Co-Op Based Engineering Education Model Supporting Students in Engineering Education Deserts

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***Abstract*— Previous work has identified that one third of Americans live in an engineering education desert, or a county without a face-to-face 4-year accredited engineering degree or a two-year face-to-face pre-engineering program, regardless of whether it results in a credential. Iron Range Engineering (IRE) is an upper division engineering program designed to help provide access to individuals who due to financial and/or geographic location would be otherwise unable to participate in engineering.**

In this paper we present data demonstrating how this model of engineering education supports students from a range of geographical areas by addressing the research questions: Is IRE supporting students from engineering education deserts, are those students returning to their home region with a paid engineering position, and if so, with what income? In 2022, students at IRE were surveyed about their co-op experiences, feelings of belonging, and demographic information. This data was analyzed using descriptive statistics of location, salary, and demographic data.

Our data supports the idea of this model of education attracting participation of students who otherwise may not have access to an engineering degree. Of the students in IRE, 67% come from engineering education deserts. Of those, 17 returned to their home state with a co-op and 8 returned to their home county with a paid co-op, at an average salary of $22/hour. Our results contribute to our understanding of engineering education deserts in the United States, and the IRE Bell co-op model as a curricular model to provide access to an affordable engineering degree for students in a wide range of locations.

Keywords—undergraduate, experiential learning, career path, engineering pathways

I. Introduction

The research question presented in this paper is how many students is the experience-based upper division engineering program, Iron Range Engineering (IRE), supporting from geographical locations without access to a four-year engineering degree, and are those students returning home with a new pathway to complete their engineering degree? This research question is part of a larger study which seeks to identify and continue to improve pathways to an engineering degree to support a diverse and global engineering workforce, and identify ways in which we are supporting and can improve supporting students from engineering desserts. Our results contribute to our understanding of engineering education deserts in the United States, and the IRE co-op model as a curricular model to provide access to an affordable engineering degree for students in a wide range of locations.

II. Background

A. Engineering Education Deserts

In a previous study [1], we identified 30.89% of the United States population does not have geographical access to face-to-face engineering education at either the two-year college or four-year college / university level. The percentage goes up when we include structurally created engineering education deserts - where lack of public transportation and other infrastructure barriers are obstacles to participation. The circles on the map in Figure 1 show the areas covered by two- and four-year engineering education. While it may appear from the map that this is a rural area problem, the reality is that of the population lacking geographical, face-to-face access, 54.50% are from metropolitan areas, 24.23% are from micropolitan areas, and only 21.27% are from rural areas. When we disaggregate two-year and four-year institutions, we find that approximately one out of every two Americans does not have geographical, face-to-face access to two-year college engineering programs, and 16.18% of those who do have access to two-year engineering programs do not have similar access to four-year engineering programs.

For students who have the ability to travel to complete their education or who have both the infrastructure (e.g., strong internet connection, sufficient devices) and the desire to do an entirely online degree, engineering education deserts are less of a concern. A 2022 study [2], however, found that 19.4% of households across the country do not have access to broadband

internet. Further, areas with higher percentages of Black households had lower broadband access, and the strongest racial/ethnic factor for not having access in their regression model was American Indian/Alaska Native. In addition, learners with strong bonds to their current place or environment [3] or who have real or perceived barriers to leaving their geographic place [4], [5] are unlikely to travel out of their engineering education desert even if they want to become an engineer. Even for learners who are not placebound, communities with limited employment opportunities are likely to have a "brain drain" of engineering knowledge as learners graduate and find jobs elsewhere or have potential engineers opt out of getting their degree because family concerns or connections to people and place of their home outweigh having to move away for employment [6].

In part to increase options for learners in engineering education deserts, learners who are placebound, and learners who value return migration to their home area after graduation, the Iron Range Engineering program at Minnesota State University, Mankato, offers a pathway to the engineering degree that allows students to:

- Complete their first two years from any college, including two-year colleges;
- Have access to advanced mathematics (e.g. differential equations) and lower division engineering courses (e.g., dynamics, circuits) that are not found at all two-year colleges;
- Choose between being on-site in Minnesota or remote from the location of their choice for the cohort-based intensive semester; and
- Find engineering co-op and internship opportunities in any location, whether they want to work near or far from their home area.

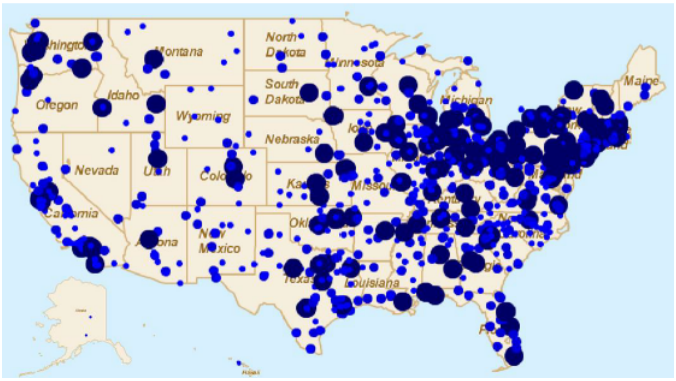

Fig. 1. Point and Radius Map of 2-Year and 4-Year Face-to-Face Engineering Education [1]

B. *Programmatic Context*

Iron Range Engineering (IRE) is an upper division, project-based learning engineering program [7]. Students balance technical, design, and professionalism skill development through the five semesters of the program. The program has been recognized as an innovative approach to engineering education: IRE has been awarded the ABET Innovation Award [8] and recognized as a top-ten emerging leader in engineering education by MIT [9]. The current version of IRE, known as the Bell engineering model, is centered around practice-based education with the students learning engineering partly through engineering co-op experiences. Practice-based learning more fully addresses the complexity of technical and social problems [10].

Students complete their first two years of their engineering degree through community colleges across the nation. Students then complete their BS in Engineering in five semesters at IRE, while working in paid co-op positions. In their first semester, called the Bell Academy, students focus on gaining technical skills through eight one-credit hour engineering technical courses. Students also take three credits of design and professionalism. The design experience further applies their technical knowledge and builds design skills through an industry sponsored project. Professionalism includes leadership, learning about learning, teamwork, communication (writing and presentation), ethics, microaggressions and implicit bias, contemporary issues, and modern engineering tools. In addition, there is a one credit-hour seminar course with a special focus on developing strong job search skills through career development. Career development workshops include resume building, creating a LinkedIn page, networking through networking fairs and career fairs, and interview practice. For the remaining four semesters, students take a 3 credit design course, a 3 credit professionalism course, and a 1 credit seminar course each semester, along with their technical competencies. The seminar topics shift to other areas of professionalism and career development.

Students throughout the program, but particularly in the first Bell Academy semester, have constant mentorship through faculty advisors for pathway to graduation and technical discipline expertise, but also through learning coaches, who are staff with an engineering degree and with various engineering industry experience. It is the goal that all students have applied for and found a paid engineering co-op position by the end of the first semester.

After this first semester of intensive technical, design, and professionalism preparation, students then work in paid engineering co-ops in a location of their choosing for the four semesters of their junior and senior years. This format allows students to complete two years at community colleges, typically close to home, with more affordable tuition than most four-year institutions. They then pay tuition for one semester before earning an engineering income to offset any future costs, as most students earn enough during their two years of engineering co-ops to cover the tuition costs for their last four semesters. The format of this program allows access to an engineering degree for those who either financially or geographically may otherwise have had limited or no access.

In 2022, IRE was awarded an NSF S-STEM grant to provide scholarships for low-income, high achieving students to support that one semester where students do not have an income to offset the tuition costs [11]. This research paper is part of the knowledge generation goal of that grant to identify pathways students are taking to receive engineering degrees and how we can better support those pathways.

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III. Method

In this quantitative paper, n=58 students were surveyed in 2022 at IRE during their end-of-semester finals week. The survey instrument included specific questions about their co-op experiences and demographic information, including high school (HS) zip code and family income. This paper uses the results of that survey to answer the research question: how many students is IRE supporting from an engineering education desert, and are those students returning home with a new pathway to complete their engineering degree?

A. Data collection—Survey Instrument

Students were prompted to complete a survey during a seminar in their finals week. They were given 15 minutes of seminar time to complete the survey but were not required to complete it. The response rate for the survey was about a 60% response rate. Students were asked to describe any co-op experiences they have had. For each co-op position they have held, they were asked to indicate company name, location, start and end dates, pay rates (typically indicated in hourly rates), number of hours worked each week, how they found the co-op, and open-ended questions on co-op and belongingness. Demographic questions were asked using the format indicated in this paper [15].

B. Data Analysis—Descriptive Statistics

For this paper, students' co-op experience information on city and state of the co-op, and hourly pay, as well as their academic and demographic information, were analyzed. Students' total amount earned was calculated from the hourly rate multiplied by their hours worked per week and the number of weeks worked, which was calculated from their co-op start and end date. If the co-op had not ended, the number of weeks was calculated based on the current date. The students' cohort, or semester they started the program, was used to identify how many semesters they had been in the program. The amount earned per semester was calculated by dividing the total money earned on co-op by number of semesters in the program, not including Bell Academy. Students who had not yet started their co-op (students at the end of their Bell Academy semester) may have indicated their co-op position that started the following semester, but they were not included in any pay calculations. Note that Bell Academy is not included in this analysis, as this work is focused on the four semesters students are on co-op.

C. Description of Participants

Of the 58 respondents, the racial and gender identity information is provided below in Table 1. All students are upper division engineering students, ranging from Bell Academy (first semester in the program, about to start their junior semester) to graduating seniors (5 semesters in the IRE program). Students reported about 30% non-traditional, over the age of 24; 24% identify as having a disability. Students come from 14 different states, as indicated by their high school zipcodes.

Students worked on average 40 hour weeks with an average hourly salary of $22.73/hour. Students have worked for 44 different companies in 17 different states. All students surveyed had a co-op by their second semester junior year (third semester in the program). These students earned an average of $21,554 per semester. Note that the average cost of attendance is calculated to be just under $20,000 per semester for IRE students, not taking into account differences in cost of living.

TABLE I. Demographic information of IRE Co-op Survey Participants (n=58)

Demographic Information	**Percentage of IRE students (2022)**	**Percentage of National Engineering Undergraduates (2021) [16]**
American Indian or Alaska Native	0.0%	0.4%
Asian or Asian American	7.7%	14.7%
Black or African American	7.7%	4.4%
Hispanic, Latino, or Spanish origin	9.2%	12.1%
Middle Eastern or North African	0.0%	Not reported
Native Hawaiian or Pacific Islander	1.5%	0.2%
White	63.1%	60.7%
Multiracial	10.8%	3.7%
Female	18.82%	22.50%
Male	77.65%	77%
Nonbinary, Transgender, Genderqueer	5.88%	Not reported

IV. Results and Discussion

From the co-op and descriptive statistics, we provide below a description of students at IRE from engineering education deserts and their co-op experiences.

A. Descriptions of IRE students from engineering education deserts

Of the 58 students who were surveyed and provided their high school zip code, about two-thirds, (n=39, 67%) indicated having a high school zip code in a county without a 4-year accredited engineering degree. We will refer to these students as being from engineering education deserts for the remainder of the discussion. These students earned, on average, $20,525/semester in paid engineering positions. The cost of attendance is calculated to be just under $20,000 per semester for IRE students, not taking into account differences in cost of living of our range of attendance across the nation. With this pay, students from engineering deserts are able to continue their pathway to an engineering degree with less burden from tuition.

Of the students attending IRE from engineering education deserts, 31 identify as male (80%), 4 female (10%), and 3 transgender (10%). Additionally, these students identify as white (54%), multiracial (15%), Hispanic, Latino, or Spanish origin (10%), Asian (10%), Black or African American (5%), and Native Hawaiain or Pacific Islander (3%). These demographic ranges indicate that we are recruiting a racially diverse student set from engineering deserts compared to our program demographics and could improve on our recruitment of women from these areas.

B. *Co-op Information for Students from Engineering Education Deserts*

Of the 39 students who came from a county without access to a 4-year accredited engineering degree, 17 returned to their home state. These 17 students have earned an average of $21/hour and $24,851/semester. The 22 students from engineering education deserts who did not return to their home state earned an average of $18,833/semester.

Eight students attended IRE from an engineering education desert and returned to their home county with a paid engineering co-op. Those students earn an average salary of $22/hour. These students are returning home to counties in California, Maryland, Minnesota, Virginia, and Oklahoma.

V. Conclusion and Future Work

Our work shows evidence that Iron Range Engineering is supporting a financially responsible pathway to an engineering degree for students in engineering deserts. Some of these students have returned home with a paid engineering co-op, better supporting the local engineering workforce for those areas. Further work will explore if our graduates are returning to their home counties with full-time engineering degrees, and explore longitudinal data related to co-op experiences and engineering identity and belonging development.

These results also indicate that we may want to explore how we can better recruit female students from engineering deserts; we may need to explore how many female students are in pre-engineering pathways at 2-year programs and if we could expand our recruitment to high schools in partnership with local 2-year institutions. Additionally, comparison data related to engineering desert enrollment at other institutions would be beneficial to better understanding how we can better support students from these areas in pursuing four year engineering degrees, with the option to return home.

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