Does EPICS as a pre-college program foster engineering identity development as correlated to doing engineering?

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Does EPICS as a pre-college program foster engineering identity development as correlated to doing engineering?

Engineering Projects in Community Service (EPICS) is a middle and high school program, supported by Arizona State University's Ira A. Fulton Schools of Engineering, Tempe, Arizona, with a focus on the engineering design process and delivering real solutions to community partners [1]. In order to evaluate the efficacy of the program, a pre/post-test design was implemented to examine changes in attitudinal and behavioral measures. Pre-data were collected at the beginning of the school year and paralleled the program's registration process to ensure high response rates; post-data were then collected at the end of the school year. Demographic data demonstrate that of all 2018 - 2019 registered EPICS participants (N = 414), 41 percent were female; 66.6 percent were non-white; and 30 percent held first generation student status. Importantly, 68.5 percent of participants reported that neither parent or guardian is an engineer, and 65.7 percent of participants reported that they "definitely will attend" a four-year university. These data suggest that the current sample is ideal for evaluating EPICS as a pre-college engineering education program, because most participants are not experiencing engineering in the home but have salient intentions to attend college. In addition to collecting demographic information, participants completed a series of measures designed to capture attitudes and behaviors toward engineering as a potential career field. The main measures of interest include Engineering Identity and Doing Engineering. Engineering Identity scores reflect participants' personal and professional identities as engineers; Doing Engineering scores indicate participants' prior experience with engineering and its related technical skills. Boys reported significantly higher engineering identities (M = 37.65, SD = 6.58) compared to girls (M = 39.54, SD = 6.09), $t(360)$ = 2.95, p = .003. Boys reported stronger and more frequent experiences with engineering, indicated by their higher Doing Engineering scores (M = 13.75, SD = 5.16), compared to girls (M = 15.31, SD = 4.69), $t(368)$ = 3.13, p = .002. Interestingly, first generation students reported higher engineering identities (M = 37.45, SD = 6.53) compared to non-first generation students (M = 39.66, SD = 5.99), $t(375)$ = 3.46, p = .001. To examine the relationship between Engineering Identity and Doing Engineering, a correlation analysis was conducted and a moderate, positive relationship emerged, such that as students' experience with engineering increased, their engineering identities also increased (R = .463, p > .000).

Introduction

Researchers have established identity development as a strong predictor of academic attainment in students. However, there exists significant variability in student identity development [2]. For example, women have consistently demonstrated lower self-ratings of academic ability and self-efficacy compared to men [3]. This finding has been used to support several theories regarding the lack of female representation in STEM [4]. If women are less confident in their academic abilities, their performance may be negatively impacted; this may account for why women earn STEM degrees at a lesser rate than men [4]. Moreover, the gender gap in STEM academia and career fields is aggravated in specific subfields, including computer science and engineering [5]. As a result, considerable effort by engineering education researchers has been given to examine students' identity development as engineers [6], [7], [8], [9], [10]. Findings implicate engineering identity as a significant indicator of success, in both academic and professional settings [4]. These data further support the notion that students who consider themselves competent and capable in STEM - therefore showcasing high engineering identities - will more likely persist in their undergraduate engineering degree programs. This is due to the demonstrable relationship between engineering identity and STEM competency [11]. This approach yields several benefits, including exploration of identity development in a diverse student sample; evaluation and assessment of a pre-college education program; and analysis of yield, retention, and persistence in a pipeline that promotes entry into one of the largest engineering schools in the country.

Engineering Projects in Community Service (EPICS) is a middle and high school program, focusing on the engineering design process and the delivery of tangible solutions to community problems [1], [12]. EPICS High is implemented by the Ira A. Fulton Schools of Engineering at Arizona State University, as part of a university-wide effort to diversify engineering [13]. Students participating in the EPICS program gain valuable engineering-related experiences [14], including interactive lessons on the engineering design process, experiential learning of technical skills such as computer-assisted design, and hands-on practice working with a diverse team. EPICS students are also invited to exclusive engineering events throughout the academic year, hosted by the Ira A. Fulton Schools of Engineering's Engineering Education and Outreach unit: EPICS Olympiad, a rapid prototyping kick-off event; Pitch Funding, a process by which EPICS teams can submit a pitch and receive funding of up to $500 to deliver their projects to community partners; and EPICS Showcase, a closing event for teams to be recognized for their hard work and earn merit scholarships from sponsors (including CISCO) [14]. These events take place at Arizona State University's Tempe campus, which provides students with first-hand university life experiences. Moreover, EPICS was developed in response to a need for creative and flexible teaching approaches to engineering, and since its adaptation in the Phoenix metropolitan area has served nearly 3,700 students. Further, implementation of EPICS targets underserved communities, including Title I and Hispanic majority schools. Because EPICS is construed as a service-oriented learning experience, the program inherently encourages a diverse group of student participants. In other words, EPICS is not billed as an engineering course, but rather as a service-learning opportunity [15], [16]; this diversifies the students who are interested in engaging with the program. Finally, EPICS features an adaptable curriculum that can be molded to fit any of the following options: i) in-school model EPICS is a required course: an example is where the school uses the EPICS course as a senior capstone experience; ii) in-school model EPICS is an elective course: an example is where EPICS is offered as an elective where students have choice from a select few courses; iii) in-school model EPICS is integrated into an existing course: an example is where EPICS is integrated into an existing STEM course such as an engineering, Career and Technical Education, business entrepreneurship or other course; and iv) out-of-school model where EPICS is offered as an after-school student organization or club (see Figure 1). All EPICS facilitators are certified teachers who undergo a two-week intensive summer training, lead by Ira A. Fulton Schools of Engineering program faculty and staff. EPICS programming is offered at no cost to schools that select to participate. The EPICS curriculum centers on the engineering design process, and features an experiential learning component that requires students to research a local problem, identify a community partner, and engineer a tangible solution that students can deliver to their community. Students participate in EPICS for at least one academic year.

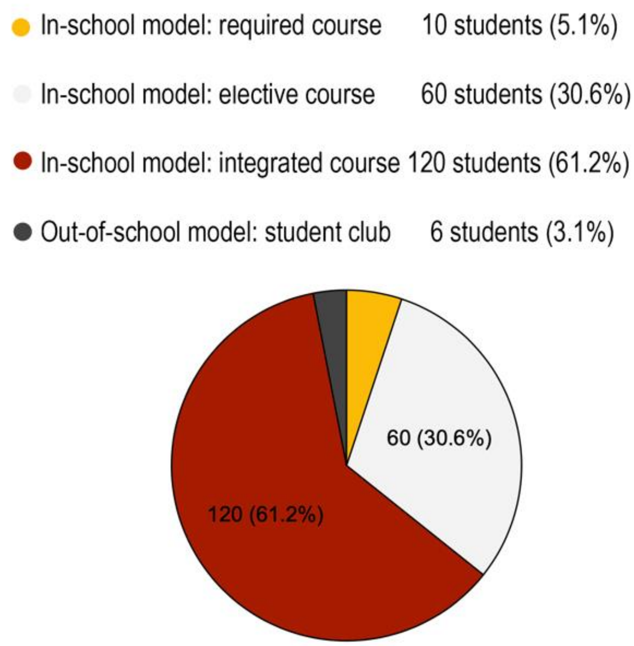

Figure 1. Distribution of EPICS High models by student enrollment 2018-19

Method and Measures

In order to assess students' changes in engineering identity as a result of participation in EPICS, a pre-post test design was used. At the start of the academic year, all EPICS students were required to register their participation via the online survey platform Qualtrics. The registration process was bifurcated; with the help of a parent, students completed consent forms, academic and health histories (necessary for risk-management purposes, as EPICS students visit the university), and provided parental contact information before completing a series of measures (see Table 1). The measures were aimed at capturing students' attitudes and behaviors toward engineering. The main measures of interest include Engineering Identity (see Table 2) and Doing Engineering (see Table 3) designed by Terence J. Tracey, a counseling psychologist and Tirupalavanam G. Ganesh, an engineering education researcher [17]. These measures were designed based on James Marcia's theory [18], [19] and building upon Betz and Hackett's [20] work in studying self-efficacy. Based on Marcia's theory [18], [19], that identity development in youth is the degree to which one has explored and committed to a vocation we posit that achieving an engineering identity includes: *crisis*—i.e., a time when one's values and choices are being examined and reevaluated, and *commitment*—when the outcome of a crisis leads to a commitment made to becoming an engineer. This time, of crisis and commitment occurs for youth during their middle and high school years. Engineering Identity scores reflect the extent to which a student self-identifies as an engineer. Students provided responses to 15 items, using a 5-point Likert-type scale ranging from *strongly agree* to *strongly disagree*; lower scores indicate higher engineering identities. Doing Engineering scores showcase a student's prior experience with engineering and its related technical skills. Students responded to 8 items, again using a 5-point Likert-type scale ranging from *strongly agree* to *strongly disagree*; lower Doing Engineering scores indicate stronger and more frequent prior experiences with engineering. In addition to these measures, students completed a demographics survey in which they provided their age, gender, race/ethnicity, first generation status, and future plans for college. At the end of the academic year, all registered EPICS participants were sent the post-survey via an anonymous Qualtrics link. The post-survey mirrored the pre-survey, but with the inclusion of open-ended questions and the removal of the registration section.

TABLE 1
PSYCHOMETRICS AND MEASURES COMPLETED BY EPICS STUDENT PARTICIPANTS

Measure	Description
Student plans for course taking	Students indicate which science and mathematics courses they have completed or plan to take in high school (i.e. Calculus, Physics)
Engineering Identity	Students respond to 15 statements related to attitudes and behaviors about engineering (see Table 3)
Doing Engineering	Students respond to 8 statements corresponding to experience with a specific engineering skill (see Table 4)
Career Expectations	Students express how important 10 factors are when considering their future career plans (i.e. salary, challenging work)
Career Awareness	Students rate the extent to which they are aware of 7 popular professions, including engineering (i.e. doctor, scientist)
Career Choice	Students rate the extent to which they believe each profession is a good or bad career choice
Describe Engineers	Students rate how well 21 descriptors accurately describe engineers (i.e. mostly male, entrepreneurial)
Describe Engineering	Students rate how well 8 statements accurately describe engineering as a career field (i.e. must be smart, too difficult)

TABLE 2.
ITEMS IN THE ENGINEERING IDENTITY MEASURE

1. I enjoy making things
2. I have spent time trying to find out more about what engineers do
3. I am not sure that engineering is for me
4. Being an engineer is important to me
5. I do NOT know what engineers do
6. I think I will make a good engineer when I grow up
7. I work hard to understand how things work
8. I understand pretty well what being an engineer means
9. I have often talked to other people in order to learn more about what it is like being an engineer
10. I have doubts about my ability to become an engineer
11. Engineers work on important projects
12. I can see myself as an engineer
13. Being an engineer is an important part of who I want to be
14. Other students seem to be more of an engineer than I am
15. I worry that I am not good enough at the subjects I need to become an engineer

TABLE 3.
ITEMS IN THE DOING ENGINEERING MEASURE

1. I have designed something
2. I have worked together with a team to solve a problem
3. I have built something
4. I have written a computer program
5. I have done a chemistry experiment
6. I have built a model
7. I have done a science experiment
8. I have worked together with a team to design, build, and deliver a solution to a problem for a client

Results

Demographic data demonstrate that of all 2018 - 2019 registered EPICS student participants (N = 414), 41 percent were girls; 66.6 percent were non-white; and 30 percent were first-generation. Importantly, 68.5 percent of students reported that neither parent or guardian is an engineer, and 65.7 percent of students reported that they "definitely will attend" a four-year university. These data suggest that the EPICS student population is ideal for evaluating EPICS as a pre-college engineering education program, because the majority of participants do not experience engineering in the home and thus lack the exposure or encouragement to choose engineering as a college major and potential career, but also because the majority of participants have salient intentions to attend college (see Table 4). Pre-survey data reveal that students begin the EPICS experience with ill-formed engineering identities. The sample's average engineering identities centered on the scale's median (M = 37.65, SD = 6.44, 95% CI [37.77, 39.05]). Paralleling extant research findings, boys reported significantly higher Engineering Identity scores (M = 37.65, SD = 6.58) compared to girls (M = 39.54, SD = 6.09), $t(360) = 2.95$, $p = .003$, $F = .037$. Boys also reported significantly higher Doing Engineering scores (M = 13.75, SD = 5.16) compared to girls (M = 15.31, SD = 4.69), $t(368) = 3.13$, $p = .002$, $F = .003$.

TABLE 4.
DEMOGRAPHIC DISTRIBUTIONS OF 2018 – 2019 REGISTERED EPICS STUDENTS

Factors	Levels	Distributions
Gender		
	Boys	59.4%
	Girls	40.6%
Race/Ethnicity		
	American Indian	1.70%
	Asian	9.40%
	Black or African American	3.10%
	Hispanic/Latinx	24.9%
	Native Hawaiian	1.40%
	White	44.4%
	Multiple Races	7.70%
	Do not wish to provide	7.20%

Factors	Levels	Distributions
First Generation		
	Yes	29.9%
	No	70.1%
Free, Reduced Lunch		
	Yes	25.3%
	No	58.6%
	Unsure	16.1%
Parent Engineer		
	Two parents	3.10%
	One parent	15.3%
	Neither parent	68.5%
Will you attend college?		
	Definitely will attend	65.7%
	Probably will attend	20.2%
	Chances are 50/50	10.1%
	Probably not	3.30%
	Definitely not	0.80%
Grade Level		
	6th	2.40%
	7th	4.60%
	8th	21.2%
	9th	4.80%
	10th	9.70%
	11th	30.8%
	12th	26.6%

These findings are unsurprising, given the theoretical link between the strength and frequency of a student's experiences with engineering and their engineering identities. To statistically test the potential relationship between Engineering Identity and Doing Engineering, a correlation analysis was conducted. A moderate, positive relationship between the two variables emerged, such that as students' prior experience with engineering increased, their engineering identities also increased ($R = .463$, $p > .000$). Not only does this finding closely follow the study's logic mod, but it is also supported by previous research on engineering identity development in adolescents (Godwin, 2016). However, one unexpected result did emerge: students who self-identified as first generation, using the Department of Education's definition by which neither parent or guardian attained a college degree, reported higher engineering identities ($M = 37.45$, $SD = 6.53$) compared to non-first generation students ($M = 39.66$, $SD = 5.99$), $t(375) = 3.46$, $p = .001$, $F = 1.39$. Because limited research on first generation status as a demographic variable has been conducted, it is difficult to contextualize this finding; one possible explanation is that students who do not experience exposure to STEM careers in the home may find engineering opportunities more interesting, given the novelty, and thus are more impressionable to forming identities as future engineers.

Discussion

Unfortunately, post-survey data are less illuminating. No significant changes in EPICS students' Engineering Identity between the pre-survey and the post-survey occurred. One potential reason is that because the sample's scores at baseline (M = 38.41) were so closely centered around the median of the measure that a floor effect emerged, preventing any further gains from being detected at the post-survey phase (M = 38.88). Another explanation is that because the majority of the sample were boys, a group which research demonstrates is more likely to show confidence and efficacy in STEM, a skewing effect emerged such that the group mean was influenced by outlying scores. There did emerge a significant increase in Doing Engineering scores, suggesting that EPICS students gained a greater understanding of who engineers are and what engineers do because of participation in the program. Moreover, an interaction effect emerged, such that girls experienced greater gains in Doing Engineering scores compared to boys. This particular finding parallels extant research on girls' experiences in STEM, by suggesting that mere exposure to engineering can cause increases in girls' STEM identities [2].

A more robust data collection procedure has been implemented in the 2019 – 2020 academic year, in an effort to further examine the positive effects of EPICS participation on students' attitudes and behaviors toward engineering. For example, qualitative analyses of interviews with EPICS students will be conducted, as well as content analysis of EPICS team charters and Pitch Funding requests. This mixed methods approach will shed light on the quantitative data to be collected. Also, the current study as designed did not include a comparison group of students in the same schools but not enrolled in EPICS. A student that includes a comparison group of students like EPICS participants may help identify the effect of self-selection into EPICS by students who already hold a high engineering identity prior to entry into EPICS. Ultimately, future research efforts will help to enrich our current understanding of how Engineering Projects in Community Service, an informal educational program aimed at increasing middle and high school students' participation in engineering-related activities, may advance inclusion of under-represented populations in engineering pathways.

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