated towards non-physical making. He didn't necessarily see programming and computer interactions as synonymous with making adding "I'm not like mechanically inclined to make like— I'm not—I don't like mechanical engineering, there we go" (interview, August 17, 2018). Community events prominently featured physical making over programming.

Luis and Nick's had fewer opportunities to build relationships with other maker-mentors due to their low attendance thus reducing the opportunity to build relational resources. Community events, carpools, and monthly training sessions helped bring the other maker-mentors together, but created a further separation for Luis and Nick. In interviews with Luis, he rarely talked about his relationship with other maker-mentors or about his connection with the group itself. Luis is the only person of color featured in this study, but never mentions race or ethnicity in interviews.

Nick also had a unique relationship with his peers. Despite the fact that Nick came in with more experience in programming and STEM than many of the other maker-mentors, he saw himself situated outside of the group in terms of intelligence. He described this relationship in an interview during the first year of the program. “I view everyone here as smarter...like more intelligent, I guess, than me so I kind of try to sometimes—I try to go higher than I can and that makes me go down more, so I just—it's kind of like a interpersonal struggle kind of sometimes” (interview, October 14, 2018). Unlike formal schooling where teachers work as intermediaries for interpersonal relationships, EMMET’s programming does not share this feature, which may have helped Nick build relational and ideational resources.

Despite this, both Nick and Luis described their favorite moments in EMMET as the experience of working with others. This was the case for Nick who, even though he went to school with six other maker-mentors was able to get to know them better while making artifacts as a group. His favorite memory from EMMET was an experiment where the maker-mentors made Oobleck, a non-Newtonian fluid made of cornstarch and water that acts like a liquid when being poured, but like a solid when pressure is applied. He explained that this “was the best [Project Name] training I've had and probably the best experience...because I just got to interact with more people than I normally do" (interview, October 14, 2018).

Much like Martin, Sarah, and Anna, Nick and Luis also recognized the importance of STEM+C. Luis mentioned that his participation in EMMET would help him pursue a future career engineering (interview, August 17, 2018) and Nick pondered more broadly mentioning that “in my generation we're going to develop a lot of important things in our world...we need kids to help progress and if we don't have kids who are interested in science or STEM we won't progress anywhere” (interview, October 14, 2018).

Discussion

We begin this discussion describing how three factors—1) leveraging resources through an interest based task within community-based projects; 2) co-facilitation and sharing knowledge with younger kids and 3) aligning tasks with career goals—promoted material, relational, and ideational resources for maker-mentors. We suggest additional scaffolding in the co-facilitation model to help all maker-mentors participate in the community-based events which were found necessary for full participation in the community. Finally, we discuss the maker-mentors co-facilitation model built into EMMET as an asset-based approach to pre-college engineering education.

Leveraging Resources Through an Interest-Based Task within Community-Based Projects

The Star Wars project exemplifies the intersection of material, relational, and ideational resources. Making artifacts for the float was interest driven, project-based, required maker-mentors to call upon their creativity, and allowed for them to use available tools and resources to create an artifact of importance and relevance to the local community.

Creation of the Star Wars float was the only wholly collaborative project in which the maker-mentors engaged. From costumes to lightsabers, each part of the project was necessary for the benefit of the larger group. Sewing machines and laser cutters were of equal importance to the success of the project. The reliance on each other and shared interest in the project helped forge relational resources among the maker-mentors and further solidified the community of practice (Sheridan et al., 2014; Wenger, 1998). The creation of the float served as a new communal asset that supported maker-mentors' new and evolving identities (Poole, 2016; Fasso & Knight, 2019).

As individual mentors could call upon their unique assets and all types of making were equally valued for the success of the project, the Star Wars float helped define "what counts" as making based on what the maker-mentors contributed to the project (Vossoughi, et al., 2016). In this way, maker-mentors' funds of knowledge worked both as individual scaffolding resources as well as collective scaffolding for the community (Moje et al., 2004). For example, Sarah—who was artistic and creative—could think about how the costumes, lightsabers, and R2D2 would physically be designed and integrated into the float to make a clear visual. Costume design allowed Sarah and Anna to be creative and artistic to leverage their assets to serve the larger group. Martin and Nick could use their previous experience with engineering and computational thinking to determine how to break down all of the smaller parts necessary to create the R2D2. Martin and Nick used their prior experience programming to approach a new, more complex creation.

We recognize the potentially gendered nature of material resources in use across this project. The male maker-mentors made robots and lightsabers and the female maker-mentors made costumes. These choices echo much of the prior research on making and gender which demonstrates that "standard" making like robot building tends to attract adolescent boys and that adolescent girls are drawn to maker activities that feature costumes and fashion (e.g. Kafai et al., 2014; Pinkard et al., 2017). Likewise, e-circuit projects like the light saber offer opportunities for those with interests in either circuitry or sewing to feel connected to making (e.g. Peppler & Glosson, 2013). Importantly, all three of these projects were equally valued in the overall completion of the Star Wars project. Material resources for all three were readily available in the space.

Relationships were also strengthened by the fact that the project itself was interest driven and ideational. While previous research has shown that allowing young makers to choose their projects can be a powerful motivator (Blikstein, 2008), prior to this event, activities such as learning to use Makey Makey or create a circuit were assigned as a top down approach, where professional staff selected projects. Yet this project allowed maker-mentors to connect making to something that was important to them. In this way, Star Wars was an ideational resource upon which the entire group built relationships and upon which engineering practices were leveraged.

Similar to previous research on rural makerspaces, we found that community resources were essential to the success of this project (Kim & Copeland, 2020; Horton, 2017). Bringing in an area seamstress created a purposeful connection between maker-mentors and a valued community resource. The impetus for the project was also community-minded. Maker-mentors were able to walk amongst more than 50 local businesses and non-profit organizations sharing their work during the community's holiday parade which is considered a local, holiday tradition.

Co-facilitation and Sharing Knowledge with Younger Makers

The unique feature of EMMET—training maker-mentors to co-facilitate making events for younger makers—offered maker-mentors numerous opportunities to build upon identity resources and remained a delineation between inbound and peripheral trajectories.

The focus on teaching and facilitation meant that all of the maker-mentors entered EMMET with areas for growth. They had numerous opportunities to gain interpersonal skills through working together and facilitating events in their local community. Whether they were more vocal and outgoing like Martin or more reserved like Anna, they were placed in a new situation and had a shared vulnerability which further required them to concentrate on relationships with their peers. Interestingly, the two mentors who followed paths on the periphery—Luis and Nick—attended fewer facilitation events, creating less time to build rapport with their peers and expand upon their material, relational, and ideational resources in the same way.

Those that regularly participated in co-facilitation like Martin, Anna, and Sarah benefitted from identity development through what Polman (2010) calls the Zone of Proximal Identity Development (ZPID) as they took on more and more responsibility based on their comfort level. Maker-mentors like Sarah were able to expand her skills when she felt she was ready to do so. Anna, who was more reserved and preferred one-on-one instruction was able to gain confidence. She constantly improved her ability to break down complex processes and explain steps in a way that was manageable for younger students (interview, July 12, 2019).

In this way, those maker-mentors with inbound trajectories built relational resources as well as material resources while facilitating maker events. They learned about new tools from watching and teaching with their peers; they had time to become comfortable with a tool before moving into the lead teaching position; and they learned how to read their peers' movements, knowing when to step in and help gaining teamwork and facilitation skills (Duran et al., 2020).

Finally, sharing knowledge and skills with youth allowed maker-mentors to move from novice to expert as they transferred activities they learned about in training sessions and then taught the same content to others. Through facilitating activities, maker-mentors continuously tried new things, learned from their experiences, and iteratively improved their explanations thereby participating in reflective knowledge-building (Roscoe & Chi, 2007). Sharing knowledge in this way can be associated with greater technical sophistication (Martin, 2015; Barron, Walter, Martin, & Schatz, 2010).

Maker-mentors who facilitated community events were also provided a position of expertise with young makers in their local communities who share similar understandings and funds of knowledge. Embracing and valuing pedagogical strategies that recognize local rural knowledge, maker-mentors from the same rural communities could, in return, enhance their younger peers' engagement in STEM practices (Avery, 2013).

Aligning Tasks with Career Goals

All of the maker-mentors believed that their participation in [project name] would benefit their future goals. This may be reflective of the growing focus on STEM in K-12 education which often highlights future career possibilities (Martin, 2015; Honey & Kanter, 2013; Peppler, Halverson, & Kafai, 2016).

As future career goals varied among the maker-mentors, so too did the range of opportunities of the program. Because [program name] trainings took place in the STEM Center at the technical college and were facilitated by the faculty, maker-mentors were also provided direct access to tools and people in STEM fields. These experiences help shape occupational aspirations (Haller & Virkler, 1993; McCracken & Barcinas, 1991; Crowley, 2001). For rural students whose funds of knowledge may feel at odds with school learning and STEM careers, this space helped them bridge the gap between questions of "who am I" and "who I *could* be" (Fasso & Knight, 2019--emphasis added). For Luis, the only participant of color, his peripheral trajectory might in part be explained by the all white instructional team, complicating his ability to see who *he* could be.

Whether they entered with a clear idea of a career path (such as Martin who knew he wanted to become an engineer) or simply wanted to see what STEM paths might look like (such as Anna and Sarah), the range of activities and facilitation built a foundation not for a single career path but skills that can be applied to many fields. Maker-mentors could explore and see what they enjoyed and didn't, opening up futures they may not have previously imagined.

Preparing Maker-mentors for Facilitating in their Local Community

The EMMET facilitation model became essential in creating opportunities for maker-mentors to build identity resources. Yet all maker-mentors did not have these same opportunities. While there were a variety of factors surrounding Luis and Nick's low attendance in these facilitation events, the following factors can be addressed to ensure that barriers can be removed for students in similar programs. Specifically, programs can create more trainings for maker-mentors on gaining facilitation skills so they feel comfortable in these events; facilitators can create varied opportunities for maker-mentors to work with a variety of peers in fun and exploratory ways to encourage the building of relational resources; and program coordinators can eliminate barriers for students by hiring diverse adult staff and mentors that are in line with maker-mentor's cultural and racial identities and varying the types of making activities at facilitation events.

Eliminating Barriers to Pre-College Engineering in Rural Communities

While each rural community is certainly as unique as the next, many rural communities share a deep connection to place (Falk, 2004; Howley & Howley, 2000). EMMET recognized the importance of place and community throughout the development of the program and EMMET staff continue to collaborate with community members to this day. Facilitators understood maker-mentor's "local rural knowledge" (Avery, 2013) and built making activities around those issues most important to the community.

Conclusion

Our study takes Nasir and Cooks' (2009) identity resources to trace the trajectories of five high school maker-mentors participating in STEM+C programming in the rural Midwest. Our findings and discussion suggest pre-college engineering programming is most successful when participants' funds of knowledge/pre-existing resources are allowed to act as scaffolding on which new material, relational and ideational resources may be integrated. Participants need not enter with predefined or exclusive resources when activities support a broad and inclusive definition of making. Sarah's success and status on the inbound trajectory shows skills in art and design are just as powerful of resources to bring into pre-engineering programs as those of Martin, who boasted a wealth of material resources prior to the start of EMMET.

EMMET's unique design in training high school students to co-facilitate making events helped build community through a shared learning opportunity. Those mentors who rarely facilitated community events followed a peripheral trajectory in the community of practice. As resources emerged to be gained interdependently, the opportunities to facilitate making in the community were pivotal for maker-mentors in developing each resource. It was out in the community where maker-mentors needed to demonstrate their familiarity with material resources, rely on each other (relational), and develop a strong connection to and knowledge of STEM practices (ideational) as they were responsible for teaching and sharing STEM information at community events.

As engineering struggles with recruiting and retaining diverse student bodies, our research with rural high schoolers indicates the importance for asset-based pre-college programming to center student interest and identity. Instead of a deficit approach to pre-college engineering education that has historically privileged white, upper- and middle-class males, the power to overcome barriers immanent to engineering lies within students' own funds of knowledge. We witnessed students use their own resources as scaffolding to begin their climb. Success was met by persistently gaining resources that were available to them in unique configurations across events and training sessions. A brighter, more inclusive future for engineering will be made possible, in part, by reorienting “what counts” as useful knowledge, and recognizing there are many paths to engineering.

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Tables and Figures

Table 1

Description and data collected for each maker-mentor

Maker-Mentors	Description of Mentor	Data Collected
Sarah	11th grade white female who describes herself as curious, artistic, creative, and positive	Interest survey, field notes, video of facilitation and making, three interviews
Anna	10th grade white female who describes herself as artistic, inclusive, organized, open-minded, and as a designer	Interest survey, field notes, video of facilitation and making, one interview
Martin	9th grade white male who describes himself as curious, dedicated, a problem solver, logical, and ambitious	Interest survey, field notes, video of facilitation and making
Luis	10th grade Latino male who described himself as curious, dedicated, open-minded, and logical	Interest survey, field notes, video of facilitation and making, two interviews
Nick	10th grade white male who described himself as curious, open-minded, a teacher, ambitious, and positive	Interest survey, field notes, video of facilitation and making, two interviews

Table 2

Maker-mentor material resources before and during time in the program

Mentor	Material Resources before entering program		Material Resources gained through program
	Favorite thing they've made	Tools mentors stated they've used/ know how to use	
Sarah	"A puzzle cube that I 3D printed"	"A little [coding] but not that much." Art and design tools, including an unspecified CAD program.	Making a circuit board, coding, sewing, programming robots, sewing machine, squishy circuits, Cricut machine, repurposing items for new purposes
Anna	"A thrown bowl made out of clay"	None specified.	Coding, Arduinos & Makey Makey; sewing and sewing machine; LED circuitry, squishy circuits, Cricut machine, wood cutting with laser cutter and with hand saw, repurposing items for new purposes
Martin	"A robot for this year's vexx competition"	Coding, Arduinos and tools necessary to create a simple quadcopter	Cricut machine, wood cutting with laser cutter and with hand saw, repurposing items for new purposes
Luis	Claimed "I haven't constructed or made anything" but later referenced building a bridge in class	"Wood and stuff" required to build a model bridge in an engineering class	Coding on Pi Tops, programming LEDs, repurposing items for new purposes
Nick	"A robot for the robotics competition this year"	Programming: Scratch, C#, Unity; soldering, circuit boards	Microcontrollers, Arduino; CAD software: SolidWorks & Fusion 360, repurposing items for new purposes

Table 3

Interpersonal skills maker-mentors gained through the program

Sarah	Found that becoming comfortable with her fellow maker-mentor boosted her confidence in taking part in discussions and explaining concepts (interview, July 12, 2019)
Anna	Being a mentor with kids from other schools has helped her become "comfortable with being uncomfortable" around new people (interview, July 12, 2019)
Martin	Martin's knowledge of how materials and tools work together and how breaking them down into their individual parts helped facilitation. He recognized the power in visually seeing how things worked as a teaching tool that "showing them the examples to show them what I am talking about" (interview, July 12, 2019)
Luis	"[Name of program] has helped me interact with other people, share my ideas...I've become more open, I would say, because, I used to not be able—I was a little social but, you get me into small groups and actually talking to other people like, almost every day" (interview, March 10, 2019)
Nick	Nick learned about visualizing and explaining his thought process. He explained that while he used to work out math problems in his head, he started writing everything down so he could explain what he was doing. Nick practiced social skills which helped him become more comfortable talking and explaining new concepts to others (interview, October 14, 2018)

Table 4

Maker-mentor career plans. Dates vary due to maker-mentors' time in the program

Sarah	*Architecture* or, "something where someone comes and goes hey we want to build this but like we don't know what to do and I'd be like, oh I have some ideas like different things like that. Like water parks or like just parks in general" (interview, July 12, 2019)
Anna	*Uncertain*, but stated that, "[Project Name] just helped me figure out things I didn't like and things I did like to help me think about what I want for the future" (interview, July 12, 2019)
Martin	*Electrical Engineer*, like his father (interview, July 12, 2019)
Luis	*Uncertain*, but wrote that he planned to use STEM+C skills in his future career (preliminary interest survey, February 13, 2017)
Nick	*Professor,* but also recognized that "any STEM skill will give you a good job and a good future in general" (interview, August 17, 2018)