Leveraging Innovation and Optimizing Nurturing in STEM: Engineering identities in low-income students across their first year of college (NSF S-STEM #2130022)

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Leveraging Innovation and Optimizing Nurturing in STEM (NSF S-STEM #2130022, known locally as LION STEM Scholars) is a program developed to serve low-income undergraduate Engineering students at Penn State Berks, a regional campus of the Pennsylvania State University. As part of the program, scholars participate in a four-year comprehensive multi-tiered mentoring program and cohort experience. The LION STEM curricular program includes Engineering Ahead (a 4-week summer residential math-intensive bridge program prior to entering college), a first semester First-Year Seminar, and a second semester STEM-Persistence Seminar. Co-curricular activities focus on professional communication skills, financial literacy, career readiness, undergraduate research, and community engagement. The program seeks to accomplish four goals: (1) adapt, implement, and analyze evidence-based curricular and co-curricular activities to support, retain, and graduate a diverse set of the project's engineering scholars, (2) implement, test, and study through research and project evaluation strategies for systematically supporting student academic and career pathways in STEM, including development of STEM identity, (3) contribute to the knowledge base through investigation of the project's four-year multi-modal program so that other colleges may successfully implement similar programs, and (4) disseminate outcomes and findings related to the supports and interventions that promote student success to other institutions working to support low-income STEM students.

The purpose of this paper is to analyze data from a repeated-measures design to provide a holistic narrative about the effects that the academic and support activities offered to LION STEM Scholars have on the development of their future-engineer role identity throughout their first year as an undergraduate engineering student. This paper presents data collected from semi-structured (Smith & Osborn, 2007) audio-recorded interviews from the first cohort of LION STEM Scholars ($n=7$) at three different time points (pre-summer bridge, post-summer bridge, end of first semester) as well as data collected from a written survey at the end of scholars' second semester.

Program Components

Engineering Ahead: The LION STEM Scholar program begins with a fully immersive four-week summer residential bridge program that focuses on both academic competencies and co-curricular activities. The math-intensive residential program includes hands-on activities typical of the Engineering disciplines and community building. A mathematics faculty member exclusively trained to teach first-year Engineering and Science students teaches math at the pre-Calculus level, with the learning outcome of preparing the students for their first-year college-

level mathematics courses. Metacognition [4] is also part of the curricular backbone of the bridge program as the coordinator of the campus Learning Center works with students on forming better study habits, time management, organization, and note-making skills. Daily interaction with other faculty and staff involves engineering lectures and hands-on labs as scholars are exposed to cooperative learning under the supervision of trained upper-class Engineering mentors. Regular interactions with alumni, numerous industry visits and a community-based engineering design service project round out the main components of Engineering Ahead.

First-Year Seminar: The First-Year Seminar (FYS) is a one credit course designed to introduce students to the University environment by providing them with an overview of curricular and co-curricular activities which include academic support programs. The course is required for all first semester students and the LION STEM Scholars remain as a cohort and are enrolled in the section of FYS taught by the same mathematics faculty member who runs Engineering Ahead. The purpose of the First-Year Seminar is to introduce new students to an open and purposeful learning community, and to help them develop the habits and pleasures of good scholarship. The common read used in the FYS class is *Atomic Habits* by James Clear. Working with a familiar faculty member and one of the same student mentors from Engineering Ahead, the first semester students explore the expectations of personal integrity, level of effort, and civility on a university campus. In addition to providing academic support for their entry level mathematics and science courses, an additional curriculum component of FYS is career exploration. Throughout the course, students refine their resume and communication skills and take part in the larger university career fair. Further, this course provides several opportunities for students to visit local industries and extend collaborations with alumni in hopes of laying the foundation for securing an engineering internship following their first year of study.

STEM-Persistence Seminar: The STEM-Persistence Seminar (SPS) is a one credit course designed as an extension of FYS and was developed exclusively for the students who are part of the Engineering Ahead cohort. In addition to continued building of mathematics and metacognition skills, the purpose of the SPS is to help students continue to build their resumes in hopes of securing a high engagement opportunity (i.e., internship, undergraduate research, mentoring) following their first year of college. Therefore, the focus of this class is community engagement and undergraduate research. One of the community engagement events includes the LION STEM Scholars developing and conducting an open house for youth in the community that is centered around engineering design. In essence, the LION STEM Scholars serve as mentors for children in grades 5-11 who run a canned food drive and then compete to build the best structures out of their sourced food. All food is then donated to the local food bank. The mathematics faculty member from EA and FYS also runs SPS, but with help from several engineering faculty members who take the lead with the undergraduate research component of this course. The engineering faculty members provide several sessions on the basics of research and then each LION STEM Scholar is paired 1-1 with a faculty research mentor. Over the course of the semester, the scholars collaborate with their mentor to develop a research proposal for either a local undergraduate research conference or a summer research experience grant application.

Theoretical Framework

The theoretical framework for this project is the Dynamic Systems Model of Role Identity [3], a holistic metatheoretical framework for motivation, engagement and learning through identity development. The conceptual principles of this framework "aim to capture the holistic and rich content, structure, and process of identity and its formation within social-cultural contexts, with anchors in established theoretical constructs" [3]. The primary unit of analysis in this research is the social context in which the development takes place, both physical (i.e., on campus) and social (i.e., interactions with friends, family, community, academic instructors, support staff and professional Engineers). The DSMRI therefore provides a coherent and systematic perspective to begin investigating the contextual Future-Engineer role identities of the LION STEM Scholars and any changes in those identities which strengthen STEM Persistence (retention in a four-year STEM degree). The components of the DSMRI include individuals: (1) ontological and epistemological beliefs of the role; (2) purpose and goals of the role; (3) self-perceptions and self-definitions of the role; and (4) perceived-action possibilities in the role. Within the DSMRI, these four components are viewed as interdependent and identity development is considered emergent, continuous, nonlinear, and contextualized.

Figure 1. The Dynamic Systems Model of Role Identity [3]

As shown in *Figure 1,* an action taken by an individual is the objective of the DSMRI framework. An action is defined here as a specific behavior and the meaning that the behavior has on the current and future state of a certain role identity. As defined by Kaplan and Garner [3], "the action, in turn, represents a systemic event that feeds back and influences future iterations of the role identity system through its manifestation to the self and to others of commitments, or lack thereof, to certain meanings in the role" [3]. For example, if an individual believes that gaining experience via a summer internship in engineering is an essential component for building their resume for future full-time employment opportunities, the action of attending a career fair

or the action of submitting an internship application validates their current and can inform their Future-Engineer role identity. Although the DSMRI has primarily been used to analyze the development of teacher role identities, we propose that the model's focus on content (frequency, type, and richness of elements), structure (the extent of harmony or discord within and between components) and process (the dynamics of change in the components) provides a coherent and systematic framework for conducting a dynamic analysis of an individual's STEM-identity and how that identity relates to STEM-persistence. The data in this paper builds on our previous work on this project and will serve as a baseline for future longitudinal analysis of identity development.

Procedure & Participants

All incoming first year engineering students at Penn State Berks who meet the requirements for S-STEM eligibility (low-income status defined as Pell eligible) were invited to apply to become a LION STEM Scholar. An online portal accepts applications on a rolling basis throughout the year prior to admissions and a team of evaluators reviews applications and interview potential scholars in early spring. Applicants are informed of the committee's decision which coincides with the release of the university financial aid package. The participants included in this paper are from the first (2022) cohort of the LION STEM scholars (*n=7*). As discussed in the results section, complete data (due to retention) was collected for only *n=4* of the scholars in this first cohort.

Table 1. Background Characteristics and retention data for the 1st Cohort of LION STEM Scholars

Variables	N	%	N r*etention*	%
Pell Eligibility	7	100	4	57
Gender				
Male	6	86	4	67
Female	1	14	0	0
Ethnicity				
African American	2	29	0	0
Hispanic	2	29	2	100
White	3	42	2	66
First-Generation College Student	5	71	2	10

This paper provides data from three semi-structured [8] audio-recorded interviews with all seven scholars (1) prior to Engineering Ahead (Appendix A), (2) post Engineering Ahead (Appendix B) and with four scholars who completed their first semester of college (3) post first semester (Appendix C). The interviews were transcribed and then an interpretative phenomenological analysis was conducted. This analysis involved identifying superordinate themes across the narratives to better understand how scholars perceive and make sense of their personal and social world. For this paper, only the questions that pertained to engineering identity(and not the questions intentionally asked about low-income or college-student identities) were analyzed (bolded questions in Appendices). In addition, a written survey (Appendix D) using a seven-point Likert scale was also given to the four retained scholars at the end of their second semester in which only the questions involving Future-Engineer identity are included in the results of this

paper. Taken together, this repeated-measures design provides valuable insight into the development of low-income engineering students' engineering identities across their first year of college.

Table 2. DSMRI example codes from scholar interviews (adapted from [3])

DSMRI Component	Description of Component	Example Scholar Statements
Ontological & Epistemological Beliefs	Scholar knowledge and emotion from formal learning about what they believe to be the role identity of a future engineer; Sense of certainty and feelings about this knowledge.	*Ontological*: "that's what engineers do, they help build things, they help people." *Epistemological: "*seeing engineers in practice shows me that they have a better quality of life than a blue-collar worker."
Purpose and Goals	The Scholars knowledge and emotion about their personal purpose and goals for becoming a future engineer.	"I want to help lead the advancement of humanity." *Purpose of pursuing engineering.*
Self-Perceptions & Self-Definitions	The Scholars knowledge and emotions about their personal/social characteristics that pertain to becoming a future engineer.	"I would always just want to build things like I always just had this weird feeling that I needed to fix something." *Self-perception: abnormal*
Perceived-Action Possibilities	The Scholars perceptions and emotions regarding actions that could or could not be completed to achieve their purpose and goals of becoming a future engineer.	"My father was an Electrical Engineer. I already knew that was like a big possibility for me." *Action Possibilities: following in steps of role models.*

Results

Engineering Identity Pre-Engineering Ahead

Interviews conducted with the LION STEM Scholars immediately after graduating from high school indicate that their Engineering Identities had not been shaped by formal educational experience but rather their natural curiosity as children. Responses to the question about why they are seeking an Engineering degree centered around hands-on experiences *(Action Possibilities)* from their childhood in which they were curious about taking something apart and "put(ting) it back together, just to see how it works" *(Self-perception: fascination).* These experiences ranged from "mess(ing) around with various electronics" like "building a TV and

helping to take apart a toaster," to just "playing with Legos," and even to the simple task of "changing a broken light bulb." Although the Scholars were open and eager to talk about these experiences, several indicated that they felt as if their childhood engineering curiosity was abnormal. Comments included "it sounds silly, but as a kid I just loved creating things" and "for some odd reason whenever I was little, I would always just want to build things like I always just had this weird feeling that I needed to fix something" *(Self-perception: abnormal).* Although the scholars felt as if their engineering curiosity was abnormal, they connected this curiosity to their desire to help people. For example, the discussion about changing the broken light bulb was followed by the following quote: "I don't know why that struck something in me…but growing up, I was kind of fascinated with the idea of helping people." Another scholar simply stated, "that's what engineers do, they help build things, they help people" while yet mentioned that they strive to "help lead the advancement of humanity" *(Purpose and Goals: desire to help people).*

When asked about who shaped their current identities, it became apparent that the scholars' Engineering Identities upon graduating high school have mainly been formed by family influence and informal educational experiences. While one of the seven scholars described the impact that two of his high school teachers *(Action Possibilities: educational experiences*) had on his decision to pursue engineering, five of the seven scholars exclusively indicated that a family member had the greatest influence on their current identities. For instance, one scholar mentioned that "my father was an electrical engineer, I already knew that was like a big possibility for me" *(Action Possibilities: following in steps of role models).* Another scholar also indicated that his father was an engineer. However, it was revealed in subsequent conversation that neither father held a four-year college degree in engineering. At least implicitly, this points to a belief that an engineering identity might not be completely tied to earning a college degree for some of these scholars. Other references to family influence on the scholar's Engineering Identities included "my dad and my grandfather had a carpentry business and hanging around them being around the environment it (engineering) kind of just grew on me" and "I think I was like five or six and I helped my grandpa like helped him with things like building things and stuff like that" *(Action Possibilities: informal childhood engineering experiences).* One scholar even described continuous encouragement from family members to become an engineer when he explained "it definitely was people around me saying oh you'd be a good engineer and bringing that up to me, my mom has called me an engineer for a while, my dad always said it to me, my grandparents always said it to me" *(Action Possibilities: encouragement).* Even with these family experiences and explicit encouragement to become an engineer throughout their childhood, when asked to explain their identity upon graduating high school, not a single scholar self-identified as a future engineer *(Self-Definitions, lack of engineering identity).*

Engineering Identity Post-Engineering Ahead

When asked to explain their current identity upon completion of Engineering Ahead (4-week summer bridge program), every one of the LION STEM Scholars identified themselves as a current college student pursuing an engineering degree *(Self-Definition: engineering college student).* Although one student did explicitly classify herself as a civil engineer in describing her overall identity, she downplayed the definitiveness of this statement when she mentioned that she

felt like a "baby engineer." This was in alignment with the other six scholars who were somewhat hesitant to self-define as an actual engineer both when asked about their overall identity and when specifically asked if they viewed themselves as an engineer (*Self-Perceptions, emotion: hesitancy)*. Scholar's reasons for not fully embracing the identity of an engineer seemed to include not yet having the skill set needed and not having what they considered to be experience working on engineering projects. Examples of statements that indicated the lack of skills needed to identify as an engineer included "not yet learn[ing] all the skills that engineers have…like take a product and optimize it to take out into the world" and "taking classes for math and stuff like that, is not the level of where I would need to be to do engineering" (*Ontological Belief: engineers need a specific skill set*). Not having "completed an engineering project on my own" or "actually doing anything hands-on where I could say I've done this, and it connects to engineering" were also typical reasons why the scholars did not self-identify as an engineer following their completion of Engineering Ahead (*Epistemological Belief: completed projects needed to be an engineer).* However, some scholars did identify various markers in their future for which they believe would indicate that they have become an engineer. For instance, one scholar mentioned that "later towards my junior or senior years, maybe I'll get more of a feeling that I'm an engineer" and yet another indicated that he still had "four years to go…a pretty long way to be able to call myself an engineer" *(Self-Definition: not yet an engineer)* Together, these statements point to the belief that obtaining a college diploma in engineering is a marker which might alter engineering identity. This was supported by another scholar who stated, "I'll only consider myself an engineer once I get into the job field and start working" *(Ontological Belief: an engineering degree makes you an engineer).*

When asked about who or what has shaped their current identity during the interviews following Engineering Ahead, every scholar mentioned that the bridge program had contributed to their current engineering identity. In discussing how engineering was now part of his identity, one scholar recognized that he "still remembers all [his] other identities but they are not as prominent right now for [his] goals." The consensus among scholars was that Engineering Ahead made them realize that "to become an engineer, there is a lot more to it that [they] have to do. There's a lot more preparation that needs to be done" (*Epistemological Belief: realization of level of preparedness)* because they "now realize that all the small details really matter in the grand scheme of things" in engineering. Time and again scholars mentioned that the bridge program showed them how difficult it would be to obtain an engineering degree (*Ontological Belief: engineering is hard)* but most of them were now even more excited to start their engineering degrees "because of how it teaches you how to problem solve and critical think*" (Ontological Belief: engineering is about critical thinking)* and "those skills are useful for real life" *(Ontological Belief: engineering degree will help beyond career).* In addition to the inclusion of being an engineering student in their descriptions of their identities, as expected, scholars talked about the impact that the summer bridge program had with changing their identity from a high school student to a more independent college student. One scholar mentioned that "before the program I didn't really feel like a college student, and I felt like a high school student still" *(Self-perception: high school student)*. This was echoed by another scholar who explained that before Engineering Ahead "I still felt like kind of a kid or more of a high school student, but now after going through the program and then getting almost to college starting, I feel like I'm an adult now and have more responsibility" *(Self-perception: scholars are now adults).*

The biggest effect that Engineering Ahead had on strengthening scholars engineering identities seems to be the four different engineering industry visits that were part of the bridge program *(Action Possibilities: industry visits)*. For instance, one scholar who had not talked at all about the professional work of engineers in her pre-Engineering Ahead interview mentioned that "experiencing the work done in those factories…I just felt at home there, like I felt like this is what I wanted to do in my life." Also pointing to the industry tours, another scholar indicated that instead of "just doing [engineering] because people have told me to, I now want to do [engineering] because of what the job entails…and what I've seen while I was at the industries *(Purpose & Goals: change, from others to self-influence*) …like the quality of life that you would have as an engineer" one scholar explained *(Epistemological Belief: saw working as an engineer increases quality of life).* This quality of life was also brought up by another scholar who explained that the industry tours showed him the "difference between what an engineer would be versus somebody who's working as just a blue-collar worker and seeing that different has cemented the fact that I want to be an engineer" *(Purpose and Goals: white- vs. blue-collar job).*

It should be noted here that for three of the seven scholars the post-Engineering Ahead interview was the last data point recorded as they either did not successfully complete their first semester or did not return for their second semester at the university. The reasons for their lack of retention ranged from academic and disciplinary related sanctions to family obligations brought on by medical issues. Although all three of these individuals did speak about the positive effects that Engineering Ahead had on their desire to pursue engineering, two of the three were the only scholars who indicated uncertainty about their exact engineering degree choice upon entering college. One student stated, "I feel as though nothing has changed with my drive for engineering, but I feel as though I'm open to looking at other possibilities" and then went on to mention the possibility of looking into a degree in Occupational Therapy because it would allow him to improve other people's lives *(Purpose & Goals: hesitancy, possible change from engineering).* The other student who showed some uncertainty with his choice of major mentioned that the industry visits seemed to reveal to him that his specific engineering degree choice "might be too much of a niche type of degree" and was considering changing to a more general type of engineering degree *(Ontological Belief: general or more common engineering degrees are better).*

Engineering Identity Post-First Semester

After completion of their first semester in an engineering degree program, all four remaining scholars self-identified as current college students when asked to explain their current identities *(Self-Definitions: college students).* Two of the scholars mentioned engineering in their identity descriptions, but both only stated that they were "pre-engineers" or "an engineer in progress." However, later in each interview when explicitly asked if they currently viewed themselves as an engineer two of the four scholars said yes without reservations *(Self-Definitions: contradiction, engineer).* When asked to explain why he identifies as an engineer, one scholar explained "because I'm focused on solving practical problems in my classes, which seems very engineery" (*Ontological Belief: engineers solve problems).* This notion of experiencing authentic academic situations seems to also be the reason the other scholar viewed himself as an engineer *(Action Possibilities: authentic academic experiences)*. He specifically mentioned a computer

programming class in which "the stuff that [he] was doing on [his] own is what an engineer would do." In other words, he believes that being more independent and struggling to solve problems is what engineers do when they "study things by themselves and practice things by themselves" *(Ontological Belief: engineers work independently).* This scholar actually had "thought about whether or not [he] wanted to stay in engineering but decided to stay because [he] started seeing a lot more things related to" his major and as a result he has "taken even more of an interest now that [he] sees the possibilities" within his future career. It seems as if the other two students might not ever view themselves as an engineer while still being a college student as one said, "I feel like I'll like an engineer once I graduate." The other scholar believes that he would not "technically [be] an engineer until [he] passes the professional engineering exam after college" *(Ontological Belief: a student cannot be an engineer)* but does not feel like an engineer since he is "not working on anything" related to what an engineer would do in practice.

It was also found that both scholars who did view themselves as engineers talked about high engagement experiences that they were involved with on campus when explaining their current identities. One of these scholars mentioned pursuing some entrepreneurship opportunities that he learned about during Engineering Ahead and the other scholar talked about his involvement with a student run engineering club. The benefit of these engagements is best summarized by the one scholar's statement that he now "feels like [he is] part of something actually organized" *(Actions: involvement in high impact engagements).* Instead of pointing to becoming involved in high engagement activities, the scholars who did not view themselves as engineers simply attributed taking on more responsibility towards their academics (i.e., increase from high school in time spent studying) to their changes in identity at the end of their first semester of college. One of these scholars also mentioned that he "learned the importance of money" during his first semester when he could no longer depend on his family for things like "food, gas, and college textbooks or supplies" *(Action Possibilities: financial literacy education before college).*

Engineering Identity Post-Second Semester

Upon the completion of the second semester of college, a written survey (Appendix D) was given to the four retained scholars. Scholars were asked to provide their level of agreement for each statement (from 1=Strongly Disagree to 7=Strongly Agree). Only the questions involving Future-Engineer identity (Questions 11-24) are included in the results of this paper. The median responses for those questions are provided in Figure 2.

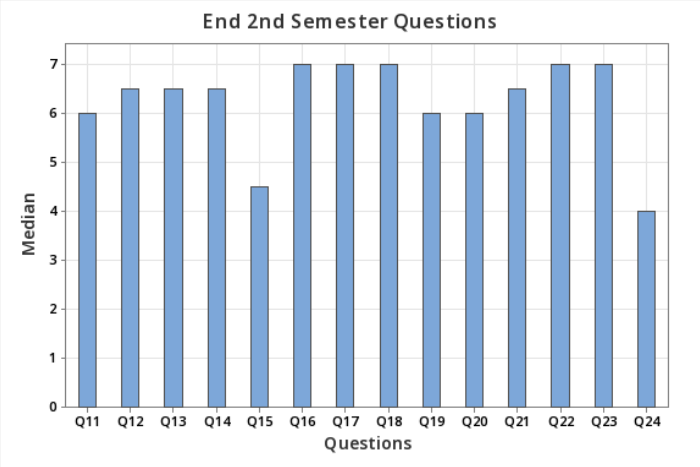

Figure 2. Median responses to Engineering-Identity post second semester survey

When asked if they viewed themselves as engineers (Q11), all four scholars provided a score of 5 or higher (*Med=6*), indicating that they all more than just agreed with that statement. This indicates a shift in identity for at least two of the scholars who did not view themselves as an engineer following their first semester of college. When asked if their families (Q12), instructors (Q13) and peers (Q14) view them as engineers, agreement was higher for each of these questions. Perhaps this difference in level of agreement is because the scholars had only a neutral agreement (*Med=4.5*) with the statement that they have had experiences in which they have been recognized as engineers (Q15).

When responding to statements about their interest and confidence in engineering, all four scholars provided a response of 7 (Strongly Agree) for their interest in learning more about engineering (Q16), their enjoyment of learning engineering (Q17), and finding fulfillment in doing engineering (Q18). These strong agreements are in harmony with responses to the statement that they have chosen the correct career in engineering (Q23). Although interest in engineering at the end of their first year of college is extremely high, agreement to statements about confidence in engineering classes (Q19) and confidence in understanding engineering outside of class (Q20) were not as strong. However, all scholars strongly agree with the statement that they can overcome setbacks in engineering (Q22) even though they do not all strongly agree that they understand the concepts that they have studied in engineering (Q21). Finally, the scholars are neutral (*Med=4*) when comparing how hard they think they work as compared to their peers in engineering (Q24).

Discussions

Results from the interviews which occurred immediately after high school graduation indicate that scholars generally struggled with expressing their personal identities—sense of self established by unique traits, affiliations, or social roles. All scholars had been accepted into a four-year engineering degree and committed to attend a large R1 institution, yet they did not self-identify as future engineers. However, the degree which individuals are seeking is one of the most common ways that universities use to classify students during the admission and enrollment process (i.e., assigning advisors, course selection). This mismatch between self and university

classifications could perhaps lead to future struggles surrounding identity development and persistence to degree completion. While an estimated one in three college students switch majors at least once [5], could this number be lowered if robust K-12 identity education programs that center on future professional and career aspirations were developed and implemented? Because future identities are known to provide a powerful source of motivation when faced with adversity [7], we hypothesize greater persistence in students who already have their future careers embedded into their identities upon college enrollment. Of particular interest to us are engineering degrees which only account for about 6% [6] of all college students but which have some of the lowest retention rates. We also believe that pre-college career identity development could have a significant impact on retention of underrepresented minorities (e.g., first generation, low-income, women, ethnic) in engineering who often report challenges with their sense of belonging [9] in a field dominated by white males.

While scholars did not include engineering in their personal identity descriptions prior to Engineering Ahead, their responses to questions about why they are pursuing engineering reveal that they indeed possess characteristics of future engineers. They often spoke about the influence that family members had on their childhood experiences in which their natural curiosity and creativity were used to build and take objects apart. Although several scholars classified these characteristics as "abnormal," they all talked about pursuing engineering because of family encouragement and their desire to help people. Missing, however, from all but one of these interviews were mentions of any formal K-12 educational experiences related to engineering. We have thus previously called for a need to normalize young children's desire to use their hands by creating more formal engineering education experiences in elementary school curriculums and a need to begin talking about engineering not just as a science or technology discipline, but as a more human service-oriented career that sets out to improve people's lives. Further, the deeply rooted family influences which shape these scholars' pre-college identities suggests that colleges and universities should look for ways to involve families in the educational pursuits of low-income students. To our knowledge, there is only one S-STEM Award (#2030665) which has taken this into consideration by developing regular family gatherings designed to include scholars' families in supporting their students' degree completion.

Summer bridge programs are often cited as one of the best practices for increasing first year student retention and thus we are not surprised with the change in identities that we found in scholars upon completion of Engineering Ahead. Not only did all scholars self-report a change in identity from that of a high school student to a college student, but they also all identified as *engineering* college students following the summer bridge program. This change in identity seemed to develop from a combination of the opportunities they had to engage in engineering related curriculum during Engineering Ahead, as well as the realization of their new responsibility of being accountable for their own education. Moreover, the four engineering industry tours that were part of the program seemed to be most impactful on the development of scholars engineering identities. Several scholars talked about the fact that this was the first time they experienced a professional engineering environment and could envision themselves one day being in those environments. Scholars were still skeptical however to fully embrace the identity of an engineer as they believed they had yet to acquire a sufficient skill set needed to work on engineering related projects. We therefore recommend embedding engineering related design projects into engineering bridge programs to provide students with real-world experiences in which they are treated and recognized as engineers. We believe that pairing these experiences

with continued industry visits will help students further develop their engineering identities prior to the start of their first semester of college.

As described in the results section, only four of the seven scholars successfully completed their first semester of college and the three who were not retained declined an invite to complete an exit interview when they left the university. Knowing more about the development (or lack of development) of the non-retained scholars' identities seems valuable in our work to help increase persistence in engineering. We therefore suggest future projects on engineering identity might consider more frequent data collection points throughout the first semester of college. When analyzing the post Engineering Ahead interviews of these scholars (our last collected data), it was found that two of the three were the only individuals who spoke about the possibility of changing their majors prior to their first day of classes. Because of their uncertainty in major choice, we suspect that these two scholars had a weakly developed engineering identity which ultimately contributed to their lack of persistence. If not retained in engineering, perhaps connecting these scholars to more career and major explorations during their first semester of college could have at least led to university retention. Undergraduate students who enroll in college as an undecided major are often provided with unique advising and interdisciplinary academic experiences to help foster their exploration of various college majors which might align with career aspirations. But how often are similar experiences provided to students who enter college with a chosen major but who might not have a strongly developed future career identity in that major? Developing a tool for assessing the strength of future career identities would be helpful in identifying this population of students who we suspect are often under-supported in higher education.

When analyzing the post first semester surveys for the four scholars who were retained, various degrees of changes in their engineering identities were observed. Although all four scholars still only self-identified as engineering *students* when asked broadly to describe their identities, two of the four scholars affirmatively responded "yes" when they were asked later in the interview if they viewed themselves as engineers. This contradiction reveals that the engineering identities for these two scholars are still forming and are not yet fully integrated into their overall identities. Integrating professional career identity development (i.e., behavioral norms, standards, values) throughout the first year of an engineering program therefore seems promising for helping students think, act, feel more confident in self-identifying engineering as part of their overall identities. Not surprisingly, differences in answers between the scholars who did and did not classify themselves as engineers also reveals that involvement in high engagement co-curricular activities (e.g., clubs, undergraduate research, mentoring) appear to strengthen engineering identity. One scholar who classified himself as an engineer talked about his involvement with a specific student-run engineering club, while the other discussed his involvement with a university-affiliated office who mentors students who aspire to become entrepreneurs. While the interviews following Engineering Ahead suggest that a change in engineering identity seems to develop at least partially from engaging in authentic engineering curriculum, the fact of the matter is that the curriculum for many first-year baccalaureate engineering students often includes only a minimum number of engineering specific classes. In fact, the two scholars who said they were not engineers pointed to the fact that they only had taken one engineering class (Engineering Design) and therefore did not feel as if they had significant experiences with engineering. In addition to helping connect students to high engagement co-curricular activities, engineering programs nationwide should review and modify

curriculums to increase the number of authentic engineering experiences for first year students. This recommendation aligns with the work that a group of researchers from the S-STEM Collaborative Research HUB (Award #2030665) is currently working on with regards to redesigning engineering curriculum based on viewing curricular complexity as a boundary object.

When given a written survey (Appendix D) at the end of their second semester, all four scholars agreed (5 or higher on a 7-point scale) with the statement that they viewed themselves as engineers. This indicates that a shift in engineering identities occurred for the two scholars who had previously not believed that they were engineers. Interestingly, the overall agreement of the scholars' views of themselves as engineers was lower than agreement to questions that asked if they believe their families, instructors and peers view them as engineers. This finding paired with slightly lower levels of agreement to questions related to their confidence in engineering (both inside and outside of the classroom), suggests that scholars might at least subconsciously be experiencing Imposter Syndrome [1]. Imposter Syndrome might also have led to the lower levels of agreement that scholars provided when asked how hard they work compared to their peers in engineering. Another possible explanation however is that following the second semester of college, scholars only reported a neutral agreement to the statement that they have had experiences in which they have been recognized as engineers. Especially underrepresented minority students, we believe that education around overcoming Imposter Syndrome and creating opportunities to recognize students as engineers, would positively impact the development of first year students' engineering identities.

Conclusions

The results of this interpretative phenomenological analysis begins to capture how low-income students develop their engineering identity across their first year of an undergraduate engineering degree program. Since low-income students tend to be a "hidden" population in higher education, this study gives a voice to the unique experiences of this ever-increasing population of students. Creating both curricular and co-curricular programs that are designed to support identity development could have a significant impact on university retention. The future of our research includes continuing to collect and analyze data for each scholar upon completion of each of their future semesters in their undergraduate programs. Replication of this process will also occur for several more cohorts of LION STEM Scholars, thus adding to the power of our results. Beyond just the development of an engineering identity, we are interested in using the Dynamic Systems Model of Role Identity to investigate the integrative nature of how low-income, college-student and future-engineer role identities affect overall identity and ultimately persistence in engineering.

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Appendix A

Pre-College, Pre-Engineering Ahead Interview Script

1. **Who are you? How would you explain your identity at this current moment in time?**
2. **Who or what has shaped your current identity?**
3. How often was the thought of you attending college discussed in your childhood? Can you explain those conversations?
4. Why did you decide to pursue a college education? Did you always know you would be attending college?
5. What are some barriers that you have had to overcome to be where you are today?
6. To what extent do your family/friends support your decision to attend college? Can you provide some specific details?
7. **Why did you decide to pursue a degree in Engineering? Who or what influenced that decision?**
8. What is your view of income inequality in America?
9. How affordable do you believe a college education is in today's America?
10. How worried are you about being able to afford your college education? Have you had any conversations in the past with your family about this?
11. **What is your purpose for attending college? At this point in time, what are some of your personal goals?**
12. How prepared do you believe you are for college? What are some specific reasons why you feel this way?
13. Is there anything about your academics that you know you will need to work on to improve to be successful in college?
14. What do you believe to be the financial benefits of obtaining a college degree?
15. What are your expectations of becoming a college student? How similar or different do you think it will be to your other educational experiences to date?
16. What do you do when you run into an academic struggle? How do you overcome academic setbacks?
17. What does the phrase academic persistence mean to you?

Appendix B

Pre-College, Post-Engineering Ahead Interview Script

1. **Who are you? How would you explain your identity at this current moment in time?**
2. **Who or what has shaped your current identity?**
3. A role is a function that is assumed, or a part played by a person or thing in a particular situation. How would you define the role of a college student?
4. Why are you deciding to pursue a college education? Has it changed due to Engineering Ahead?
5. What are some barriers that you believe you will have to overcome to be successful?
6. To what extent do your family/friends support your decision to attend college? Can you provide some specific details?
7. **Why did you decide to pursue a degree in Engineering? Has this changed due to Engineering Ahead?**
8. **Do you view yourself as an engineer? Why or why not?**
9. How worried are you about being able to afford your college education? Have you had any conversations since we last spoke with your family about this?
10. **What is your purpose for attending college? At this point in time, what are some of your personal goals? What actions will you take to achieve these goals?**
11. How prepared do you believe you are for college? What are some specific reasons why you feel this way?
12. Is there anything about your academics that you know you will need to work on to improve to be successful in college? Do you have any plans to improve this?
13. What do you believe to be the financial benefits of obtaining a college degree?
14. What are your expectations of becoming a college student? Has this changed due to Engineering Ahead?
15. What are you planning on doing when you run into an academic struggle? How do you plan to overcome academic setbacks?
16. What does the phrase academic persistence mean to you?

Appendix C

Post-First Semester Interview Script

1. **Who are you? How would you explain your identity at this current moment in time?**
2. **Has your identity changed since the last time we spoke? What led to this change in identity?**
3. What is the purpose of attending college? Do you have any personal goals?
4. How often and to what extent do you or your family worry about college affordability?
5. Do you have a job outside of being a college student? Why do you have this job?
6. Describe an obstacle that you have been faced with since we last talked and explain how you overcame that obstacle.
7. What obstacles do you anticipate having to overcome in your future?
8. What effect has the LION STEM scholarship had on your college career?
9. What do you believe to be the financial benefits of obtaining a college degree?
10. Are you a "typical" college student? Why or why not?
11. Can you tell me about a recent experience in which you felt very successful and proud? What do you think caused your success? Why did this event make you feel proud?
12. Can you tell me about a recent experience in which you felt that you had failed? What do you think caused the failure? What did you do as a result of the failure?
13. How is your level of academic success related to the amount of effort that you put into your studies?
14. Who or what has been most influential in your college education thus far? Who is your support system?
15. How has being a member of the LION STEM program impacted your college experience?
16. What components of the LION STEM program have been most beneficial? Least beneficial?
17. Do you ever feel like you do not belong in college? Why or why not?
18. How have your friends or family said you have changed or are different since enrolling in college?
19. What could you do to become a better college student? Is there anything that stops you from doing this?
20. **Who or what has influenced you to stay in your major? Have you ever felt pressure to remain in your degree? Do you believe you are pursuing the correct degree? Why or why not?**
21. What do you hope your life will look like after college?
22. **Do you view yourself as an Engineer? Why or why not?**
23. What does the phrase academic persistence mean to you?

Appendix D

Post-Second Semester Survey

Directions: Please rank your level of agreement with the following 40 questions from Strongly Disagree (1) to Strongly Agree (7).

(1) In general, I find mathematic boring.

Strongly Disagree	1	2	3	4	5	6	7	Strongly Agree

(2) I am good at mathematics.

Strongly Disagree	1	2	3	4	5	6	7	Strongly Agree

(3) When someone asks me questions to find out how much I know about mathematics, I worry that I will respond poorly?

Strongly Disagree	1	2	3	4	5	6	7	Strongly Agree

(4) I have a certain amount of mathematical intelligence and there is no way to change this.

Strongly Disagree	1	2	3	4	5	6	7	Strongly Agree

(5) I like mathematics.

Strongly Disagree	1	2	3	4	5	6	7	Strongly Agree

(6) I was born with a fixed mathematical intelligence, and I cannot change this intelligence throughout my life.

Strongly Disagree	1	2	3	4	5	6	7	Strongly Agree

(7) I am better at mathematics than most of my peers.

Strongly Disagree	1	2	3	4	5	6	7	Strongly Agree

(8) I have a certain amount of intelligence, and I can't really do much to change it.

Strongly Disagree	1	2	3	4	5	6	7	Strongly Agree

(9) My intelligence is something about me that I have the ability to change.

Strongly Disagree	1	2	3	4	5	6	7	Strongly Agree

(10) I can learn new things, but I can't really change my basic intelligence.

Strongly Disagree	1	2	3	4	5	6	7	Strongly Agree

(11) I view myself as an engineer.

Strongly Disagree	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Strongly Agree**

(12) My family sees me as an engineer.

Strongly Disagree	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Strongly Agree**

(13) My instructors see me as an engineer.

Strongly Disagree	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Strongly Agree**

(14) My peers see me as an engineer.

Strongly Disagree	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Strongly Agree**

(15) I have had experiences in which I was recognized as an engineer.

Strongly Disagree	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Strongly Agree**

(16) I am interested in learning more about engineering.

Strongly Disagree	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Strongly Agree**

(17) I enjoy learning engineering.

Strongly Disagree	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Strongly Agree**

(18) I find fulfillment in doing engineering.

Strongly Disagree	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Strongly Agree**

(19) I am confident that I understand engineering in class.

Strongly Disagree	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Strongly Agree**

(20) I am confident that I understand engineering outside of class.

Strongly Disagree	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Strongly Agree**

(21) I understand concepts I have studied in engineering.

Strongly Disagree **1 2 3 4 5 6 7** **Strongly Agree**

(22) I can overcome setbacks in engineering.

Strongly Disagree **1 2 3 4 5 6 7** **Strongly Agree**

(23) Engineering is the correct career for me.

Strongly Disagree **1 2 3 4 5 6 7** **Strongly Agree**

(24) I work harder than my peers in engineering.

Strongly Disagree **1 2 3 4 5 6 7** **Strongly Agree**

(25) I made the correct decision to attend college.

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree

(26) I feel a sense of belonging to the campus community.

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree

(27) My experiences at Penn State have helped me to set *personal* goals.

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree

(28) My experiences at Penn State have helped me to set *professional* goals.

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree

(29) Program and services at Penn State meet my needs.

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree

(30) I have relationships with other Penn State students.

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree

(31) I am a typical college student.

Strongly Disagree	1	2	3	4	5	6	7	Strongly Agree

(32) I have professional relationships with Penn State faculty.

Strongly Disagree	1	2	3	4	5	6	7	Strongly Agree

(33) I have professional relationships with Penn State staff.

Strongly Disagree	1	2	3	4	5	6	7	Strongly Agree

(34) Penn State has helped me progress in my career development.

Strongly Disagree	1	2	3	4	5	6	7	Strongly Agree

(35) I have developed as a leader during my time at Penn State.

Strongly Disagree	1	2	3	4	5	6	7	Strongly Agree

(36) Education is the best pathway out of poverty.

Strongly Disagree	1	2	3	4	5	6	7	Strongly Agree

(37) Poverty can affect the ability to perform well in school.

Strongly Disagree	1	2	3	4	5	6	7	Strongly Agree

(38) Obtaining a college degree will help me become financially stable.

Strongly Disagree	1	2	3	4	5	6	7	Strongly Agree

(39) I often worry about money.

Strongly Disagree	1	2	3	4	5	6	7	Strongly Agree

(40) Graduating college with little to no student debt is important to me.

Strongly Disagree	1	2	3	4	5	6	7	Strongly Agree