

Work in Progress: Engineers from Day One

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Work in Progress: Engineers from Day One: A Pilot Collective Impact Alliance Effort to Foster Engineering Identity

Introduction

This Work in Progress paper reports on an effort that aims to address the broadening participation challenge in engineering. Through a National Science Foundation sponsored project, a pilot collective impact alliance [1], [2] was formed to enhance entry and persistence in engineering of first-generation students, women, under-represented ethnic minorities, and those with socio-economic need. The distinctive mark of this alliance is that it comprises a range of organized to self-adapting systems [3] that learn from and respond to each other around the goal of broadening participation in engineering.



Figure 1. Outcomes essential to foster Engineering Identity

The approach adopted is to foster engineering identity [4], [5], [6], [7] development through advancement of (AEIOU) **awareness**, **enjoyment**, **interest**, **opinion formation**, and **understanding** of engineering via deliberately designed experiences centered on how engineering is socially and personally relevant. We posit that **awareness** about engineering and its social relevance will lead to **enjoyment** that could engender a deep **interest**. This **interest** will lead to **opinion formation** and **understanding** about engineering that will result in purposeful choices to pursue engineering pathways thereby affecting entry coordination between one of the largest comprehensive research public universities and one of the largest countywide community college systems in the US with select K-12 feeder systems. The pilot alliance aims to ultimately identify and

develop effective mechanisms to impact entry and persistence in engineering at scale [8] to expand the alliance for the region, serving as a model for [the state] and other universities nationally. And a key aspect of heightening awareness of such an effort is to disseminate information about proposed mechanisms and seek continuous input from a community of practice and scholars such as national level conferences.

This work in progress paper will report on initial measures implemented to collect data about participants' awareness and interest in engineering and engineering identity development. As the alliance is in its initial formative stages, data and analysis about how the pilot collective impact alliance is developing, what mechanisms are effective, and their potential for scalability will be presented in future reports.

The systems involved in the pilot alliance are—Arizona State University, a large comprehensive public research-intensive university; Maricopa Community Colleges, one of the largest community college systems in the nation, four area high school districts, industry and community foundation partners, along with participants’ families—are inherently complex and represent dynamic networks of interactions among various actors. The actors are students, parents and family members, K-12 teachers, faculty and academic advisors at the university and community college, high school counselors, near peer and peer mentors, alumni and industry mentors, university career specialists, and academic leaders of partnering institutions. The relationships between these actors, their institutions, and their respective students are such that behaviors are adaptive and can self-organize to the change-initiating micro-events of supporting student success. This adaptation and change is possible through deliberately designed activities and experiences—micro events for participants—that ensure entry and persistence across the education spectrum. These activities and experiences at various levels across high school, community college, and university expressly address the challenges faced by first-generation students who may lack the incentives and motivation to pursue engineering pathways.

Specifically, in the framework adopted by the pilot alliance, the thread of engineering identity development as *Engineers from Day One* is woven through the K-12, community college, and university continuum [9] to enable a dynamic and adaptive systems approach for broadening participation [10], [11] in engineering. The AEIOU framework (Figure 1) undergirds a common agenda and the pilot alliance’s data collection efforts, and will be used to study the efficacy of the proposed mechanisms [12] while supporting continuous improvements in broadening participation [13] across the alliance.

Motivation and Rationale

It is well established that attracting and retaining more first-generation students, women, underrepresented ethnic minorities and those with socio-economic need in the engineering workforce will augment innovation, creativity, and global competitiveness. A diverse workforce [14] will result in enhanced scientific and technological products, services, and solutions that will be better designed and represent all users. Fostering diversity driven creativity requires a collective effort with a cross-section of social institutions to open a multiplicity of pathways for students to enter, retain and persist in engineering degree pathways. Therefore, the pilot alliance seeks to address the ways in which school districts, community colleges, and a university can adapt their actions to meet the goal of diversifying engineering.

Why the focus on first generation students? Overall enrollment of engineering first-time freshmen at Arizona State University [15] that acts as the backbone organization for the collective impact alliance increased 152% to 2,849 in 2016 from 1,131 in 2011. First generation student enrollment increased 100% to 581 from 290 in 2011.

Table 1. Fall 2016 Engineering Enrollment Demographics by First and Continuing Generation Status

Fall 2016 Enrollment	URM	Multiple Races	White	Asian	Female	Male
First (n=581)	56%	4%	32%	9%	21%	79%
Continuing (n=2,268)	20%	6%	61%	13%	22%	78%

The proportion of under-represented ethnic minorities who are first generation first-time students is disproportionately higher than those who are continuing generation (Table 1), while the proportion of females who are first generation is comparable to continuing generation students.

Table 2. Persistence of Fall 2011 Engineering First-Time Full-Time Freshmen

Fall 2011 Enrollment	Fall 2012	Fall 2013	Fall 2014
First (n=290)	62%	45%	40%
Continuing (n=841)	72%	63%	60%

Persistence (Table 2) of first generation students is significantly lower than that of continuing generation students. Often first generation students perceive engineering as economically infeasible, and socially and personally irrelevant to their lives [16]. This unmet need is worthy of attention and represents an untapped talent pool [14] in engineering. First generation entry into engineering is viewed as challenging in comparison to other disciplines (e.g., social sciences, liberal arts) for reasons, such as lack of role models and a support system within and outside the confines of family [17] [18].

Lack of adequate financing and a paucity of knowledge about potential revenue streams to support college completion [19] [20] also impact entry. *Engineers from Day One* aims to assess the efficacy of mechanisms to mitigate these barriers across the K-12 to university continuum using AEIOU strategies to develop engineering identity. For many first-generation students, transition to university settings includes developing the confidence to become successful engineering students and envision future possible selves as engineers. Thus, a general framework to characterize the challenges in diversifying engineering is: 1) lack of *awareness* about engineering and what engineers do; 2) absence of *enjoyment* or an affective response to engineering; 3) dearth of *interest* in engineering pathways and careers; 4) paucity of *opinion* formation about the impact of engineering on society; and 5) poor *understanding* of engineering and its social value. These are further compounded by *affordability* and *challenges with transition to college*, especially for first generation students, women, under-represented ethnic minorities, and those with socio-economic need.

Conceptual Framework for Identity Development

We use a conceptual framework based on James Marcia's theory [21], [22] that identity development in youth is the degree to which one has explored and committed to a vocation. 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. To this end, the alliance collectively offers engineering experiences during the crisis phase to influence values and choices and to facilitate commitment—choosing to become an engineering student. Upon entry, identity development is being fostered through: 1) targeted mentoring [23], [24] (industry, alumni, peer coaching) and ways to fund college attendance; 2) experiences [7] that increase knowledge of professional practice as socially [25] impactful; 3) experiences that reveal creativity, collaboration, and communication as essential in engineering. Strategies to impact persistence [20], [26], [27] upon entry to the university include: 1) support transition to becoming an engineering student; 2) promote first-hand understanding of engineers and their workplaces; 3) increase engagement in engineering activities beyond coursework. While many of these strategies build upon prior efforts conducted individually and collectively by alliance members, the proposed mechanisms

are also being instituted to vigorously challenge barriers to entry [28], [29] at critical junctures, starting from one's identity and beliefs as to who can be an engineer to confronting stereotypes of engineers and their workplaces, to highlighting the value engineers add to society and their profession, and finally to demonstrating how engineers find personal satisfaction [30], [31]. This collective impact alliance, thus aims to use an adaptive systems approach to create affinity [32], [33] for participants across the K-12, community college, and university continuum as *Engineers from Day One*.

Overall Goal and Objectives

The overarching goal of this collective impact alliance (Figure 2) is to identify, institutionalize, and scale effective, evidence-based mechanisms that *increase entry and persistence in engineering* by working collectively with different social institutions through an inclusive large network of actors. Over a 2-year period, *Engineers from Day One* will directly impact opportunities for *entry* into engineering of 500 high school students and 100 community college students. Efforts to support *persistence* in engineering at the university will directly impact 200 students.

The specific objectives are as follows.

- 1) Identify successful mechanisms that advance entry into engineering;
- 2) Identify successful mechanisms that advance persistence in engineering; and 3) Identify key mechanisms that successfully **foster engineering identity development**. These mechanisms will be in the form of programs built upon successful engineering education practices tailored to increase entry and persistence in engineering of first generation students. Descriptions of these mechanisms follow.

1) *Hermanas Conference, Diseña Tu Futuro* (*Sisters: Design Your Future*), introduces high school 200 Latinas to engineering through extra-curricular experiences at a day-long conference offered by area community colleges. Arizona State University is expanding opportunities for conference attendees by introducing undergraduate mentors and a series of experiences to encourage participants with family involvement to explore college going, financial aid, and confront stereotypes about engineering.

2) *Young Engineers Shape the World* (YESW) encourages high school girls who are juniors and seniors to explore engineering through an extra-curricular experience. Designed as a 60-contact hours/year program directed by the university, this effort will serve 150 girls who are high school

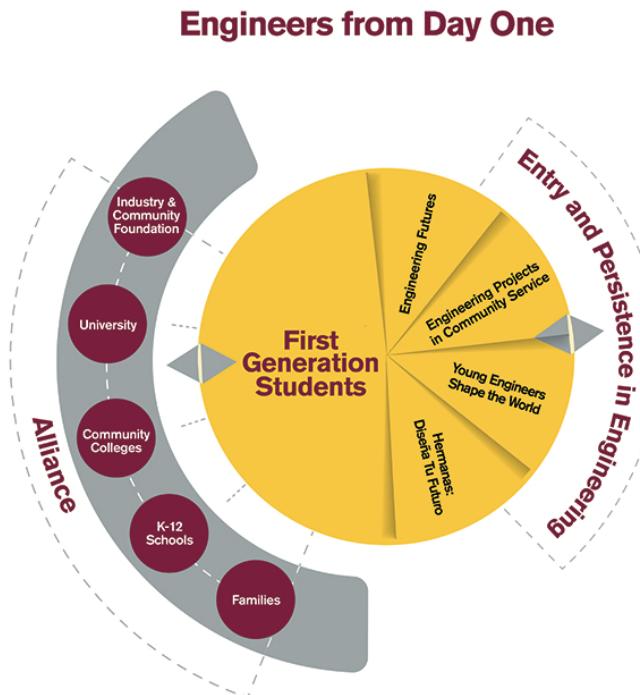


Figure 2. Collective Impact Alliance Model

juniors over two years, through high school graduation to enter college. In 2017, 75 participants were recruited from schools. Undergraduate mentors support the program with planned activities to explore engineering around the types of problems engineers solve and their impact on society, experiences to confront stereotypes, facilitate access to industry mentors, and university site visits.

3) *Engineering Projects in Community Service (EPICS)* at the high school grades 9-12 and community college encourages exploration of engineering as socially relevant through social entrepreneurship efforts in a co-curricular experience. The university will serve 200 students in high schools and community colleges will serve 100 students—where implementation of EPICS is integrated into existing courses. An articulation agreement between community colleges and the university allows transfer students to transfer credit for EPICS coursework completed at the community college to the university. The university provides professional development, curricula for human centered design solutions, funding for student teams, undergraduate and industry mentors, facilitated design reviews, and a final showcase for its high school and community college partners to support expansion of this human-centered engineering design effort.

4) *Engineering Futures* at the university supports persistence in engineering of first generation students, women, under-represented ethnic minorities, and those with financial need. Cohorts of first-generation students are created with 200 served directly. The cohort model is being used to create a built-in network for students and is an avenue for the university to reach out and engage with this population, which has unique needs. Retention /academic advisors (staff) have been assigned to monitor progress. A team of peer counselors drawn from first generation students who are juniors and seniors were trained to support persistence and engender the cohort's engineering identity development. These peer counselors have been prepared to help students develop an asset map of their existing familial and community resources and identify their cultural capital from which to develop their future possible selves as engineers. Throughout the first two years, students will be mentored to foster their engineering identity while focusing on support for transition to college. Support for transition to college includes encouragement and help to form peer learning study groups, study habit workshops, note-taking methods, time management, and financial aid-education. Support for engineering identity development in year 1, include opportunities to meet industry professionals, visits to industry sites to learn first-hand what engineering workplaces look like, engage with engineering leaders through a speaker series, and attend recurring choice-based 2-hour technical and soft skills building workshops. In year 2, students will be encouraged to engage in social entrepreneurship through interdisciplinary coursework in EPICS; and/or join a student organization of choice with over 60 to select from. At the end of year 2, qualified students will be encouraged to apply to serve as an undergraduate teaching assistant with pay. In year 3, students will be encouraged to engage in the university undergraduate research initiative with pay and support for materials.

Data Collection

The measures of whether participants evince awareness and interest in engineering and the degree to which they develop engineering identity are key in assessing the influence of the pilot alliance efforts. The following methods are used to measure efficacy of the implemented strategies. **1) What is Engineering**—is designed to elicit students' recognition of engineering

problems as relevant to society *and* whether they find social and personal relevance in wanting to solve these problems. Modeled after a National Academy of Sciences [34], [35] study this survey was piloted with high school students at the start of the academic year. This survey will be used with high school, community college, and first-year engineering students as a pre-post survey each year. **2) Engineering Identity** [21], [22] survey—designed to elicit students’ sense of belonging and whether students are exploring and learning what engineers do. Developed by [authors] to integrate James Marcia’s theory of identity development, this survey was piloted with university freshmen at the start of the academic year. This survey will be used in high schools, community colleges, and university engineering students as a pre-post survey each year. **3) Qualitative Study** [36], [37]—a subset of participants (~20-30) from each alliance institution will participate in focus group interviews [38] and artifact reviews that offer evidence of their personal identity development. **4) Correlation of student participation levels** in activities with longitudinal data collected via repeated measures [39], [40], [41] and student entry and persistence results will tell us how well the mechanisms work in advancing the common agenda. Pilot collective impact alliance members have agreed to collect these data in addition to seeking first-generation status information from families of students they serve using the proposed mechanisms.

Data Analysis

For the purposes of this work in progress paper, only the results of the #1 What is Engineering and #2 Engineering Identity survey (pre-program administration) will be presented here. However, by the time the conference is held, if this paper is accepted for presentation, data from the end of the academic year (post-program year 1) administration will be presented. Survey data will be analyzed using comparisons of frequency statistics and nonparametric hypothesis testing [42].

Awareness of Engineering

Part 1 of the What is Engineering asked high school students (n=269) to identify whether examples given were representative of engineering examples or not.

Table 3. Percent Students (Pre-Program) who identified examples as engineering or not engineering

Example	PRE (Percent)	
	This is Engineering	This is NOT Engineering
1. Natural disaster warning systems	84	16
2. Smart traffic solutions	57	43
3. Machines that allow blind people to see	71	29
4. Protecting the global water supply	23	77
5. Developing new fabrics	19	89
6. Growing more nutritious food	34	66
7. Preventing nuclear terror	82	18
8. Researching new methods of outer space exploration	59	41
9. Protecting the rainforest by reducing need for new farm land	28	72
10. Growing organs for transplants	16	84

When post-survey data are available, comparison of frequency statistics for pre and post

responses with a Wilcoxon signed rank test will be conducted to identify statistically significant changes in participants awareness of engineering examples. Effect size and significance level ($p<.05$) will be reported. From pre-program surveys, it is clear that a majority of the students enrolled in *Engineers from Day One* experiences indicated awareness that “natural disaster warning systems, smart traffic solutions, machines that allow blind people to see, preventing nuclear terror, researching new methods of outer space exploration” are examples of engineering. However, many students were not aware that “protecting the global water supply, developing new fabrics, growing more nutritious food, protecting the rainforest by reducing need for new farm land, and growing organs for transplant” were all examples of engineering.

Interest in Engineering Examples

Part 2 of the What is Engineering survey asked high school students ($n=266$) to identify whether the examples given were appealing to their interests (5=very appealing, 4= somewhat appealing, 3=neutral, 2=not that appealing, 1=not appealing at all). Once the data were cleaned, select frequencies were calculated (median, mode, percent by mode, and standard deviation) for each question. Initial analysis consisted of comparing the mode values of the entire data set across each question. Each question response was classified as high, neutral, or low. Where a classification of high indicated a mode value of 5 or 4, a classification of middle indicated a mode value of 3, and a classification of low indicated a mode value of 1 or 2. Analysis consisted of comparing the mode values of the entire data set across each question. Table 4 shows the responses for how well a specific example of engineering creates interest for participants in the field of engineering. When post data are available, comparison of frequency statistics for pre and post responses with a Wilcoxon matched pairs test will be conducted to identify statistically significant changes in participants awareness of engineering examples. Effect size and significance level ($p<.05$) will be reported.

Table 4. Frequency of Scores for Examples that Create Interest

Example	PRE		
	N	Mode	Standard Deviation
1. Natural disaster warning systems	266	4	1.06
2. Smart traffic solutions	266	3	1.15
3. Machines that allow blind people to see	266	5	1.03
4. Protecting the global water supply	266	4	1.10
5. Developing new fabrics	266	3	1.27
6. Growing more nutritious food	266	4	1.16
7. Preventing nuclear terror	266	3	1.08
8. Researching new methods of outer space exploration	266	5	1.10
9. Protecting the rainforest by reducing need for new farm land	266	4	1.13
10. Growing organs for transplants	266	3	1.18

Students found the examples of “machines that allow blind people to see and researching new methods of outer space exploration” as very appealing indicating interest. However, students were neutral regarding the following examples: “smart traffic solutions, developing new fabrics, preventing nuclear terror, and growing organs for transplants.”

If *Engineers from Day One* experiences successfully offer ways for students to see how these problems are socially relevant and that engineering impacts the everyday life, health, security, well-being, and happiness of individuals, then we anticipate that post-program responses may indicate increased awareness and interest in engineering examples. In addition, increasing the number and variety of examples that represent a wide range of engineering topics may provide a more accurate response of students' awareness and interest in engineering. However, we also run the risk of students losing interest in the survey and not completing the survey. As a tradeoff we reduced the number of items for parts 1 and 2 in the What is Engineering survey from 22 to 10.

Engineering Identity

A 22-item survey was developed based on James Marcia's theory of vocational identity by a senior counseling psychologist and psychometrician who has advised The College Board and an engineering education researcher. A confirmatory factor analysis will be conducted on the pre and post data, when we have obtained a data set that is sufficiently large i.e., ~20 cases for each item. A pilot administration at the start of the academic year netted 261 responses. Ideally for a survey of this type, it would be best to conduct a confirmatory factor analysis with ~500 cases or more. We are working to survey over 1,000 freshmen to help identify factors that will form our engineering identity measure. From a theoretical perspective as laid out in the conceptual framework for this study, we anticipate three major factors that will help categorize these items upon successful factor analysis. Students were asked to rate their agreement (strongly agree, agree, neutral, disagree, strongly disagree) for specific statements.

Factor 1: Exploring Engineering (indicates sustained awareness, interest, and enjoyment)

Statements are about spending time finding out what engineers do; doing engineering to understand what engineers do; and talking with engineers and engineering students to learn more about what engineers do.

Factor 2: Commitment to Engineering (indicates opinion formation and understanding)

Statements are about importance of being an engineer, understanding of what it means to be an engineer, a sense of belonging or attachment to engineering, and self-identification as an engineer.

Factor 3: Self-Efficacy in Engineering

Statements are about choice of engineering as a major and engineering as a career, effort to learn subjects in the engineering major, willingness to invest time and effort necessary to complete the engineering course of study, and ability to become an engineer.

In delineating survey responses by first-generation (n=110) and continuing generation (n=151) students, significant areas of difference emerge. Greater percentage of first-generation students indicated that they had explored engineering (48%) in comparison to continuing generation students (69%). A greater percentage of first-generation students reported lower self-efficacy (76%) in comparison to continuing generation students (22%). However, when it comes to commitment to engineering, both first generation students (74%) and continuing generation students (77%) indicated their commitment to engineering.

Clearly, the initial pilot data reported here are not census level data for the high school and university level students we work with in *Engineers from Day One*. They are opportunity samples and are therefore not generalizable to the larger population of students in our programs.

As the effort progresses from its initial stages to completing its first full year of programming, we anticipate collecting data systematically to full test the efficacy of the implemented mechanisms to support entry and persistence in engineering for targeted populations.

Anticipated Results

It is anticipated that the alliance institutions will develop into adaptive systems that respond to the common goal of broadening participation in engineering for first generation students. The ensuing complex adaptive system and the emerging patterns with leverage markers resulting in broadening participation will be identified for expansion. The collective alliance has the potential to transform institutionally engendered identities to be inclusive of the multiple and mutable engineering identities. At the end of the two-year effort, *Engineers from Day One* anticipates the development of a model that will be useful regionally and nationally to broaden participation that can reduce and eliminate barriers to engineering education and career pathways.

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